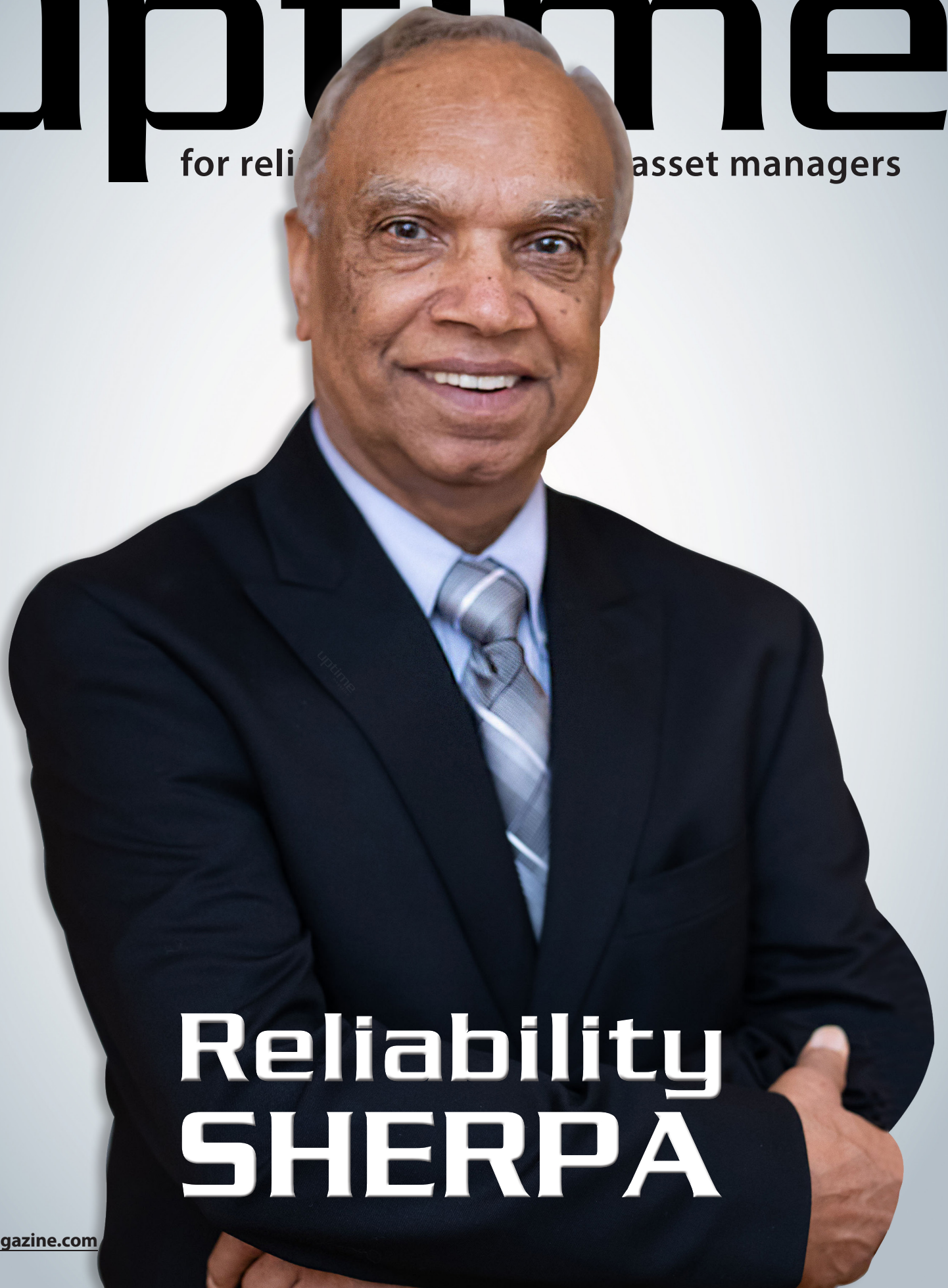# uptime ®

june/july 19

for reli... asset managers

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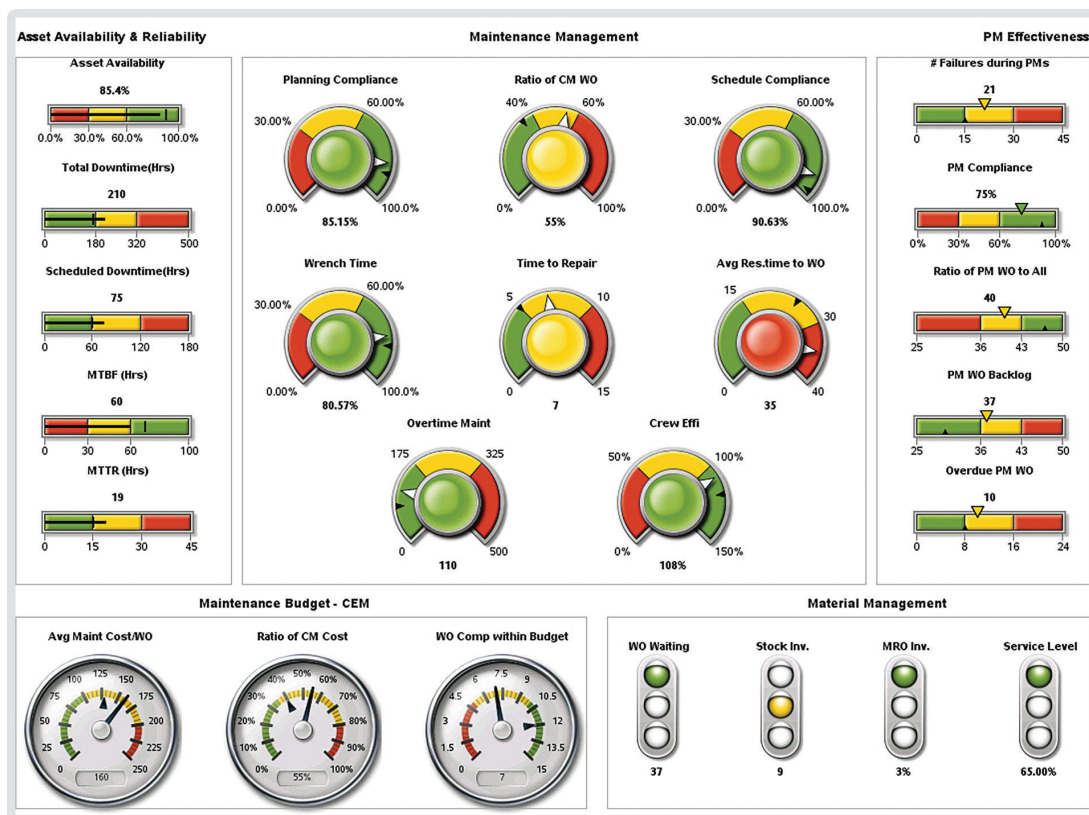# AssetAnalytix

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ROI

VALUES

COMMUNITY

NETWORK

JOURNEY

RELIABILITY PARTNERS

Vision: Advance the industry toward ZERO **Accidents • Downtime* • Waste** through a holistic reliability framework.

A Powerful Community of **Reliability Partners** to Advance Reliability and Asset Management with You.
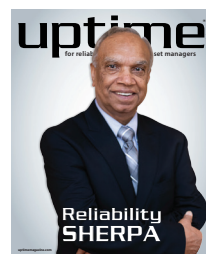
Contents

june/july 2019

Opx Operational Excellence

Are You a Hero or a Leader?
Ramesh Gulati

10

FEATURES

ARTICLES

18

22

36

Contents [Continued]

RELIABILITY PARTNERS

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

Uptime® Elements

Technical Activities

REM Reliability Engineering for Maintenance
ACM Asset Condition Management
WEM Work Execution Management

Leadership

LER Leadership for Reliability

Business Processes

AM Asset Management

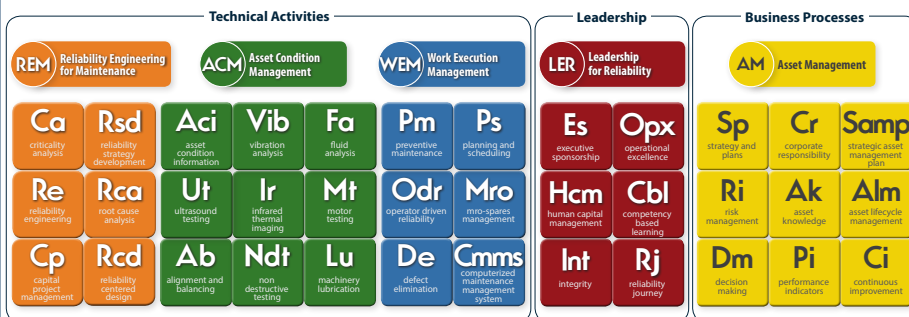| Ca criticality analysis | Rsd reliability strategy development | Aci asset condition information | Vib vibration analysis | Fa fluid analysis | Pm preventive maintenance | Ps planning and scheduling | Es executive sponsorship | Opx operational excellence | Sp strategy and plans | Cr corporate responsibility | Samp strategic asset management plan |
| Re reliability engineering | Rca root cause analysis | Ut ultrasound testing | Ir infrared thermal imaging | Mt motor testing | Odr operator driven reliability | Mro mro-spares management | Hcm human capital management | Cbl competency based learning | Ri risk management | Ak asset knowledge | Alm asset lifecycle management |
| Cp capital project management | Rcd reliability centered design | Ab alignment and balancing | Ndt non destructive testing | Lu machinery lubrication | De defect elimination | Cmms computerized maintenance management system | Int integrity | Rj reliability journey | Dm decision making | Pi performance indicators | Ci continuous improvement |

A Reliability Framework and Asset Management System™

Reliabilityweb.com's Asset Management Timeline

Business Needs Analysis → Design → Create/Acquire → Operate / Maintain / Modify/Upgrade → Dispose/Renew → Residual Liabilities

Asset Lifecycle

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Uptime® Elements - A Reliability Framework and Asset Management System™ is in use at over 2,800 organizations around the world to engage and empower reliability culture.

PRACTITIONER PRACTICE

"Practice is everything. This is often misquoted as practice makes perfect. " - Periander

Several significant new paradigms related to reliability strategy were discovered with the release of Nowlan and Heap's reliability-centered maintenance report in December of 1978.

The maintenance world at the time was not formerly organized but generally understood to include practitioners (a person engaged in the practice of maintenance, e.g., maintenance manager, maintenance planner, maintenance supervisor, maintenance worker) and supplier/service provider/consultant (offering a product, software, training, service, advisory, consulting for a fee to a practitioner). Both factions embraced these new paradigms and began to explore ways to express best practice. As a result, the community slowly evolved.

Eventually, a dedicated group of practitioners formed a community of practice. Membership was initially limited, but participation was open to practitioners. This group rolled up its sleeves and began hosting quarterly and annual meetings that were attended by 100 percent practitioners. It was unique in that it had no commercial, vendor or expo point of view at all, allowing the focus to be exclusively on fulfilling practitioner objectives.

During the first ten years of meetings, vendors could not even buy a seat to attend a meeting or annual conference. Attendance was restricted to maintenance practitioners, so when you ate breakfast, mingled at a cocktail reception or fielded a question during a presentation, you were assured it was with a fellow maintenance practitioner. That group and its context is long gone; however, it had a deep impact on me as I began my reliability journey. I never forgot the incredible power of making a journey that involved developing new practices as community of practice.

In 2013, we at Reliabilityweb.com® introduced Uptime® Elements, which included several new paradigms related to advancing reliability and asset management. As we explored its application and effectiveness in the real world, creating a community of practice was a natural extension. The Reliability Leadership Institute® was born with an aim to discover best practices for implementing the combined people side and technical side of the reliability journey. There are many formal deliverables designed to advance reliability and asset management, including quarterly face-to-face meetings to share implementation experiences for rapid group knowledge gains.

Member organizations include:

- Arizona Public Service
- BNSF Railway
- Boeing Company
- Bristol-Myers Squibb
- CBRE Group
- Central Arizona Project
- Clark County Water Reclamation District
- DC Water
- Gwinnett County Water
- Honda of America
- Jacobs Engineering Group
- JLL
- Medtronic
- Metropolitan Council

This is where the idea for the Reliability Leadership "Zombie Apocalypse" Game originated as we searched for more ways for the community of practice to "practice" reliability leadership. Even people who dislike playing games love the Reliability Leadership Game!

We are also in the process of renewing our effort to create local chapters for the Association of Asset Management Professionals (AMP - www.maintenance.org) with the following guidelines:

1. Requires two practitioners as officers
2. No bureaucracy
3. No membership dues

"Best practice" requires "practice," so creating a local community of practice provides your team with a low-cost, convenient option to advance reliability and asset management. Leadership is an action, not a title!

All value is local. If you would like to learn more about creating an AMP Chapter for practitioner learning and networking in your area, please send an email to crm@maintenance.org

Hoping to work with you soon,

Gene O'Hanlon

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

RELIABILITY
IN THE NEWS

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Central Arizona Project, Phoenix, Arizona

Metropolitan Sewer District of Greater Cincinnati, Cincinnati, Ohio

Reliabilityweb.com Hosts Series of Roundtables

With the rapid diffusion of technology driven by the Industrial Internet of Things (IIoT) and machine learning, Reliabilityweb.com hosted roundtable discussions to discover common solutions to advance reliability and asset management, including digitalization strategies. These discussions are based off of the Reliability Leadership Institute® (RLI) Community of Practice group, a network of 15 asset intensive organizations that use Uptime® Elements – A Reliability Framework and Asset Management System™.

Each participant may be at a different maturity level, even those within the same organization; however, even though each has a different business or operating context, others can learn by sharing experiences around the implementation journey, thus benefiting the entire network.

Several executives from both the public and private industrial sectors participated. Reliabilityweb.com's Terrence O'Hanlon and Maura Abad facilitated the roundtables.

Central Contra Costa, San Francisco Bay Area

UPCOMING DATES:

June 18 – Atlanta, Georgia

June 20 – St. Paul, Minnesota

October 25 – Singapore

Maximo UK and Ireland User Group Held in Dublin, Ireland

Deloitte Maximo Center of Excellence hosted the UK and Ireland user group meeting in Dublin, Ireland, May 22, 2019. Over 100 IBM® Maximo® users participated in interactive asset management group discussions. In addition, there was an interactive keynote address by Reliabilityweb.com CEO and Uptime Magazine Publisher, Terrence O'Hanlon.

Group Chairman Richard Barber reported excellent participation and feedback and expects continued growth from the community.

CONGRATULATIONS

Valerie Kobialka, Medtronic, is our first female to earn a Certified Reliability Leader (CRL) belt!

Reliability Engineering for Maintenance (REM) Belt
Grieve Oven, Preventative Maintenance

CRL Workshop, Budapest, Hungary

San Francisco Bay Area AMP Chapter Meeting

CRL Workshop, Fort Myers, FL

Boeing "Future of Flight" Tour

Fluke Corporation Headquarters Tour

THE SHERPA
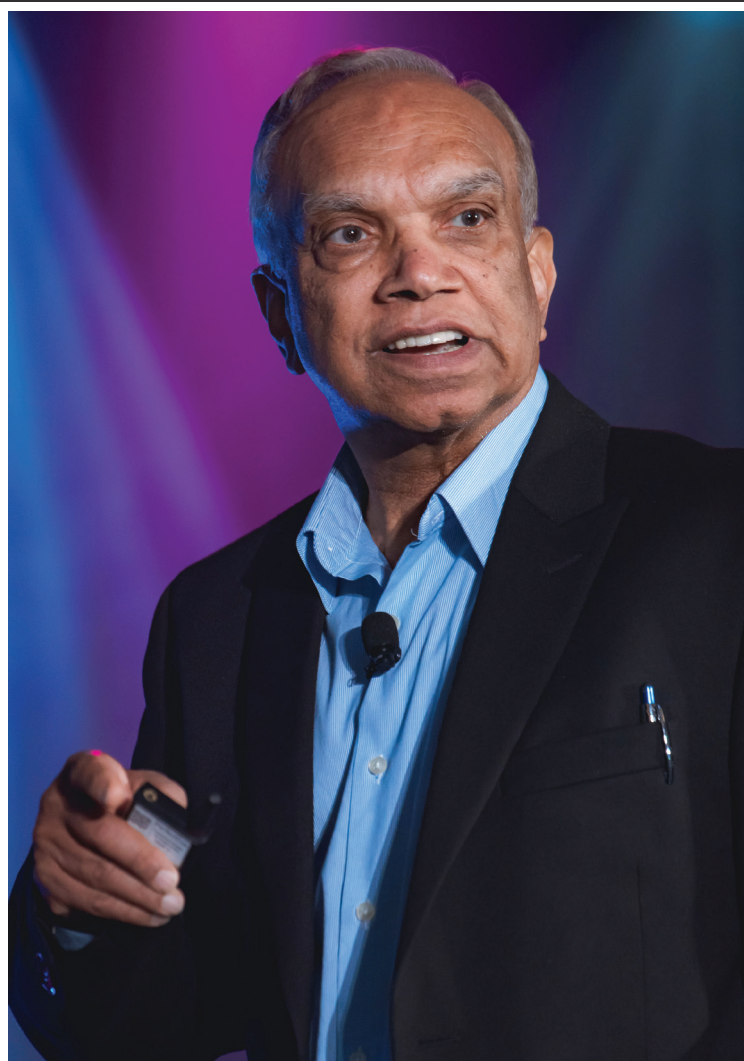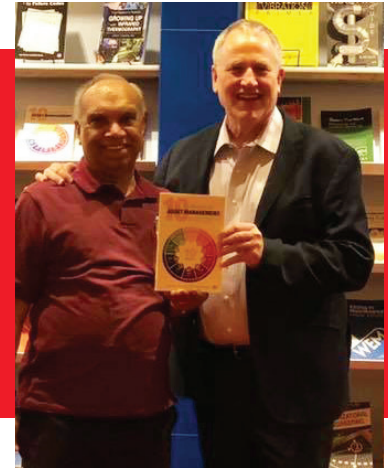
I wonder if back in 1964 when Heavy Engineering Corporation, Ltd., of Ranchi, India, hired a young mechanical engineer fresh out of university to install a total maintenance program that they had any idea what kind of 55 year reliability journey they were unleashing on the world with the hiring of one Ramesh Gulati.

His improvement work began 14 years before Nowlan's and Heap's reliability-centered maintenance report changed the paradigm from equipment repair to ensuring critical asset function.

Eventually, his path landed Ramesh a reliability leadership position at the prime contractor for Arnold Engineering Development Center (AEDC), one of the most important U.S. national security installations, a mission critical test for anything and everything our defense forces flies.

You might imagine a slick control room and ultramodern equipment under his care, but that would be far from reality. Some of the equipment actually came from captured World War II enemy territory, other equipment was one of a kind, specially made for the mission. All of it required the highest reliability and had to be ready to function when called upon.

Add the special challenge of a new base commander every two years, federal government procurement rules and a fix it maintenance mind-set and Ramesh had a new challenge.

I was an outsider looking in, but from what I saw, Ramesh formed a motivated team of insiders who wanted to make things better at the base. He reached out to the best of the best outside advisors in reliability-centered maintenance, computerized maintenance management, condition monitoring, work management, reliability leadership and asset management. He leveraged conferences, training, certifications, associations and professional meetings.

I visited the site often, under the umbrella of adviser, but often times Ramesh would simply drag me from department to department asking his team to present their latest improvement to me, knowing I would ask a million questions. As he drove me to the airport, I would often comment to Ramesh that I was sorry we ran out of time to make the presentations I had prepared for his team. It was not until years later I realized that was his plan all along. By bringing a respected visitor on site, it forced his team to organize their thoughts into a coherent story that described the strategy and plan they were using to advance reliability and asset management.

The other thing I observed about Ramesh is that everyone knew that if they saw him approaching, they were about to discuss reliability. It did not matter what their role was. Purchasing agents, human resources, engineering, operations, senior management, even Air Force commanders all knew that if they bumped into Ramesh, they were going to be talking about reliability and being encouraged to study and get certified. This created one of the broadest cross-functional reliability programs I have ever witnessed where everyone understood their role and played an important part, akin to safety.

New base commanders were often barely unpacked before Ramesh was knocking on their office door to explain the benefits and deliverables of the reliability program and the dangers of cutting resources.

Simply put, Ramesh was the guide for reliability. He was the base's Reliability Sherpa. Ramesh led himself with **integrity**, **authenticity**, **responsibility** and worked to an **aim** bigger than one's self. He made sure it sustained for the entire time he was employed and the entire time his company held the prime contract. He led the reliability program and made sure it sustained for the entire time he was employed and the entire time his company held the prime contract.

It was the single longest, most sustained high reliability program I have witnessed in my 20 years at Reliabilityweb.com.

Ramesh is a true reliability leader and earned a well-deserved, but rare, Reliabilityweb.com Lifetime Achievement Award at The RELIABILITY Conference, May 8, 2019, in Seattle, Washington.

I am proud to have learned from Ramesh. I am proud to know him as a professional colleague. I am proud to be his coauthor for *10 Rights of Asset Management* and, most of all, I am honored to be his friend.

Terrence O'Hanlon
CEO/Publisher
Reliabiltityweb.com
Uptime Magazine

LEADER

Ramesh Gulati

The fact is, organizations and their management teams create heroes and leaders through their behavior and actions. This article explains the differences between heroes and leaders and defines the attributes of a special kind of leader, reliability leaders: the real heroes.

ARE YOU, OR SOMEONE IN YOUR WORKPLACE, A HERO OR A RELIABILITY LEADER?

HERO

Someone who is admired for their courage, outstanding achievements, or noble qualities.

LEADER

One who guides others and exercises a high degree of influence over others to do more.

RELIABILITY LEADER

One who helps another person, a machine, or gadget to do a better job. One who creates a new future by eliminating defects, reducing total cost of ownership, and supporting the organization's objectives.

WHAT IS A HERO?

The dictionary definition of heroes are people who are admired for their courage, outstanding achievements, or noble qualities. They do extraordinary things. In organizations, particularly plants and factories that operate in reactive mode, when an asset breaks down, they may have a couple of people on the plant floor whose knowledge they can count on to fix the asset quickly. Sometimes, they are called in from home if they are not in the plant. These individuals may already have the parts in their toolbox or take the initiative to find the parts, tools, or support they need. They can anticipate when failures are going to happen and are ready to fix the asset.

Organizations treat these people as heroes and encourage them with rewards and recognition. They celebrate their accomplishments in fixing things so quickly; to some, they saved the day. Management supports this notion by their actions of recognizing them publicly for a great job. From watching management's actions and behavior, the workforce gets the signal that responding to breakdowns quickly is this organization's mode of operation. Preventive and proactive steps, such as finding the root causes, are not recognized and not appreciated by management. Their main focus is to simply get the asset fixed to an operating mode as soon as possible.

These so-called heroes may not do all the right things, but people start treating them as heroes anyway.

Do you have this type of employee(s) in your workplace?

WHAT IS A RELIABILITY LEADER?

As renowned management author John C. Maxwell stated, "A leader is one who knows the way, goes the way, and shows the way." President John Quincy Adams once said, "If your actions inspire others to dream more, learn more, do more, and become more, you are a leader." There are many similar descriptions about leaders. All of them can be summarized in a simple statement: A leader is one who guides others and exercises a high degree of influence over others to do more.

A reliability leader, as defined in the *Uptime® Elements Dictionary for Reliability Leaders & Asset Managers*, is "one who helps another person, a machine, or gadget to do a better job." Reliability leaders eliminate or minimize defects that can cause failures by their actions or by influencing others to do the same or better at any stages of the asset's lifecycle.

A broader and newer definition of reliability leader, described by Reliabilityweb.com CEO Terrence O'Hanlon in *10 Rights of Asset Management,* is "one who creates a new future by eliminating defects, reducing total cost of ownership, and supporting the organization's objectives."

In organizations, besides the group of so-called heroes, there may be another group of people that management can count on to not only perform the needed repairs as quickly as possible, but with safety and quality in mind. They also find the root cause of the problem, when possible. Later on, they get involved in failure analysis. Whereas the team and the manager may be interested in simply repairing the asset, these others also focus on finding the root cause of the failure and in developing and implementing a long-term solution to build reliability. They have this focus all the time.

Management encourages them by recognizing their proactive actions. In these cases, the workforce gets the signal that proactive actions are the organization's mode of operations.

People who take proactive actions are the real heroes. They are the people who are reliability leaders.

Do you have this type of employee(s) in your workplace?

ATTRIBUTES OF RELIABILITY LEADERS

The four fundamentals of reliability leadership, as identified in the *Uptime Elements* body of knowledge, are:

- Integrity;
- Authenticity;
- Responsibility;
- Aim or objective.

Integrity – Reliability leaders do what they say they will do to achieve a state of being that is complete and whole. Integrity is built on consistency of actions, values, methods, measures, principles, expectations and outcomes.

Authenticity – Reliability leaders are who they say they are. Authenticity is important in reliability leadership discussions. Today's workplace environment is more informal and less hierarchical than in the past. Command and control management doesn't fly with people hired for their creative work. They want leaders who inspire them and give them reasons for working beyond a paycheck. "Being authentic is much more than 'being yourself,'" says Gareth Jones, coauthor of *Why Should Anyone Work Here? What It Takes to Create an Authentic Organization*. "If you want to be a leader, you have to be yourself—skillfully."

Responsibility – Reliability leaders are accountable and take a stand for reliability. Responsibility implies a duty or obligation to satisfactorily perform or complete a task assigned by someone or created by one's own promise or circumstances, and take ownership and responsibility for its success or failure.

Aim or objective – Reliability leaders work for something bigger than themselves. Their aim is the purpose or intention they hope to achieve, the desired outcome for an organization based on its objectives.

A reliability leader can be anybody, and may or may not be a manager or supervisor. Nothing in the definitions of leader or reliability leader suggests or implies that notion. Rather, a reliability leader can be anybody, regardless of rank or position, at any level of the organization during any asset/equipment lifecycle phases, such as:

- Specifications/requirements;
- Design;
- Sourcing/procurement;
- Build/fabrication;
- Installation/commissioning;
- Operations and maintenance (i.e., utilization);
- Improvement;
- Disposal/decommissioning;
- Manage, all phases.

Anyone who supports eliminating or minimizing defects and failures to improve reliability and availability and reducing the lifecycle costs (i.e., total cost of ownership) can be classified as a reliability leader. It's not a position or rank, but a philosophy—a culture that supports working together with all stakeholders to eliminate defects so assets can be operated safely and cost-effectively.

ARE YOU A RELIABILITY LEADER?

Are you a leader? If you work in the reliability, maintenance, or asset management field, the better questions to ask yourself are:

- Am I a reliability leader?
- What qualifies me to be a reliability leader?
- What attributes do I have or do I need to become a reliability leader?

Conclusion

The workforce may have people who are called heroes. They are good at fixing things, but don't focus on the proactive steps required to minimize and eliminate failures. By recognizing and rewarding these employees in a way that creates heroes, management encourages a reactive culture.

The workforce also may have employees who don't just repair assets, but also try to find the root causes of the failures. Management supports such actions by recognizing and rewarding only those who take proactive steps. These are the workers who are reliability leaders—the real heroes.

Reliability leaders help others, or even a machine or device, to do a better job. They create a new future for the organization.

References

1. Gulati, Ramesh. *Uptime Elements Dictionary for Reliability Leaders & Asset Managers.* Fort Myers: Reliabilityweb.com, 2016.
2. Gulati, Ramesh *and* O'Hanlon, Terrence. *10 Rights of Asset Management*. Fort Myers: Reliabilityweb.com, 2017.

Ramesh Gulati *is an Asset Management & Reliability Leader with Jacobs. He is an author, change agent, teacher and also known as a "Reliability Sherpa." He is a frequent speaker at many maintenance, reliability and asset management events and has been involved in supporting societies and standards organizations.*

WHY MACHINE LEARNING AND AI ARE THE
FUTURE
OF OIL ANALYSIS

Cary Forgeron

Oil analysis is essential for maintaining equipment reliability and life span. In this process, data analysts assess whether samples indicate abnormal working surface wear and tear likely to impede performance or shorten specific equipment life span. The problem is, traditional analysis occurs after the fact. By then, signs of wear and tear when finally detected threaten optimal operation and increase the possibility of downtime.

But, what if the algorithms that create predictive analytics could be harnessed to detect potential abnormalities in engines, turbines, hydraulics and other equipment from a seemingly normal oil sample *before* they occur? In fact, such algorithms have been put to use successfully and are growing in acceptance in the form of an artificial intelligence (AI) platform. Combined with the expertise of data analysts and the concept of machine learning, AI has become vital for maintaining equipment and ensuring its useful life.

The Oil Analysis Process

Oil analysis, also referred to as oil condition monitoring (OCM), begins with a small sample provided by a company to a laboratory for analysis of wear, fluid condition and contamination. If any of these conditions are present in the sample, a human analyst recommends corrective action. Analysis per sample can take up to five minutes, which may not sound like much time, but feels like an eternity when you consider the quantity of samples submitted on a daily basis. One U.S. firm reports 1.2 million samples for oil analysis in 2018.

> But, what if the algorithms that create predictive analytics could be harnessed to detect potential abnormalities in engines, turbines, hydraulics and other equipment from a seemingly normal oil sample before they occur?

Traditional analysis is limited in scope and scale, which creates a major problem. There are only so many data points an analyst has time to consider. A typical figure is 100, which may be inadequate considering the seemingly endless number of data points and, equally important, the interrelationship of those points in determining one of four sample severity classifications: normal, monitor, abnormal and critical. Some abnormalities, such as the unwanted presence of iron and lead, in a sample are obvious for showing wear, but others may not be readily apparent.

DATA FLOW

CHARLES

NORMAL

ANALYSIS OF
OIL SAMPLE

MACHINE
LEARNING

DATA ANALYST

ABNORMAL & CRITICAL
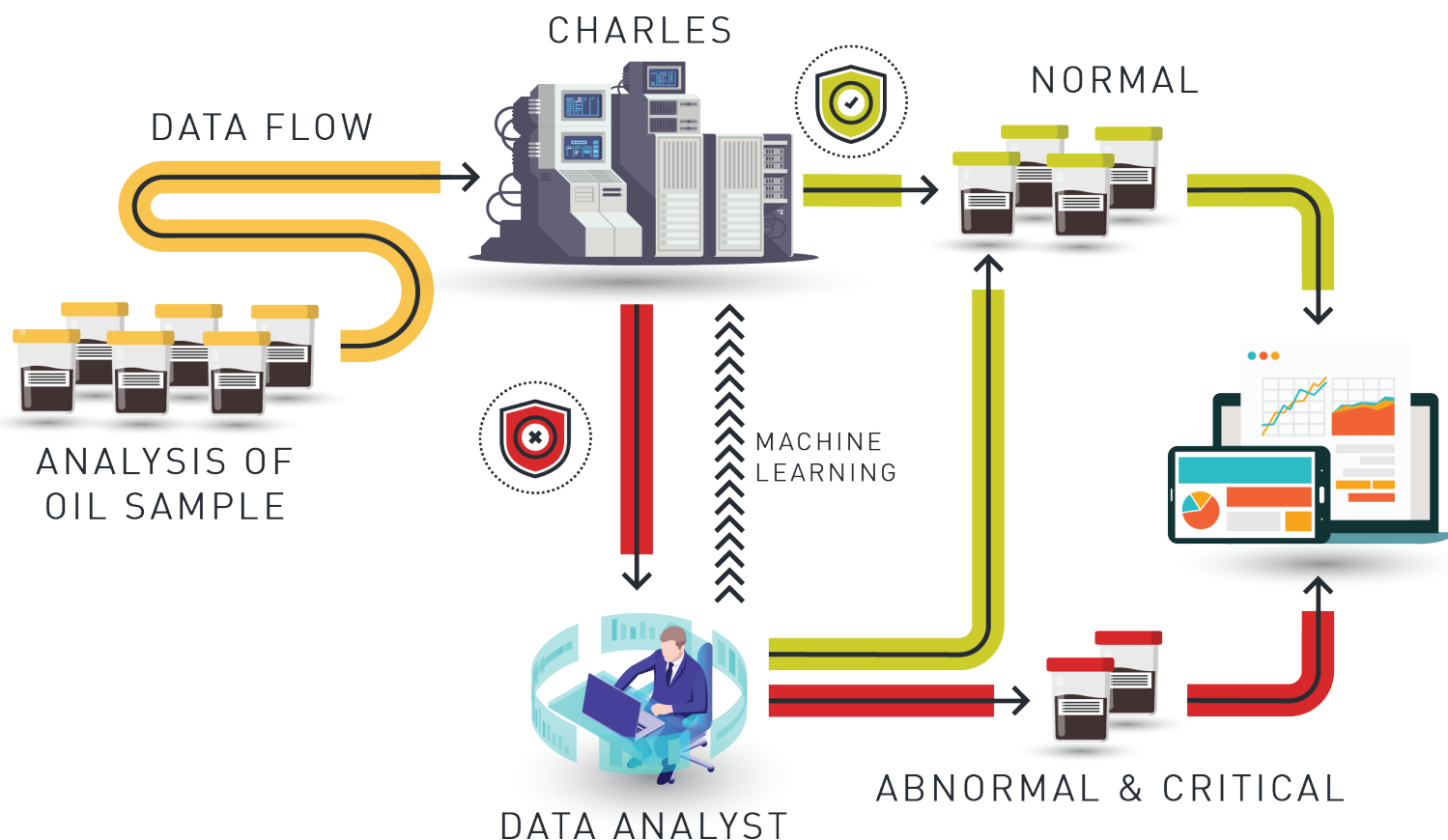
After analysis, the majority of samples are categorized as normal, but that does not change the time that must be committed to each one. Even normal findings can be time consuming, which is why some in the OCM industry have turned to two high-tech resources for quicker, accurate and more efficient data analysis: artificial intelligence and machine learning.

The Transformation of the Oil Analysis Process

To understand how all this applies to equipment maintenance, start with what's commonly called big data. Accessing potentially vital information buried in the reams of big data is as vital to maintenance as it is to economics and investments. For equipment, such as engines, gears and hydraulics, AI has become the platform to enable identification of troubling trends in a sample. It accesses thousands of data points, many of which are inaccessible through traditional analysis, and produces a report for the analyst to review.

Machine learning is a subset of AI. Here, the focus is on patterns and relationships between data. The machine learns from historical material fed by the data analyst. Information of this type is developed into a model that enables the computer to learn. The model, unlike traditional analysis of oil samples, is not rules-based, allowing for different interpretations to be easily factored in.

There is a direct relationship between the quality of traditional oil analysis and the machine learning model. Quality demonstrated by the experience of the analyst in many ways is as fundamental to machine learning as it is to the AI platform. Both learn from experience in much the same way as an apprentice learns a craft from a longtime practitioner.

The reality is that the machine continues to learn after AI does the data points' heavy lifting prior to the analyst's review. The impact of this process on maintenance is clear. Unlike traditional analysis and its after-the-fact detection of abnormal trends, an AI platform-driven oil analysis identifies *precursors* of wear on equipment or changes in fluid conditions. A department can take action before there is either downtime or a reduction in the equipment's useful life. One example already in use by an international certification agency is a platform containing an aggregate consisting of millions of samples and results from more than a decade of analysis.

"It's a hugely rich data set we were able to mine," says Jonathan Rudnicki, the OCM project leader for the international certification agency. "We were able to look for correlations between different results to assist in identifying

> …An AI platform-driven oil analysis identifies precursors of wear on equipment or changes in fluid conditions
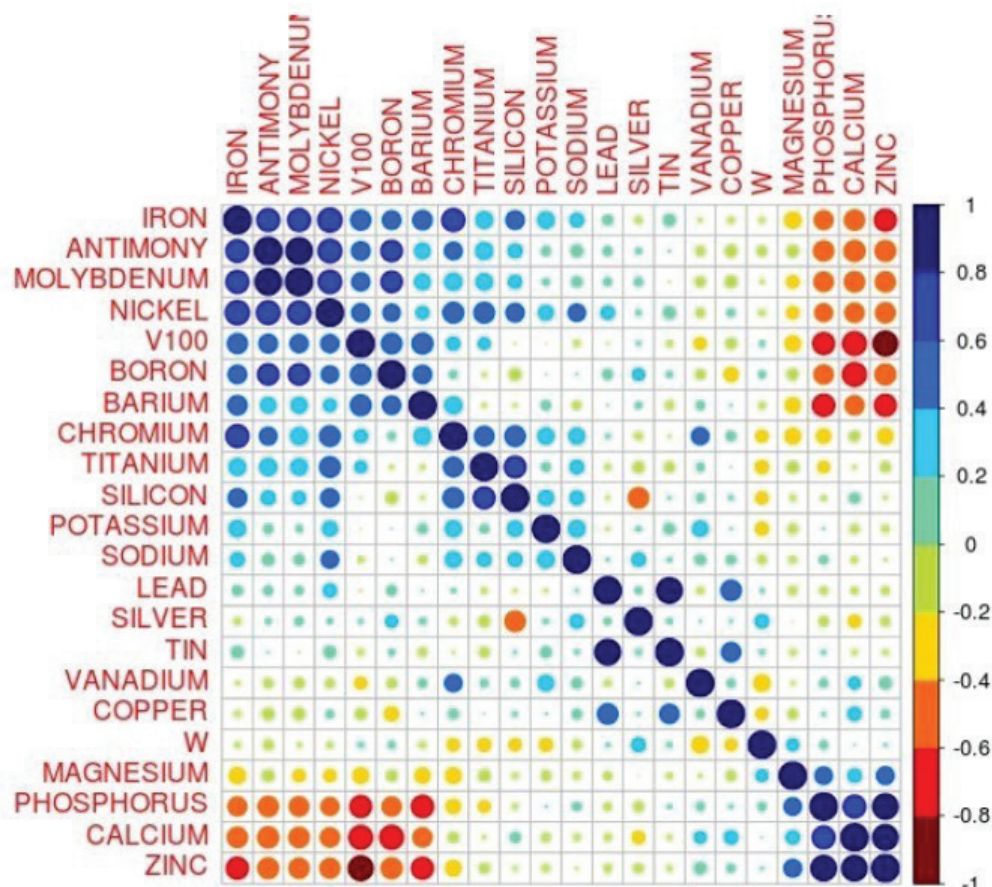
Figure 1: Machine learning identifies patterns and correlations in historical data

different permutations that best predicted the condition of the sample and whether any actions were required."

Historical data in this AI/machine learning environment is divided into two parts: one for training and the other for testing the model. During the latter, areas with potential data quality issues are identified and resolved. The model deep dives into data relationships as it explores features and/or feature combinations from the millions of samples. Details from each sample are recorded into a laboratory information management system and sent to the AI platform for interpretation on the level of severity. If the sample is found to be abnormal or critical, the system, along with the analyst, assesses possible corrective actions, followed by a quality control check to assure the accuracy of the findings before returning the sample to the company that submitted it.

The Experience of a User

Jami Melani, heavy duty/technical services field manager for a longtime provider of motor oils and specialty lubricants, experienced firsthand the importance of accurate and timely oil analysis. He says AI/machine learning platforms are inevitable because of rapidly evolving changes within the industries his company serves.

"Equipment and lubricants are advancing at a faster rate and you have to automate to keep pace," Melani said. "(Traditional) platforms don't take into account severity of the duty cycle." Some examples he provided include haul trucks and loaders with unique load and wear ratings. Their differences may slip through traditional analysis, but are adjusted within automated programs.

"Every time someone puts another sample in, the system will weed out anomalies and learn on itself," he said.

AI and the Future of Lubricant Maintenance

AI and machine learning are not threats to the continuing need for OCM analysts. Since the platform can determine normal samples instantaneously, analysts can better spend their time on more detailed analysis of exceptional samples. However, there will still be a few normal ones they review as part of the ongoing quality check.
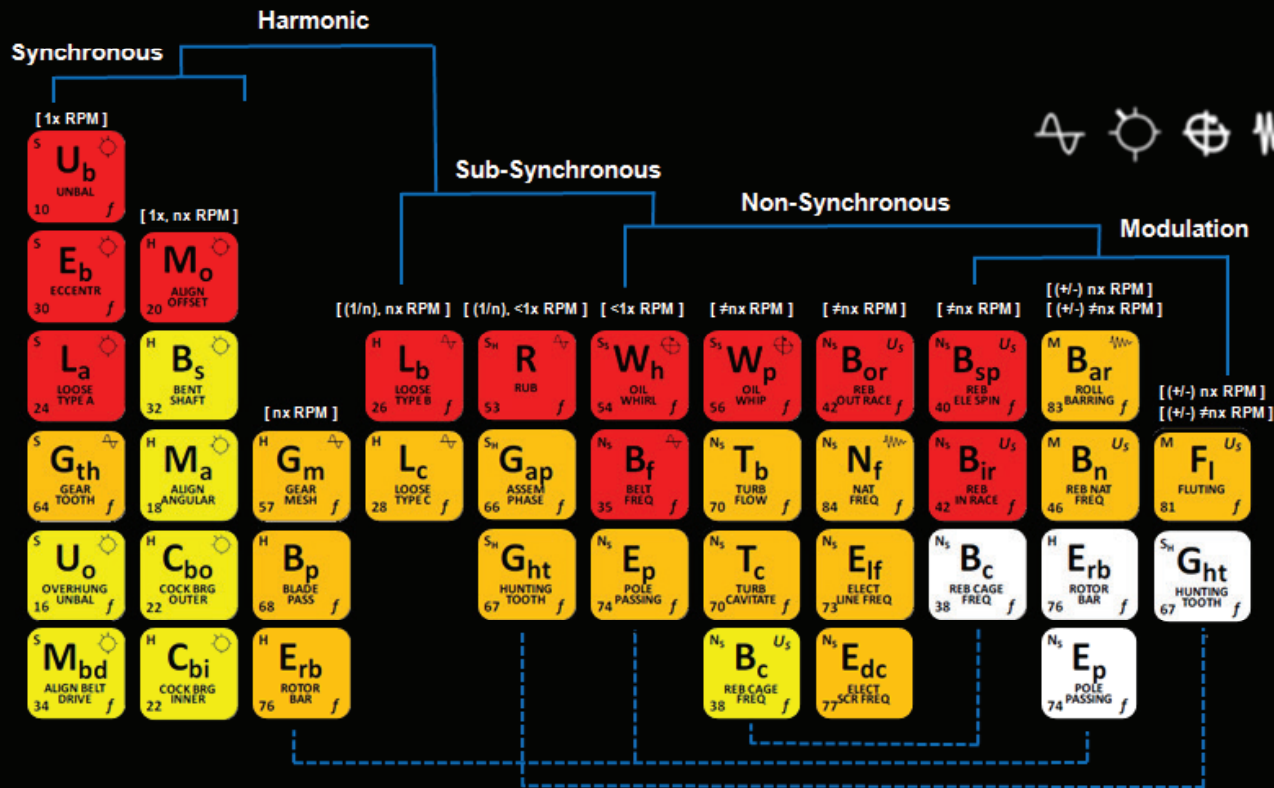
Additionally, findings and relationships subject to data analysis are integral to continued machine learning and the growth of predictive analytics for maintenance. Both are proving to be indispensable for maintaining engines or other equipment by reducing unplanned downtime and the possibility of machine failure while increasing return on investment.

As Melani aptly summarizes, "It's data and what you can do with it."

Cary Forgeron is the North American Director for Oil Condition Monitoring for Bureau Veritas, a global leader in testing, inspection and certification. He has worked on OCM with large industrial clients for more than 15 years. www.bureauveritas.com/oil-analysis

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Modulation

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[1x, nx RPM]

[(1/n), nx RPM]   [(1/n), <1x RPM]   [<1x RPM]   [≠nx RPM]   [≠nx RPM]   [≠nx RPM]   [(+/-) nx RPM]
[(+/-) ≠nx RPM]

[nx RPM]

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[(+/-) ≠nx RPM]

U_b UNBAL 10									
E_b ECCENTR 30	M_o ALIGN OFFSET 20								
L_a LOOSE TYPE A 24	B_s BENT SHAFT 32		L_b LOOSE TYPE B 26	R RUB 53	W_h OIL WHIRL 54	W_p OIL WHIP 56	B_{or} REB OUT RACE 42	B_{sp} REB ELE SPIN 40	B_{ar} ROLL BARRING 83
G_{th} GEAR TOOTH 64	M_a ALIGN ANGULAR 18	G_m GEAR MESH 57	L_c LOOSE TYPE C 28	G_{ap} ASSEM PHASE 66	B_f BELT FREQ 35	T_b TURB FLOW 70	N_f NAT FREQ 84	B_{ir} REB IN RACE 42	B_n REB NAT FREQ 46
U_o OVERHUNG UNBAL 16	C_{bo} COCK BRG OUTER 22	B_p BLADE PASS 68		G_{ht} HUNTING TOOTH 67	E_p POLE PASSING 74	T_c TURB CAVITATE 70	E_{lf} ELECT LINE FREQ 73	B_c REB CAGE FREQ 38	E_{rb} ROTOR BAR 76
M_{bd} ALIGN BELT DRIVE 34	C_{bi} COCK BRG INNER 22	E_{rb} ROTOR BAR 76				B_c REB CAGE FREQ 38	E_{dc} ELECT SCR FREQ 77		E_p POLE PASSING 74

F_l FLUTING 81

G_{ht} HUNTING TOOTH 67

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DISP VEL ACCEL

Hz CPM

U_S

f

VFG   VTG   CASES   TIPS   MEDIA

D IPS	D Hz	D	D	D	D	D	D f	G	G	P	P	G
A AMP 86	F FREQ 6	P PHASE 13	T TWF 10	O ORBIT 40	U_S HFD 18	T_R TRANSIENT 44	F FORMULA 94	V_{FG} FAULT GUIDE	V_{TG} TECH GUIDE	C_H CASE HIST	E_T TIPS	M MEDIA
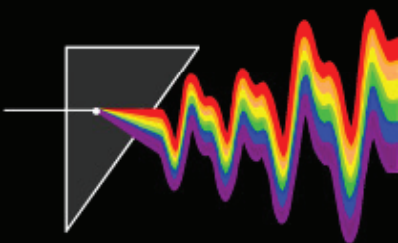
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BATTLE
OF THE WORK TYPES

Robert Brieck

Terminology used by maintenance departments produce a wealth of information when performing an Internet search. World-class maintenance status, cost benefits of preventive maintenance vs. corrective maintenance, 6:1 maintenance golden rule and maintenance effectiveness are just a few examples. As you scan through search results for terms such as these, you'll come across professional articles, opinions, exercises and infinite calls to action inviting searchers to contact an organization for additional information. You will likely find guarantees to improve your maintenance operations and overall bottom line by following recommendations. However, what you likely won't find is a clear-cut understanding of the differences between these maintenance terms due to a lack of consistency among sources.

> " **THE PROBLEM IS AN INCONSISTENCY BETWEEN DEFINITIONS OF VARIOUS WORK TYPES** "

Key Maintenance Terms

After reviewing various definitions of common maintenance terms, a relationship between preventive maintenance (PM), corrective maintenance (CM) and emergency maintenance (EM) work types is apparent. The vast array of articles written on these topics suggest percentage values for man-hours dedicated to PM, CM and EM based on total man-hours available within maintenance operations. These values range from between 50 and 85 percent for PM, 20 and 70 percent for CM, and five and 30 percent for EM.

The broad ranges listed in Figure 2 are indicative of widely separated values by work type, which suggests the industry authors of these articles do not differ significantly on their opinions of what constitutes a well-run department. They do, however, lead one to believe an organization is world-class or at least managed sufficiently based on these values. The problem is an inconsistency between definitions of various work types.

For example, take the following definitions from the online Business-Dictionary:

- **PREVENTIVE MAINTENANCE** – Systematic inspection, detection, correction and prevention of incipient failures before they become actual or major failures;

- **CORRECTIVE MAINTENANCE** – Activities undertaken to detect, isolate and rectify a fault so the failed equipment, machine, or system can be restored to its normal operable status;

MAINTENANCE
EFFECTIVENESS

MAINTENANCE

CORRECTIVE MAINTENANCE

MAINTENANCE STRATEGY

WORLD-CLASS MAINTENANCE

EMERGENCY MAINTENANCE

6:1
MAINTENANCE
GOLDEN
RULE

PREVENTIVE MAINTENANCE

Figure 1: Various terminology commonly referenced in maintenance management, yet industry standard definitions for many of these terms do not exist

- **EMERGENCY MAINTENANCE** – Sudden, unexpected, or impending situations that may cause injury, loss of life, damage to property and/or interference with the normal activities of a person or firm and, therefore, require immediate attention and remedial action.

While these definitions appear to create a sound relationship between the varying maintenance tactics, many industry authors deviate throughout their explanations. "Corrective maintenance identifies and corrects a maintenance fault after it has occurred," according to one source.[1] Additionally, "Corrective maintenance is the act of performing some repair or adjustment for a condition that was identified during the accomplishment of a PM or PdM (predictive maintenance) evolution, and cannot reasonably be corrected within the allowed labor time for accomplishing the PM or PdM," says another source.[2] Furthermore, "Corrective maintenance is the set of tasks destined to correct the defects to be found in the different equipment and that are communicated to the maintenance department by users of the same equipment," says yet another source.[3]

Each Organization is Unique

Between organizations, there are vastly different definitions of PM, CM and EM. While they are not wrong, their interpretations aren't uniform—at times within their own organization or departments. Definitions of work types and how those work types are applied to work orders can influence an organization as a whole. These definitions reflect on maintenance management tasks, including scheduling, work order completion and overall equipment effectiveness (OEE). Activities such as these indicate man-hours expended versus man-hours available displayed in reports as key performance indicators (KPIs) for the department.

Sources with varying definitions of PM, CM and EM often suggest that a specific percentage by work types, levels, or balance between those work types reflects a well-managed department and organization. Regardless of industry or organizational type, the ideal level or balance for each maintenance department is unique. It should be closely aligned with an organization's mission statement and should be defined only by that individual department or organization.

As far as the overall premise of measurement concepts offered in the various sources mentioned, many of their ideas and values should be embraced. In fact, organizations are encouraged to consider these definitions at times. However, the ideal level or balance point among PM, CM, EM and other work types should:

- Account for the assets or equipment available for use in production when scheduled and for the entire scheduled production period;
- Apply to assets or equipment operating according to intended specifications and speeds, within the design and tolerance outputs, and at the production throughput quantity;
- Cover all expenses associated with those assets, including the maintenance department's expenses.

A Uniform Approach?

Each organization needs to clearly define and record its own, unique meaning associated with each work type to eliminate any potential misun-
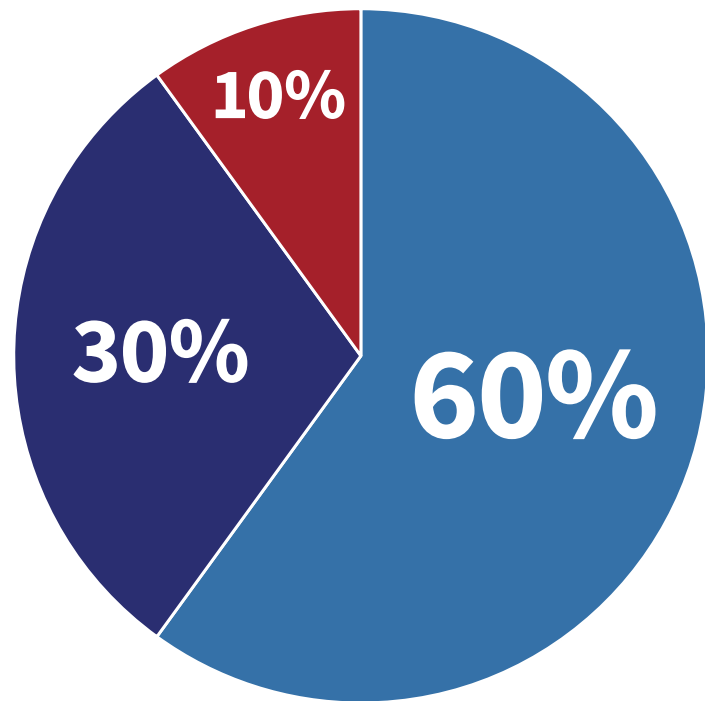
TOTAL AVAILABLE MAN-HOURS

Preventive Maintenance 60%
Corrective Maintenance 30%
Emergency Maintenance 10%

Figure 2: Pie chart displays one possible scenario of the ratio between PM, CM and EM within a maintenance department

derstandings. Most computerized maintenance management system (CMMS) software solutions allow users to enter this type of information, such as in a comment field. It would be extremely beneficial for an organization, such as the International Facility Management Association (IFMA), APPA: Leadership in Educational Facilities, or perhaps another relevant group to publish consistent definitions of terms used by maintenance departments. Undertaking an effort of this magnitude would provide an industry standard for the term, world-class maintenance. Consistent definitions for PM, CM, EM and others would certainly provide unification for maintenance departments across the board, regardless of sector.

In conclusion, the following advice is offered to organizations:

- Discuss the need for work types with all stakeholders, not just the production department, maintenance employees, or upper management.
- Obtain a consensus on work types and what each work type umbrella covers.

Only after following these key pieces of advice can an organization adequately generate, monitor and report against those agreed upon work types. Performing the correct work at the correct time allows the productive use of assets when needed, which leads to cost saving opportunities.

References

1. Life Cycle Engineering, Inc. *Analyzing the Relationship of Preventive Maintenance to Corrective Maintenance*. https://www.lce.com/Analyzing-the-Relationship-of-Preventive-Maintenance-to-Corrective-Maintenance-1091.html
2. Measure Twice. "Cost-Benefit of Preventive Maintenance vs. Corrective Maintenance." *Preventive Maintenance Tips*: January 19, 2017. http://preventivemaintenancetips.com/preventive-maintenance-cost-benefit/
3. Garrido, Santiago Garcia. "Types of Maintenance." *PetrochemicalMaintenance.com*. https://www.mantenimientopetroquimica.com/en/typesofmaintenance.html

Robert Brieck *is a professional services consultant for DPSI, a CMMS software company. Robert has over 40 years of experience as a senior level maintenance administrator at a number of organizations, most recently with the Community College of Allegheny County.* *www.dpsi.com*

From the Publisher:

Thank you for the thought-provoking article. We completely agree with your suggestion. Reliabilityweb.com has been working within our community over the last year and created a virtual special interest group (vSIG) to tackle just those definitions!

Our special thanks to vSIG members, Paul Crocker, Tom Pann, Laura Phillips, Greg Perry, Steve Sloane and several others dedicated reliability leaders, who worked on this project. Keep an eye out for a future article in *Uptime* magazine and a complimentary resource guide on this topic published by Reliabilityweb.com. Stay tuned!

From the vSIG:

In April 2018, a virtual special interest group (vSIG) was formed with the purpose to tie the seminal learnings from Nowlan and Heap's Reliability Centered Maintenance back to the work types that are used today. The group, composed of a broad cross-section of industries through numerous discussions and research, have developed the initial work types to be used across industries. These work types were presented at The RELIABILITY Conference, May 6-9, 2019, for feedback from a broader audience. This feedback will assist us as we create the upcoming detailed resource guide on work categorization.
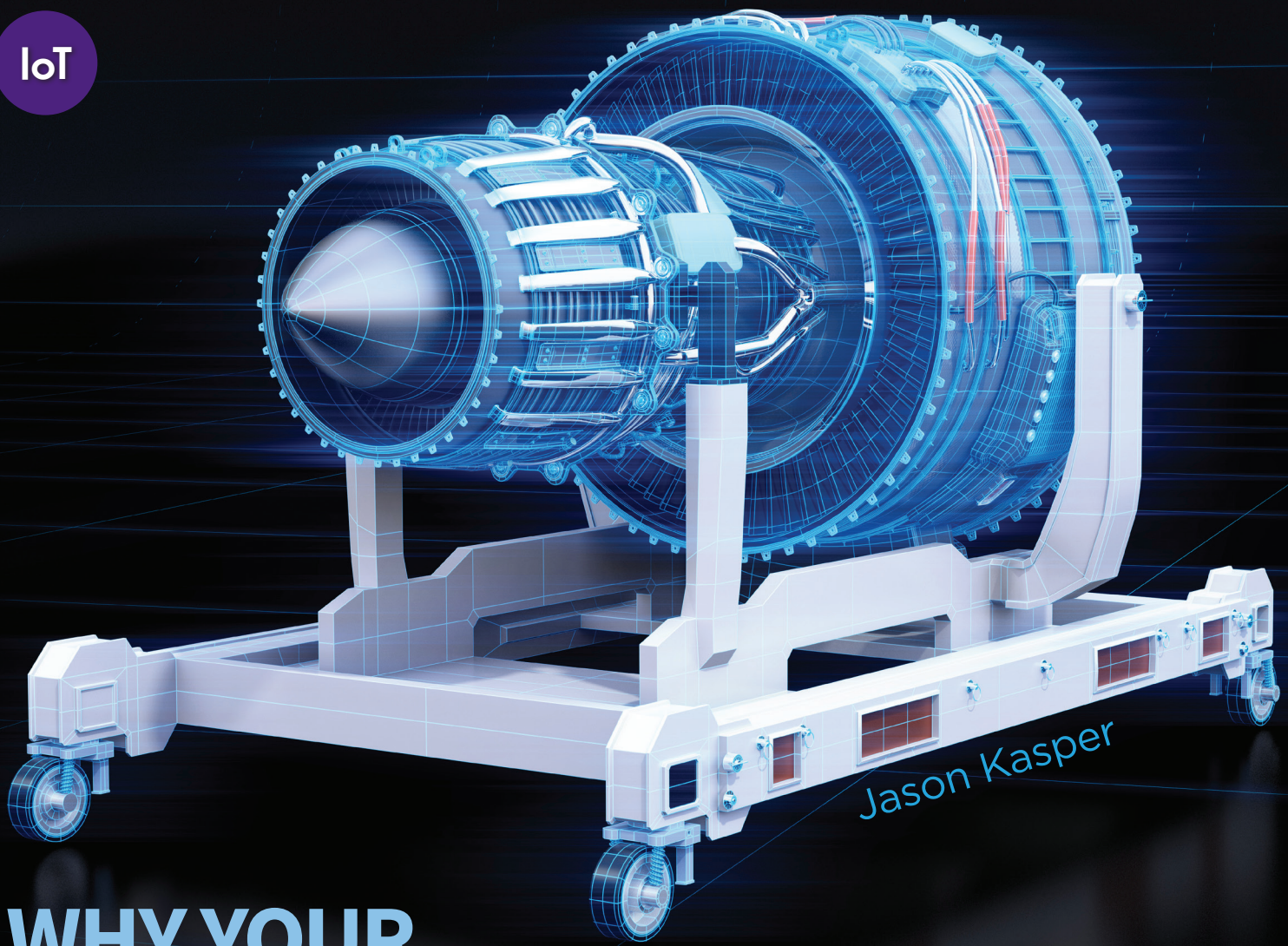
Jason Kasper

WHY YOUR
DIGITAL TWIN
APPROACH IS NOT BUILT TO LAST AND WHAT TO DO ABOUT IT NOW

P redicting the failure of assets is the holy grail of maintenance. And, there has never been a better time to achieve it than now. At stake is millions of dollars in savings through uptime improvements and downtime avoidance. Two things that are critical for investments in capital costing huge sums of money and revenue generation.

Over the past few years, technology advancements in the Internet of Things (IoT) sensors, analytics and simulation have emerged as possible panaceas to solve the puzzle of predicting failures with increased accuracy. These technologies take information generated from individual assets or systems over time and couple them with complex algorithms to predict failures.

The good news is there have been some promising results, such as reducing equipment downtime by five percent by predicting a valve failure.

However, such stories are mostly about pilot projects that haven't yet moved to full deployment with enterprise level monitoring, analysis and maintenance execution.

More recently, there have been increasing references to digital twins: the idea of creating an exact replica of a physical asset by combining computer-aided design (CAD) and simulation models, IoT sensors, time series data and maintenance records to build a picture of an asset and its current operating condition.

Now the hype has reached its peak. It's time for organizations to take a step back and understand, in depth, what these technologies are capable of achieving. For example, is the approach you are taking with these new capabilities really providing the picture of asset health you require to make important decisions on proactive maintenance activities?
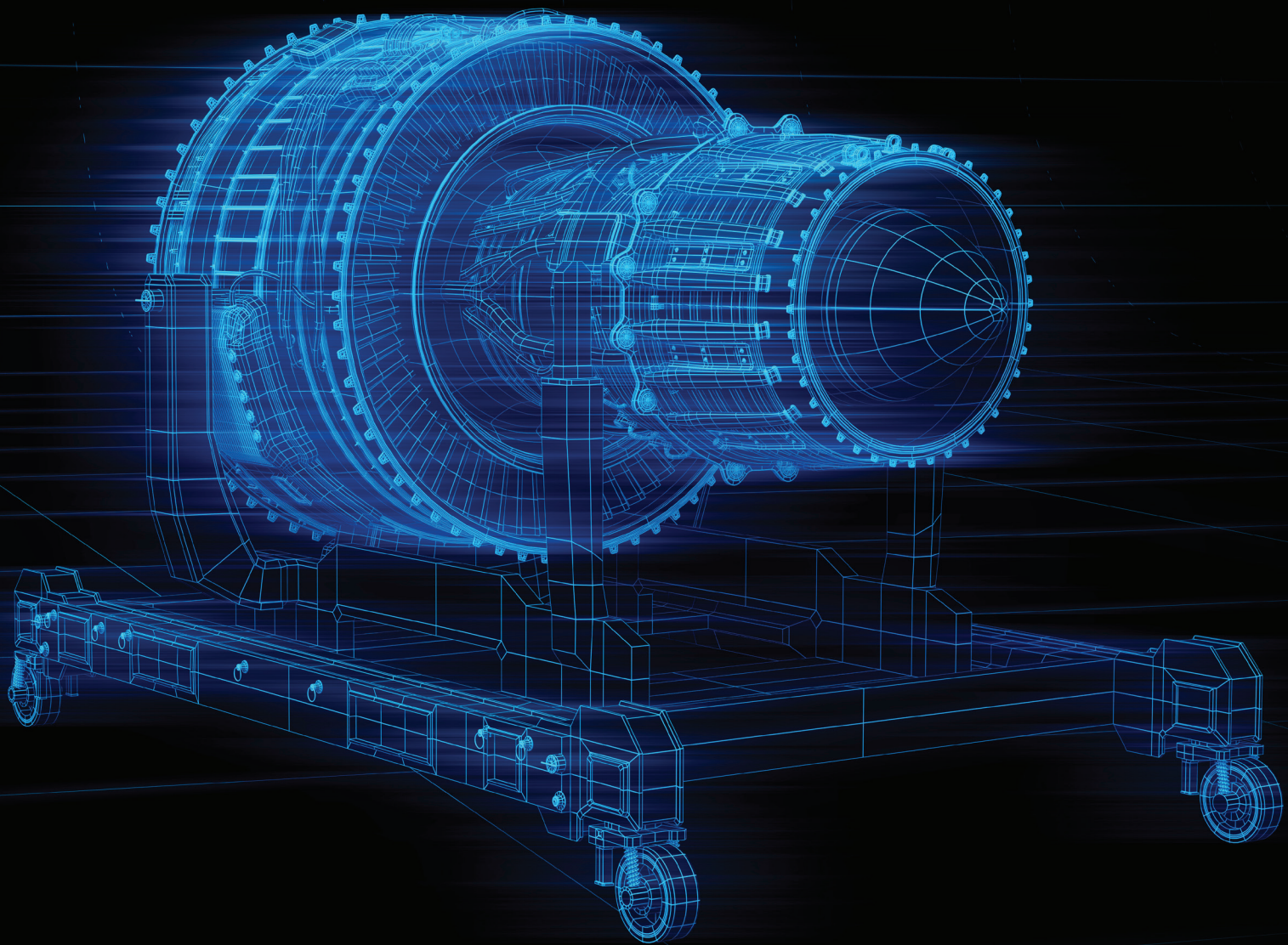
In reality, the top-down approach that has taken shape in the market will fail. Why? Organizations are addressing the underlying problems: what is the asset I am focusing on in the first place, what is the history, does it provide the ability to follow information easily, what is its current makeup and how is this different than the rest of the assets I need to manage?

A Digital Picture, but Not the Whole Story

In recent years, IoT sensors have emerged as a powerful tool, monitoring things like torque, temperature, corrosion, and start and stops, to name a few. The information from these sensors is then coupled with other historical data sources and predictive analytics to provide a picture of an asset's health and forecast when components might fail. When you look at an asset in isolation, which is the definition of a pilot project, you will likely see some good results. However, the algorithms are based on one individual asset and its related sensor data.

The problem is when you try to scale hundreds or thousands of similar assets. The predictions you created are specific to the asset in the original pilot project. Applying these same predictions to other assets could lead to maintenance issues, as parts with useful life remaining are replaced or assets taken out of service due to an unforecasted failure.

> " An individual asset's content is king "

Why? Assets are not manufactured equally and over their time in operation, in some cases 10 to 40 years, they diverge further, even if sitting right next to each other.

For example, two similar assets might have different electric motors, each from a different manufacturer. One of the manufacturer's components may be designed to last longer. Is your prediction based on that? Now, factor in the many other ways in which your assets differ. Will the predictions reflect the differences in thousands of similar, yet different assets?

Digital Models Will Never be Digital Twins

There is an emerging trend to use simulation models created during the engineering phase of the product lifecycle as the digital twin of an asset. The concept is that comparing these digital models with operational data may result in the identification of failures while running the many different simulations. After all, the simulation models are tested for many types of possible operational scenarios and the related failures that would occur if they persisted.

At first look, this is a vast, rich resource of information that can be used by maintenance to monitor the signals for failure in the field. The problem is that these simulation models may not necessarily reflect the final as-built configuration of the asset that went to the customer. As assets go

through manufacturing, much can change. For example, as suppliers change, modifications are incorporated and defects are rectified. The original simulation models will not reflect these differences and the actual performance profile will differ from that predicted. Fast forward to the asset operating in the field that, over a few years, has undergone maintenance and upgrades to the point that its configuration is now significantly different from that assumed in the original simulations.

Flip the Process on Its Head – Make Your Digital Twin Built to Last

What is the maintenance group to do? Promising technologies are available; IoT data, predictive analytics and simulations all have value, but only when used in context. This means building and maintaining a digital record of the configuration of products as they are manufactured, maintained and upgraded. This is the key to keeping the asset in the field and its digital twin synchronized.

This first viable, contextual digital twin is created during the as-built phase of manufacturing. This is the first view into the exact makeup of the asset in context. This involves recording the exact product configuration, including any special features or options used, as well as capturing serial numbers. The digital twin is subsequently updated whenever a significant change happens to the asset. For example, if electric motor serial number #001 is replaced with electric motor serial number #002, the corresponding change is made to the digital twin.

Now, using the digital twin configuration, simulation models can be built specific to the characteristics of a particular asset and coupled with IoT data generated from the asset to predict potential failures.

Conclusion and Recommendations

Technology advancements in sensors, analytics and simulation can be the solution to predicting maintenance problems, but only if you take a digital twin configuration approach first. An individual asset's context is king. Use it as the baseline to predict failure from data generated from IoT sensors and validate it with purpose-built simulation models.

A few key points to remember as you pursue a digital twin configuration strategy:

* Develop the business processes and technology to support tracking and changing an asset's configuration first. Without being good at this, there will be no value in applying other technologies.
* Use IoT sensors and data compared against an individual asset's configuration, not the generalization of all "like" assets. Doing the later will result in weak results.
* Use the power of simulation to build digital models of individual configurations of assets. The digital model from the manufacturer will have a short life or no life at all.

Jason Kasper joined Aras Corporation in April 2017 and is a Product Marketing Manager with his primary focus being maintenance, repair, and overhaul (MRO), manufacturing execution systems and their importance within the product lifecycle. Jason has over 20 years of experience in working with customers to develop enterprise software solutions. *www.aras.com*

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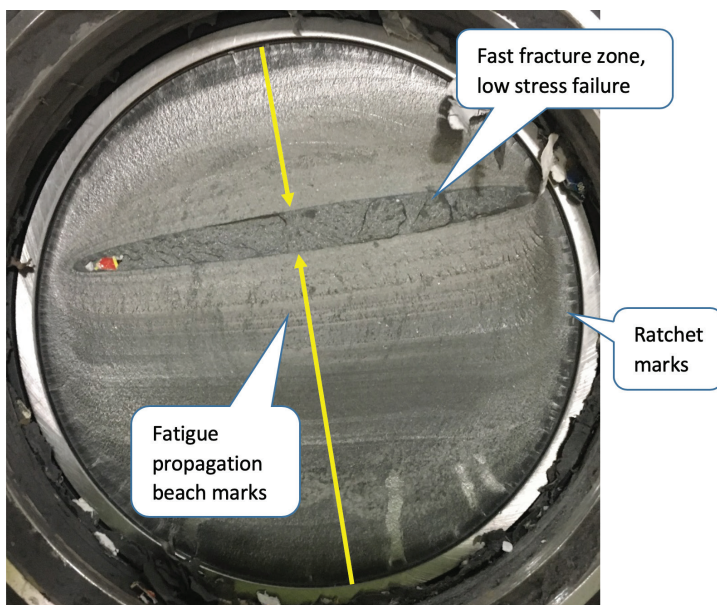# SOLVING FATIGUE:

Randy Riddell

THE
SILENT KILLER

Fatigue is a failure mode that every manufacturing plant will experience at some point and can become chronic if not solved. While understanding fatigue has advanced since its inception in the early 1800s, there are still some misunderstandings in manufacturing in solving these failures. A characteristic of fatigue failures is stress, which is typically below the yield strength of the material. This is what makes fatigue a silent killer.

Fatigue occurs on a part that is subjected to alternating or cyclic stress. Cyclic stress can cause failure after a certain number of cycles. Fatigue becomes a failure mode when cracks initiate where stresses have concentrated on the part. When solving fatigue failures, there are two key areas on which to focus the analysis: External forces that cause the cyclic stress and component design that reduces the endurance limit of the material. It is in one or both of these areas where the solution to fatigue failures can be found. So, let's take a closer look at these two key areas.

Identify Then Reduce or Eliminate the Cyclic Stress

The first key step is correctly reading the fracture surface to determine the type of fatigue. The different types of fatigue will point to the type of stress causing the fatigue. The fatigue may be unidirectional bending, reversed bending, rotating bending, torsion, or tension. Rotating bending is one of the most common failure mechanisms for rotating equipment when fatigue fracture occurs. Torsional loads are typically constant in a combined stress application and, if variable, are typically pulsating stresses. High strength materials typically exhibit brittle fractures, while low strength materials typically exhibit ductile type fractures. The fracture plane also can help identify the type of fatigue. Most torsion failures occur at a 45° fracture plane, while bending is typically a 90° fracture plane.

The fatigue fracture may be further described as high cycle or low cycle and high stress or low stress. The size of the fast or final fracture zone compared to the fatigue area will reveal if the failure is high or low stress fatigue. The fast fracture zone is the area of the fracture that failed due to overload after some amount of fatigue had propagated on the part. The fatigue may be pure mechanical fatigue or corrosion fatigue. Corrosion fatigue drastically reduces the fatigue strength of the material. Ratchet marks on the outside of the fracture indicate fracture initiation sights. Beach marks (i.e., progression marks) show the crack's progression history and path. The location of a crack's
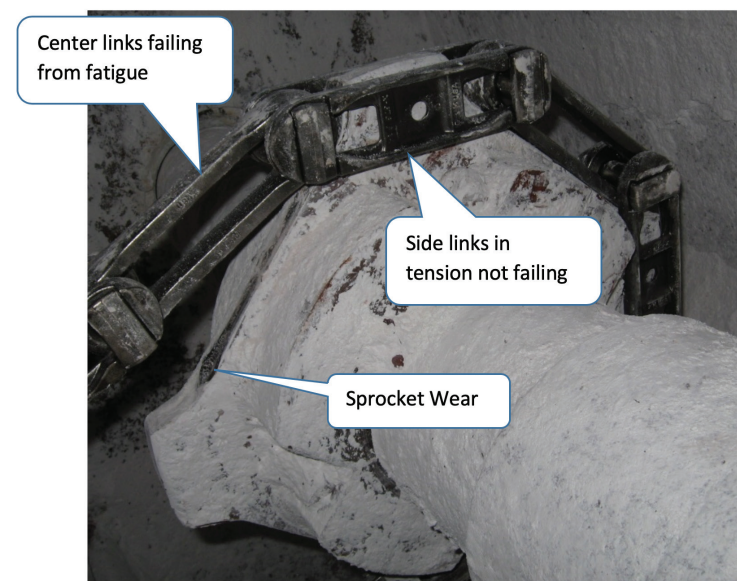
origins may be a keyway corner or shaft step radius. Figure 1 shows an example of some basic fatigue features. Assistance from a metallurgical analysis lab may be needed to identify the fatigue mechanism.

Once the type of fatigue is known, the source of the cyclic stress that matches the fatigue fracture can be located. Bending stress is one of the key types of stresses that cause fatigue failure. It can originate from reaction forces from a chain or belt drive, overhung loads, misaligned shafts, or reaction loads from equipment operation.

As an example, a drag chain link fatigue was identified as reversed bending fatigue. Initially different chains were installed, but with the same failures.

Reversed bending fatigue, crack initiation at chain forge line

Fast fracture zone
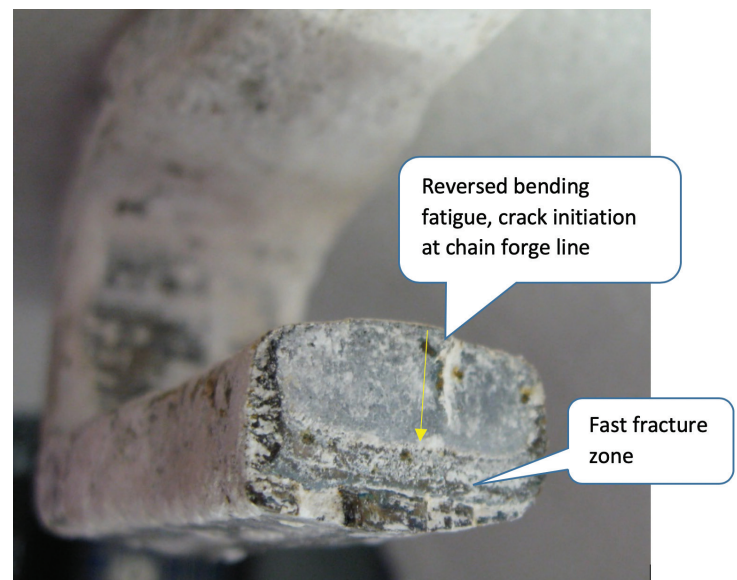
Figure 2: Fracture surface stress analysis

Fast fracture zone, low stress failure

Ratchet marks

Fatigue propagation beach marks

Figure 1: Low stress bending fatigue with severe stress concentration on shaft

Center links failing from fatigue

Side links in tension not failing

Sprocket Wear

Figure 3: Evidence of a worn sprocket

A closer investigation showed this chronic failure was only occurring on the center link of the chain. The only area where bending stress could occur on this center link was around the sprocket. Each revolution around the sprocket tooth created a cyclic bending stress on the chain link. The cause of the cyclic stress was found to be a worn sprocket (see Figures 2 through 4). Removing the cyclic bending stress by replacing the worn sprockets removed the force initiating the fatigue. The result was a cyclic stress below the endurance limit of the material. The stress concentration at the forge line on the chain link was where the crack initiated, but removing the large cyclic stress was the root cause. However, there are other times where the cyclic stress may be reduced by precision assembly, such as proper belt/chain tension on a drive shaft.

Figure 4: Evidence of sprocket wear causing bending stress

Analysis of Component Design to Improve Endurance Limit and Reduce Fatigue Risk

In most cases, cyclic stress is just a function of normal operation and can't be reduced or eliminated. In these cases, the solution must look at two areas: component design and flaw elimination. A focused analysis of the fatigue crack initiation location on the component may yield additional actions to insulate against future fatigue failures.

Component design starts with the material. The material is critical to understanding the fatigue resistance of the component. The endurance limit is the stress level at which a part can withstand a cyclic stress without a fatigue failure. A part's design, where the cyclic stress is lower than the endurance limit, will eliminate fatigue failure for the life of the part. The S-N curve in Figure 5 shows how the endurance limit of a component's design can lead to infinite life and how a reduction in the endurance limit may lead to a finite fatigue

> Bending stress is one of the key types of stresses that cause fatigue failure
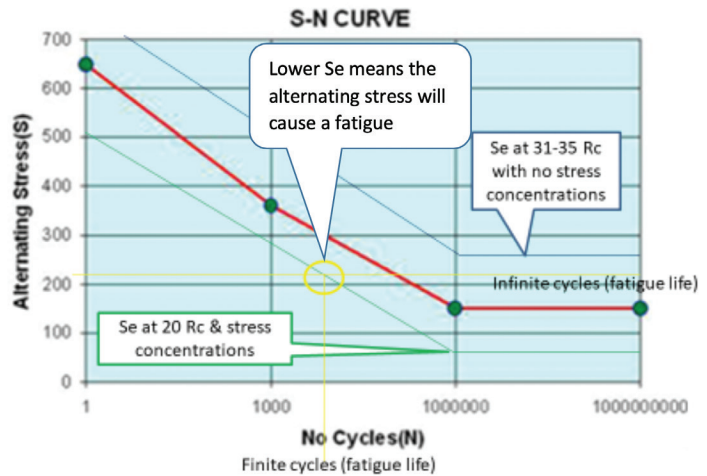
Figure 5: S-N fatigue curve

life of a machine's component. Design flaws lower the endurance limit to a point where a finite or certain number of cycles will lead to a fatigue failure.

The endurance limit of the material is directly proportional to the material tensile strength.

Se' = .504 Sut

Where Sut = Ultimate tensile strength of material
Se' = Endurance limit of test specimen

The basic concept is simple, however, the endurance limit can be reduced by many design factors, such as surface, size, load and temperature, as well as miscellaneous factors, like notch stress concentration, shaft radius and corrosion. These corrections may be applied to find the corrected endurance limit as shown:

Se = Se'KaKbKcKdKeKr

Where Se = Endurance limit of mechanical element
    Se' = Endurance limit of test specimen
    Ka = Surface factor
    Kb = Size factor
    Kc = Load factor
    Kd = Temperature factor
    Ke = Miscellaneous factors
    Kr = Reliability factor

The highest stress is typically at the surface of the material, so this is a key area to focus on. The surface factor can drastically reduce the endurance limit. Many times, the surface finish or surface defect will be what localizes a cyclic stress that initiates fatigue. A general rule is to have a surface with no more than a 32 roughness average (Ra), which would keep the surface factor, Ka, in the .85 to .9 range for most mild steels. Surface roughness increases from 32 Ra to 250 Ra can reduce the endurance limit by 25 percent.

Not only is the material strength of primary importance, but the material will also have very different machining characteristics that can lead to machine toolmarks and stress concentrations. Fine grain materials also typically yield more fatigue resistance than coarse grain material. More grain boundaries can impede crack propagation. Material toughness is also a factor to consider with material selection. Toughness is the area under the stress

Machine toolmarks in radius

90° fracture plane means bending fatigue
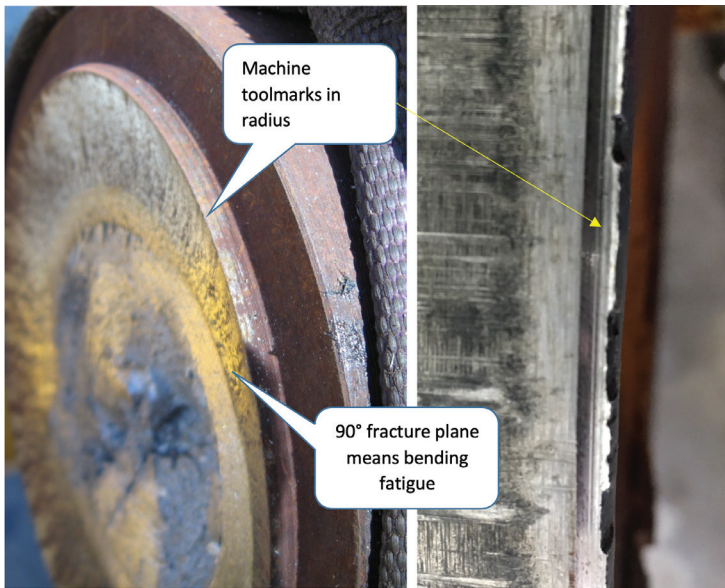
Figure 6: Shaft fracture with machine toolmarks (surface defect) with a small radius stress concentration

strain curve and is defined as the energy per unit volume prior to fracture. Material toughness allows the material to absorb the stress energy. Medium carbon steels have the highest toughness when compared to high carbon and low carbon steels.

An example of the effects of surface factors would be a typical rotating bending fatigue on a shaft like that in Figure 6. Machine toolmarks on the already small shaft radius increased the shaft stress concentration, which initiated a rotating bending fatigue failure.

Corrected shaft radius & surface finish
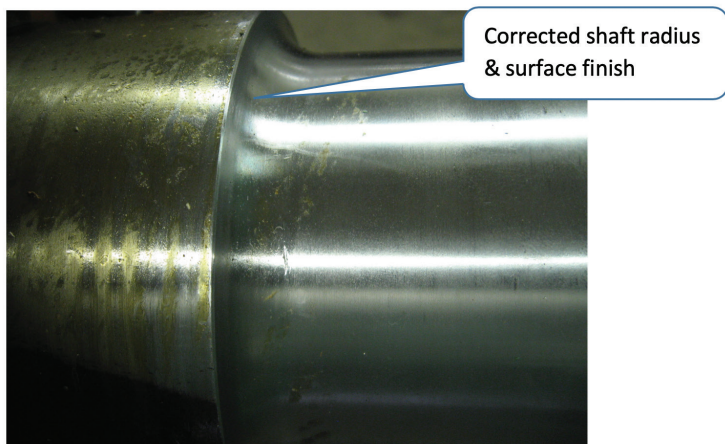
Figure 7: A corrected shaft radius, complete with a smooth surface finish

Due to the surface factor being one of the most important fatigue design and manufacturing elements, there are many surface treatments that can insulate surfaces from cyclic stress and fatigue crack initiation. Many of these induce a compressive surface stress at some case depth. The surface tensile stress on the part must overcome the surface compressive stress before the part sees a cyclic fatigue stress. Some of these include carburizing, nitriding, or shot peening. Electropolishing provides a super smooth finish that improves the surface factor, but it removes some material from the part. Electroplating can reduce the endurance limit as hydrogen embrittlement is a concern.

> Design flaws lower the endurance limit to a point where a finite or certain number of cycles will lead to a fatigue failure

For many systems, there is little that can be done to reduce the cyclic stress for normal operation. Increasing the part size will also reduce the cyclic stress on the part without having to reduce the cyclic force. For temperature, many mild steels will have little impact up to 400° F, but can be significant with temperatures approaching 1,000° F.

Changing the stress concentration, such as increasing the shaft radius, will reduce the fatigue stress induced on the component. Most standards do not provide details on what is a reasonable shaft radius. Without doing detailed calculations, use as large of a shaft radius as the design will allow. Some general guidelines for shaft radius are similar to those shown in Figure 8.
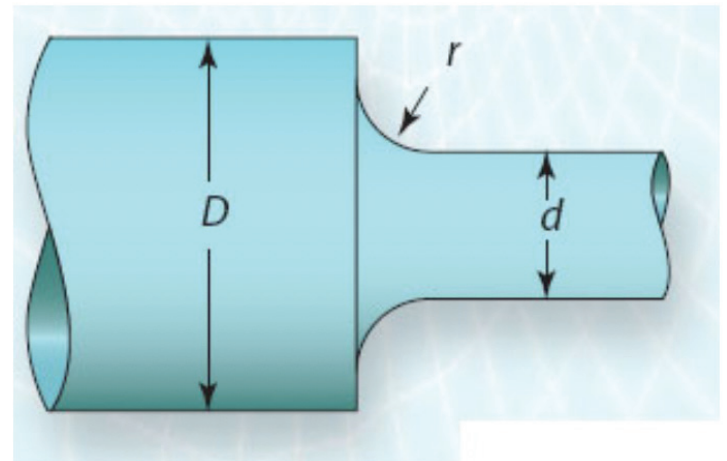
For a shaft with D/d >1.2, the r/d >.1
For a shaft with D/d <1.2, the r/d >.05
Figure 8: Shaft radius general guidelines

Fatigue failure doesn't have to stay a mystery or become chronic in your plant. By focusing on the two key areas of reducing cyclic stress and improving the endurance limit, fatigue can be solved.

Randy Riddell, *CMRP, PSAP, CLS, is the Reliability Manager for Essity at the Barton Mill in Alabama. Randy has over 30 years of industrial experience with a career focused on equipment reliability.* www.essity.com

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HOW MANUFACTURERS CAN MAKE

Keith Flynn

IIoT

A PROFITABLE REALITY

Manufacturers are still struggling to get a return on investment (ROI) out of their Industrial Internet of Things (IIoT) investments. In order to realize a digital transformation, companies need a low cost, highly scalable IIoT infrastructure that works with what they have in the plant today. There's a big barrier to realizing ROI on IIoT, and there's no time or money for rip and replace. The answers to these frequently asked questions should help in getting your organization on the path to realizing ROI on its IIoT.

As more Industrial Internet of Things (IIoT) data is being used, what do manufacturers have to do in order to segue to smart plants?

In manufacturing, a smart plant refers to a connected digital factory. However, when you look inside a typical plant today, you often see older infrastructure and assets. Common challenges that prevent manufacturers from achieving smart, fully connected plants can range from location – remote facilities sometimes without even basic Internet service or low connectivity – to issues of older assets that aren't inherently IIoT-enabled. In the industrial world, these environments lead to stranded assets and up to 40 percent of a plant's assets fall into this category.

Many manufacturers believe they must rip and replace their entire infrastructure to get connected assets and a smart plant. But, with sensors and edge device advancements, this isn't the case. Manufacturers can drive reliability enterprise-wide *without* ripping and replacing, instead using network enabled edge gateways, wireless sensors, edge-based connection software and cloud computing. Connectivity at the edge makes it possible to run IIoT applications and helps seamlessly integrate and interoperate with legacy systems.

What are the *first steps* a manufacturer should take to do this?

It's imperative to first take a step back and identify the business outcomes or operational excellence objectives. What's at the top of the list? Preventing downtime? Environment, health and safety (EHS) initiatives? Profitability? More reliable operations help boost performance to reach these objectives, but job number one is to focus on priority improvement areas.

Next, do a quick inventory of what you *already have* (e.g., what assets are in place, what level of instrumentation and connectivity exist, etc.) and identify the gaps.

After manufacturers identify the missing pieces in their infrastructure, they should bring together their information technology (IT) and operational technology (OT) teams. It's important for these teams to ask: What is our business objective and what new IIoT technology is needed for this to happen? The answers will include a closer examination of software applications because the key to success in today's digital world is how the data is applied to solving problems and creating opportunities. And, the enabling technology making digital transformation a reality is software leveraging IIoT, cloud computing and advanced analytics.

Why are stranded assets still a problem for manufacturers?

One of the biggest reasons stranded assets are still a burden for manufacturers is cost. If a manufacturer takes the approach of upgrading its equipment to avoid stranded assets, it becomes a costly, capital intense project and certainly requires shutdowns. A plant must take the equipment offline, engage a team to upgrade it and then get it back online—and if a plant does this with several machines, the costs add up quickly.

Alternatively, a manufacturer can more cost-effectively add sensors or a wireless network without ripping and replacing an entire infrastructure. This way, it can be up and running in hours, not weeks, avoid hefty installation costs and, in some cases, avoid downtime altogether.

How can manufacturers connect their stranded assets without replacing their entire infrastructure?

Today, technology leveraging the IIoT can be used to connect all of a manufacturer's assets from any plant or facility, collect that data, and roll it up to their plant historian, enterprise data center, or the Cloud. What's important here is an approach that avoids unnecessary heavy data lifting and shifting by making data science quickly and easily deployed and scalable. The return on investment (ROI) comes from the ability to interface to all commercial data systems without requiring unnecessary data lakes or IIoT platforms, although the solution must be able to integrate as needed. Each manufacturer's use case must be carefully considered; not every solution requires a top-of-the-line cloud approach and companies should be considerate in using as much existing infrastructure as possible.

How do stranded assets in manufacturing differ from other verticals, such as stranded assets in oil and gas?

The reasons for stranded assets vary greatly, but when you look at stranded assets inside a plant, you are usually dealing with connectivity issues from a lack of network infrastructure, remote locations, old equipment not yet wired with sensors, a mash-up of incompatible protocols—or original equipment manufacturers (OEMs) equipped with custom controllers and programmable logic controllers (PLCs). Typically, in the oil and gas industry, the infrastructure already exists, so the biggest difference is stranded assets are usually caused by older automation. As such, companies have to remove and replace the technology or consider the addition of IIoT sensors.

Differences aside, the best ROI comes from asset-agnostic software that can work in any industrial environment.

How can companies utilize the IIoT to show ROI and optimize performance?

Where companies truly find value in the IIoT is *after* they connect their assets. ROI is achieved with the aggregating of data and performing advanced analytics around specific, real-world operational excellence use cases, like predictive and prescriptive maintenance. The IIoT, then, has the potential to offer a huge competitive advantage to companies that can then use those real-time operational insights to make faster and smarter business decisions, drive reliability and asset performance and reduce operating costs. However, being able to connect your assets won't automatically translate to value if you can't prioritize the areas that are most important to demonstrate ROI.

To project and report savings from prescriptive maintenance convincingly, think about the shared operational excellence goals everyone is trying to achieve. This is often in the form of cost savings, higher volume and quality outputs, and increased return on infrastructure or assets.

> …The key to success in today's digital world is how the data is applied to solving problems and creating opportunities

For example, a plant manager may have the business objective to save on costs from equipment downtime. With today's machine learning capabilities, a manufacturer can move from preventive to predictive maintenance scheduling—the difference between fixing the plant during an optimally scheduled downtime or scrambling due to a surprise failure.

How can maintenance professionals best report these results back to senior leaders in a way that shows value?

A recent IDC report forecasts global IoT spending to grow by more than four percent and top $1 trillion by 2020—it's growing exponentially. The National Association of Manufacturers (NAM) also reports that worldwide manufacturing is a $14 trillion business and that 10 percent is lost to breakdowns. For maintenance professionals, it makes sense to implement smart manufacturing initiatives now rather than later to remain competitive.

To best report savings from prescriptive maintenance to senior leaders in a way that shows value, think like them. Report back on metrics that can be directly linked to the company's bottom line. This would be things like: How far in advance was the failure detected? How much downtime of equipment was prevented? What did that save in a dollar equivalent? These examples should help illustrate the shared operational excellence goals everyone is trying to achieve.

Keith Flynn, *certified professional engineer, is the Sr. Director, Product Management, R&D – Architecture & Security, at AspenTech. With over 20 years of industry experience, his insight informs product development, ensuring that products integrate the latest technical capabilities and deliver the best results for customers.* *www.aspentech.com*

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FOSTERING
ASSET
RELIABILITY
FROM THE FLOOR LEVEL

Paul Durko

Conventional road maps and training indicate more than 70 percent of reliability initiatives fail because the programs supporting them lack backing by senior leadership. However, an equally significant aspect that can quickly undermine program success is the absence of buy-in from craft workers. Such was the case at the Y-12 National Security Complex, a U.S. Department of Energy National Nuclear Security Administration facility. Here's how the facility turned things around by cultivating asset reliability from the floor level.

At Y-12, more than 250 craft workers support the site, completing an average of 33,000 work orders annually. Over the years, Y-12 has only made modest gains in asset reliability because its considerable size and multiple missions have made sustaining an effective reliability strategy difficult. The site spans 811 acres, with 2-1/2 miles between its east and west boundaries. Some of the more than 300 facilities are categorized as nonnuclear facilities.

Background

Y-12 was constructed in Oak Ridge, Tennessee, as part of the Manhattan Project to provide

The majority of Y-12's existing facilities were built to support the Manhattan Project. Sustainability for more than 70 years was not foreseen.

enriched uranium for Little Boy, the atomic bomb dropped on Hiroshima, Japan, to facilitate the end of World War II. Afterward, Y-12 provided lithium separation and key components for the thermonuclear weapons that helped end the Cold War. Y-12's expertise in machining, handling and protecting radiological materials has made the site central to the nation's nuclear security.

Because Y-12 was built from a tactical perspective, ensuring asset reliability on numerous aged facilities and processes presents a unique and complex challenge. Many of the advantages of standardization routinely found in a manufacturing environment, such as identical process lines, fan and motor configurations, and instrumentation, are nonexistent at Y-12, where a long-term mission was not envisioned. Although stringent processes are in place to ensure safe operation of the nuclear facilities and equipment,

understanding and ensuring asset health across the site remains tenuous.

Maintenance Feedback Approach

Using a maintenance feedback approach, Y-12 partnered with its workforce to gain a better understanding of asset health across the site. The craft workforce presents the best opportunity to understand the health of a facility or asset because of their close proximity. In essence, they are the eyes and ears within the functioning plant.

Working with craft personnel, a process involving maintenance history, feedback and improvement was developed for corrective and preventive work activities. This continuous improvement process allows Y-12 to augment data in its computerized maintenance management system (CMMS).

Using maintenance history data, Y-12 can do the following:

- Spot emerging equipment trends;
- Pinpoint chronic issues with components, processes, etc.;
- Identify systemic issues and concerns;
- Forecast likely equipment failures;
- Develop a bill of material;
- Close the feedback loop to the initiator.

Figure 1 & 2: Arial view and one of 300 facilities on the Y-12 site

Maintenance Data Collection Forms

To complete each work package, the craft worker must complete one of the data collection forms developed as part of the process.

The Corrective Maintenance Form asks the craft worker to:

- Identify the components replaced. (This list is used to develop a bill of material.)
- Perform root cause analysis where practical.
- Determine failure versus symptom of unidentified failure modes.

> **Y-12 employs 250 craft workers who complete 33,000 work orders annually.**

> **Craft personnel work in close proximity to the facilities and assets.**
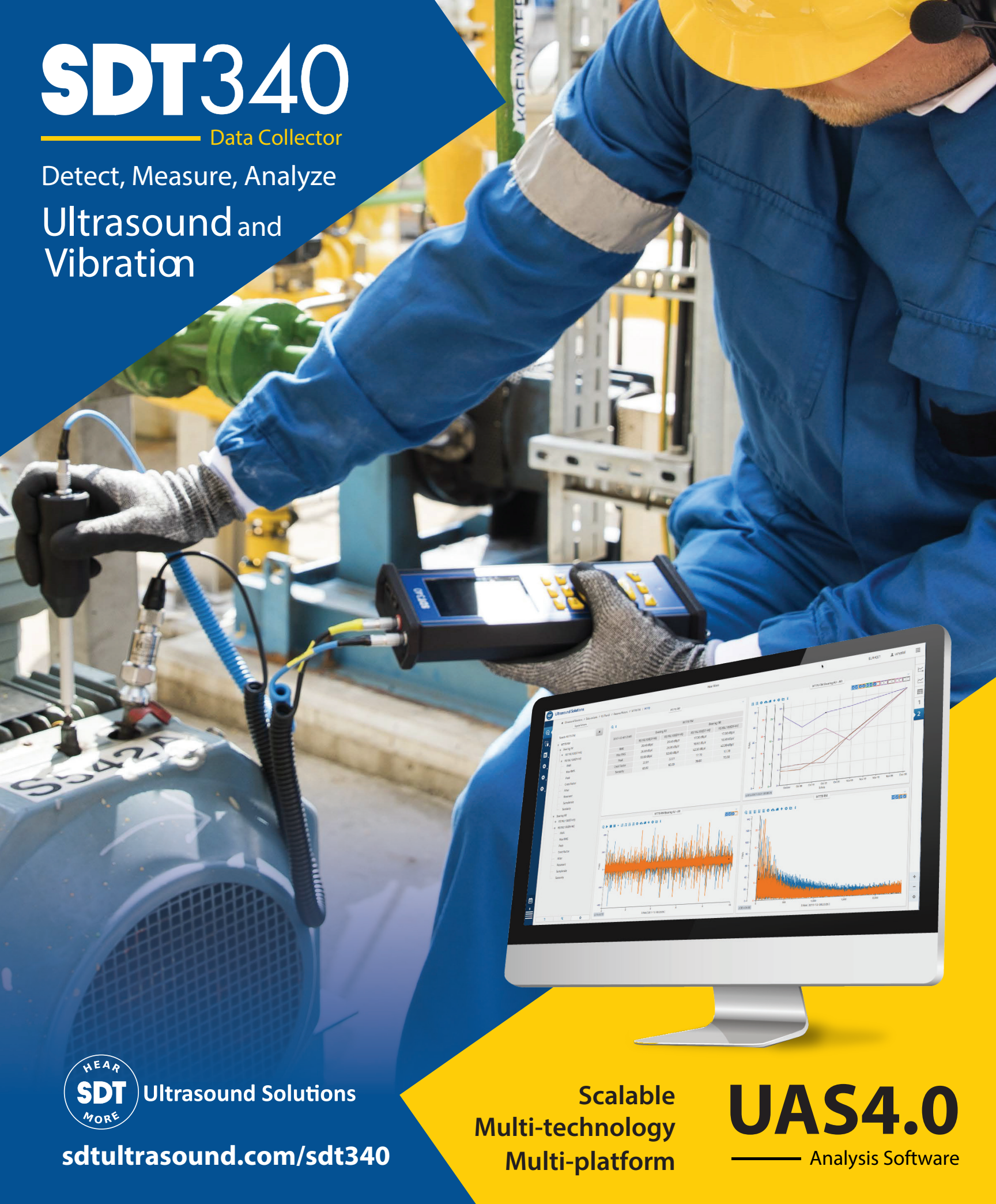
> **Craft personnel are the eyes and ears within the functioning plant.**

> **Analysis of information collected in the field is often the best opportunity for understanding facility and asset health.**

- Assess the overall field condition of the asset from a systemic viewpoint.

The Preventive Maintenance Form asks the craft worker to:

- Describe the condition of the unit as found and its fitness after preventive maintenance.
- Determine the material requirements for the job kits.
- Identify optimization activities, such as task intervals, additional failure modes, augmented task instructions, etc.
- Note uncorrected or observed issues with the system or supporting systems.

The data collected on the forms are entered into the CMMS for review by Y-12's Reliability and Maintainability Team and then segregated by issue into these categories:

1. Low rating with no comments;
2. Additional work required;
3. Scheduling of preventive maintenance or work package;
4. Scope of preventive maintenance or work package;
5. Materials reordering or bench stock needed;
6. Waiting for upcoming project work;
7. Lacking tools or equipment.

The maintenance engineer can then directly respond to the concern, develop a follow-on work order, create or augment a bill of material, or perform additional functions aimed at ensuring safe and efficient work execution.

Preliminary Benefits

Although the feedback process is still maturing, the return on investment has been exceptional. Since this process began in fiscal year 2015, issues in four of the seven categories (1, 3, 6 and 7) have declined steadily, while those in the other categories have remained somewhat stable. Craft workers are recognizing that the process is not only working, but also proving to be sustainable.

The quality of their comments is steadily increasing, providing a distinct understanding of what drove them to give low ratings.

Another benefit is the improvement to the CMMS with more comprehensive maintenance data. This enhancement gives the supply chain management organization a high-level view of spare parts requirements, which contributes to the strategic planning of scheduled maintenance. Supply chain management is now responsible for ordering the preventive maintenance parts required for each job as part of the job kitting process developed two years ago. This change frees valuable time for the planner, plus craft workers benefit from the job kits since they eliminate having to search for parts required to execute the work.

Return of Ownership

Perhaps the most important benefit from this feedback process is the return of a sense of ownership at the floor level. As the craft workers' trust in the process evolves, the level of detail in the feedback advances and the asset health data expands, enhancing the usability of the information.

For instance, craft workers now have the capability to review open work orders against an affected asset in the CMMS or from printed versions. This capability prevents the craft worker from duplicating information previously submitted and it provides essential data that may impact the craft worker's ability to completely perform the work required on that particular work order.

Developing and sustaining the maintenance feedback process was an essential springboard for Y-12's preventive maintenance initiative. Clearly, craft worker engagement should not be underestimated, but should be viewed as important as senior leadership support.

Paul Durko, CMRP, CMRT, RMIC, is the Manager of the Reliability & Maintainability (R&M) team at Consolidated Nuclear Security (CNS) llc. Paul's team is responsible for the development and implementation of the proactive maintenance program at both the Pantex and Y-12 sites. www.cns-llc.us

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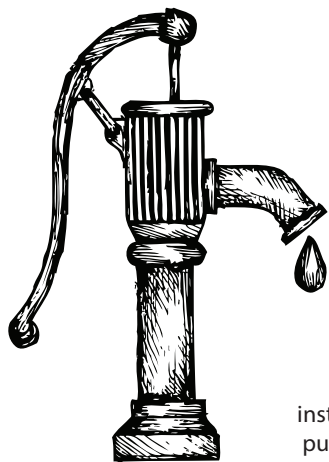
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HOW THE QUEST FOR BETTER PUMPS

CAME TO (ALMOST) NOTHING

Heinz P. Bloch

Pumps are fluid machines that move liquids over short and/or long distances. They were invented well before the industrial revolution and even Archimedes tinkered with pumps, on or about 250 B.C., somewhere near the historic city of Siracusa in Sicily. Without pumps, modern process plants would not exist. But not all pumps are well constructed, well maintained, correctly installed, or properly operated. And while some pumps have stayed on-line without interruption for six years, others continue to experience random failures several times in the course of a year. Pump improvement can be both a career enhancer and a value-adding proposition, as this two-part article will show.

Why Better Pumps Are Needed

Most pumps in chemical process plants and oil refineries operate below 300 psig and 350° F. Yet, even at these conditions, an inordinately high percentage of a plant's maintenance expense for rotating equipment goes into pump repairs. In the late 1980s, the estimated repair cost for an ANSI B73-compliant pump was slightly over $5,000 at one of many similar U.S. Gulf Coast process plants. The true cost of repairing an average API 610-compliant refinery pump in 2019 is thought to well exceed $15,000. Additionally, for every 1,000 pump repairs there was, and still is, one costly fire event.
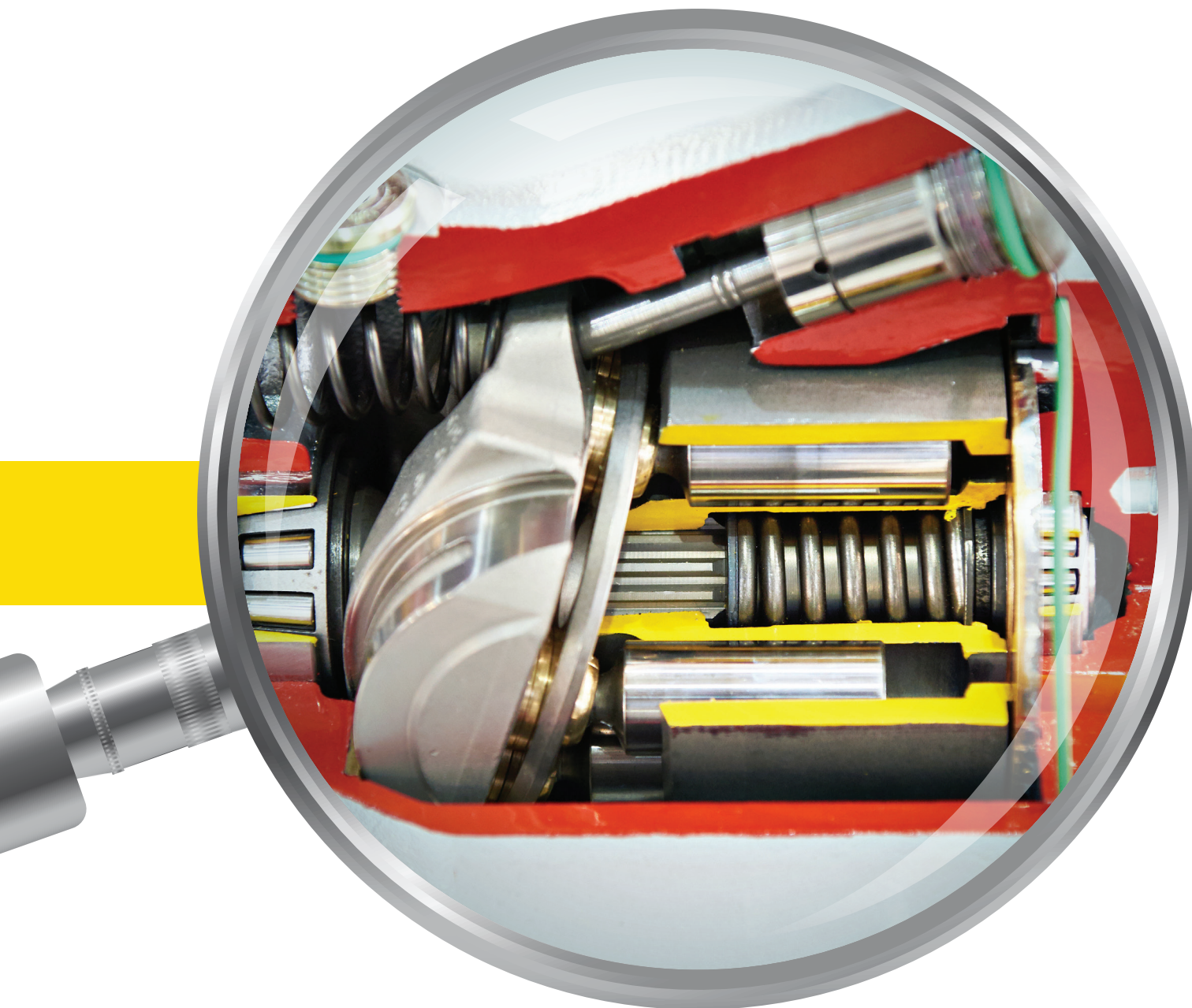
As early as 1972, computerized recordkeeping and straightforward failure analysis made it possible to identify when and why a machine failed. Improving pump reliability was the motivation of companies when statistics demonstrated significant incentives to upgrade their pumps. Oil and gas companies were on the same page and routinely, but informally, compared their pump failure frequencies and repair costs with similar equipment operating under similar process conditions.[1] Such recordkeeping soon led to an 80-page report titled, "How to Build a Better Pump," which was made available to any pump manufacturer interested in reading it.[2] Originally issued in 1973, the report explained and commented on the following:

- Although, undoubtedly, there were many exceptions, standard American National Standards Institute (ANSI) pumps in the late 1990s had a mean time between failures (MTBF) of only 26 months in what were considered well-maintained facilities in North America. The actual total industry average was probably closer to 12 months.

  (Note: Unless otherwise noted, MTBF calculations were made by dividing the number of all installed pumps by the number of repairs per year. Also, every incident of parts replacement is counted as a full-fledged pump repair.)

- Attempts to correct the causes of pump failures had traditionally been repair-focused. Parts broke and parts were replaced in kind. This old style, reactive approach to maintenance was no longer deemed appropriate. Plants were encouraged to purchase better pumps and plant personnel were asked to take the lead in implementing the reliability-focused approach. In a reliability-focused approach, systematic upgrading was advocated wherever feasible and cost justified.

> The true **COST OF REPAIRING** an average API 610-compliant refinery pump in 2019 is thought to well **EXCEED $15,000**

- Allowing pumps to be outside the dimensional constraints of ANSI specifications was often deemed justified. In other words, some of the ANSI pumps installed in 1972 could be replaced with types or models having performance improvements that exceeded the then observed hydraulic efficiencies by as much as 10 percent.
- American Petroleum Institute (API) pumps in medium duty service were not always cost-effective. Therefore, before choosing an API pump for a mild service, potential users were asked to consider buying an in-between pump. It was established that ISO and modified ANSI pumps fit this description.

Typical shortcomings of certain ANSI pumps needed to be identified. A study[2] revealed the following weaknesses:

- Shaft deflection was often excessive.
- The dimensional limits imposed by ANSI B73.1 did not generally allow sufficient space for the application of the now available superior mechanical seals and often curtailed the attainment of optimum efficiency.
- Bearing life was shorter than it could be because of weaknesses in present bearing designs and lubrication systems.
- Frangible, pressure-containment sealing devices can create an unnecessary safety hazard.
- The average ANSI design base plate does not always provide adequate structural integrity and load-bearing capability.[3]

However, one multinational oil and gas corporation modified its then existing nonproprietary basic practice document for medium duty pumps to incorporate the new findings and called it the upgraded medium duty (UMD) standard. When invited to submit bids for such pumps on upcoming projects, some pump manufacturers complied in part, but took exception to certain clauses or paragraphs. Only one Iowa pump company went beyond merely complying with the UMD standard. One of the pump company's key executives and innovative engineer-managers saw an opportunity for pump users and manufacturers.[4] It began developing their pump line, seen in Figure 1, and today, those pumps are also available as API 610 compliant pumps. Regrettably, no other manufacturers saw fit to build such pumps; some inexplicably went on record strongly asserting that ANSI B73 and API 610 were all that was ever needed by industry users.

As to developing a UMD standard, the pump manufacturers prevailed and pump users asking for better pumps at meetings of API subcommittees were outvoted. Today, there is no formal industry standard covering UMD pumps. Moreover, in examining API 610 and its various commendable

Figure 1: A successful UMD pump (Source: Carver Pumps, Muscatine, IA)

clauses, there are many minimum recommendations that are not accepted by well-informed subject matter experts at best of class companies. When challenged, the API organization's legal staff was quick to point out that the clauses in API 610 are meant to be viewed as *minimum* and not *mandatory* requirements. If users see fit to install better components, provide better fits, utilize superior materials, and so forth, the lawyers at API point to the wording on the inside covers of many API standards. This wording encourages users to go for higher quality, if needed.

> Less than **10 PERCENT** of all ball bearings run long enough to succumb to normal **FATIGUE FAILURE**

In other words, users may elect to upgrade, the choice is theirs to make. So, the uninformed and indifferent buy on price alone; they often became the lawful prey of marketers who are fondly remembered for providing doughnuts and baseball caps for everyone.

Concerns over Excessive Shaft Deflection

In the mid-1960s, reliability-focused maintenance facilities at the major oil and gas companies started to specify better pumps. One company decided to purchase overhung impeller pumps only if shaft deflection was kept in check.[5] Other companies soon followed suit in the common sense observation that slender shaft pumps with overhung impeller construction are prone to excessive shaft deflection. Excessive shaft deflection often leads to internal contacting of wear rings, bushings and sleeves. As such, reduced shaft deflection would become a key feature of any new pump design after 1972.

The amount of shaft deflection can be readily calculated and is simply a function of L^3/D^4, the overhung distance "L" from the pump impeller to the nearest bearing and the mean shaft diameter "D."[6] The oil and gas companies required the L^3/D^4 ratio to be defined and disclosed by the vendor. This ratio was called the shaft flexibility factor (SFF). In competitive bidding, the SFF values given by bidders are compared against the lowest available or offered SFF. Offers with higher values were assigned a dollar equivalent maintenance assessment of a certain percentage of their bid price.[7] The imputed cost adder could disqualify the vendor even if base pricing was low.

Shaft deflection changes as a function of the fluid flow rate through the pump. As the throughput capacity of a pump increases or decreases and thus moves away from the best efficiency point, the pressures around the impeller become unequal, tending to deflect the impeller end of the rotor. In an overhung impeller pump with a standard single volute casing, this deflection can reach serious magnitudes. Accordingly, a shift to casings with diffusers and double volute casings was encouraged. However, not even the best designed casing can eliminate pressure-induced shaft deflections completely.
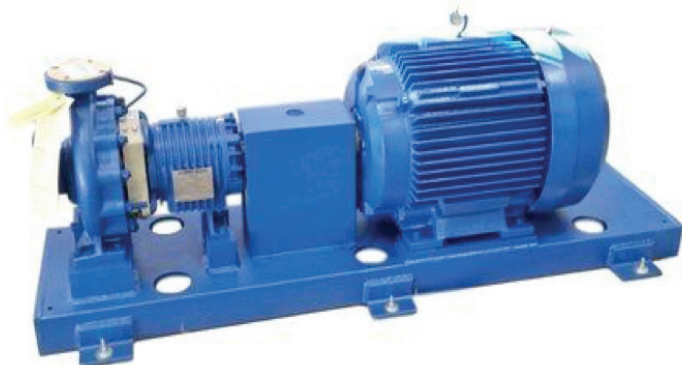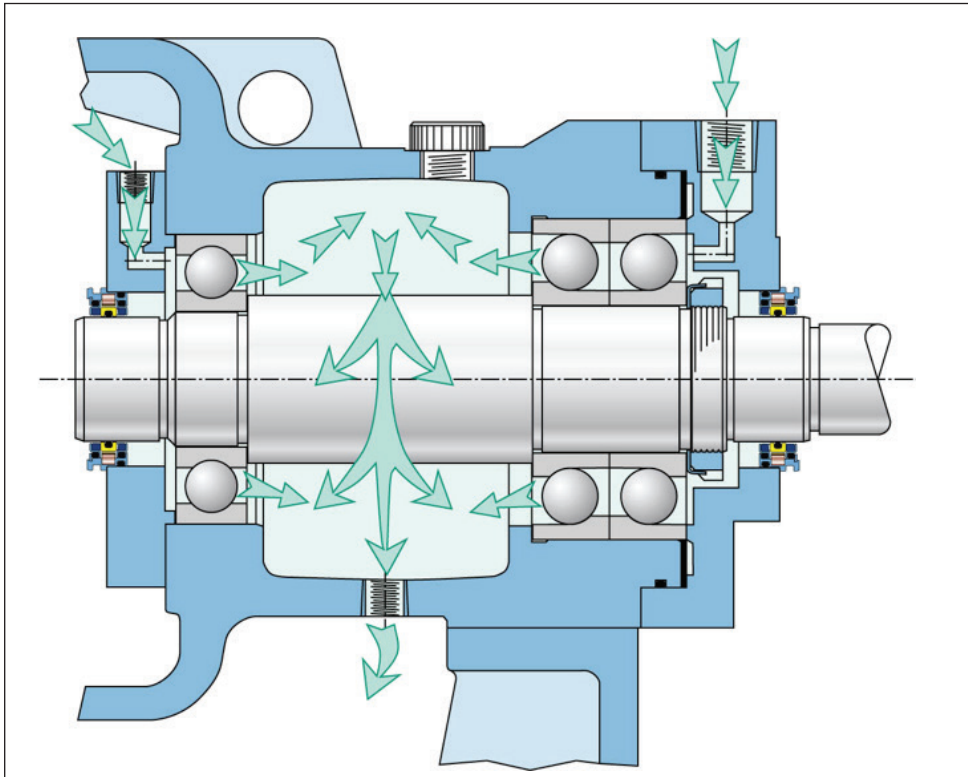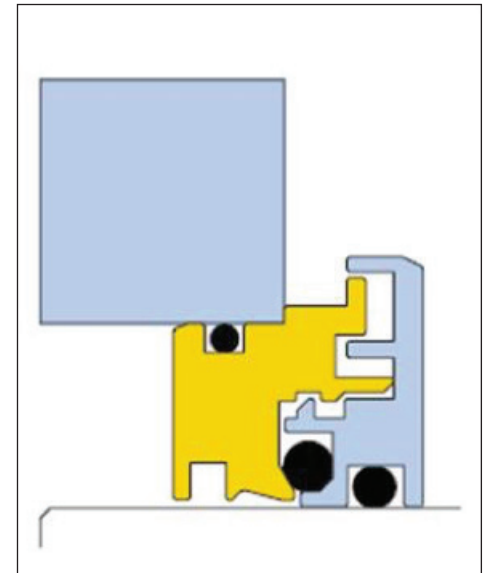
Figure 2: A UMD pump bearing housing with built-in oil mist reclassifiers and dual-faced magnetic seals

Figure 3: A state-of-the-art bearing housing protector seal with a dynamic O-ring that cannot make contact with sharp edged surfaces (Source: AESSEAL Inc., Rotherham, UK and Rockford, TN)

That a single volute pump will not give satisfactory long-term service if operated too far from its best efficiency point is generally known.[7] Companies learned to discount meaningless claims, such as one manufacturer's pump model "A" deflecting only 20 percent of the deflection calculated for Competitor "B." If "A's" actual shaft deflection is only 0.0001 inches, then even a fivefold deflection of 0.0005 inches in Pump "B" will be of no significance. The upshot of this observation: It deals with marketing and advertising strategies; both "A" and "B" should be considered acceptable selections in this instance.

Quantum steps forward were made in the early 2000s. Since then, good pumps make extensive use of wear-resistant, high performance, nonmetallics, particularly perfluoroalkoxy carbon-filled polymers (PFCP). Although these materials are in the PTFE family and are thus related to Teflon®, PFCPs have a number of superior properties.

Factors Affecting Pump Bearing Life

Less than 10 percent of all ball bearings run long enough to succumb to normal fatigue failure. According to three renowned bearing manufacturers, most bearings fail at an early age because of static overload, wear, corrosion, lubricant failure, particle contamination, or overheating.[8] Skidding of rolling elements can occur in a bearing operating without load and is a frequent cause of failure in angular contact ball bearings installed and operating as flush ground, mirror image oriented pairs. It was recognized that this problem could be solved by using a matched set of bearings and proper shaft fits which, in combination, result in a slightly preloaded condition after installation.

Alternatively, bearings can be purchased as sets, with dissimilar contact angles. Sets with a 40 degree load angle on the primary load side and a 29 degree angle on the secondary, usually unloaded side, are available. The two bearings are mounted back-to-back. The superior performance of these bearings is well-documented, but a higher cost and the lack of care during installation seem to be unsurmountable impediments in some maintenance cultures. This refers to locations and situations where the quick fix and low initial cost carry more weight than education and insistence on quality of workmanship. Denying that the quick fix/low-cost mentality exists is likely to cause long-term grief.

Actual operations have shown that better bearing specification practices will avert most static overload issues. Problems caused by wear, corrosion, contamination, lubricant failure and overheating can be prevented by the proper selection, application and preservation of lubricants. Much can be accomplished with oil application strategies that completely eliminate oil rings and constant-level lubricators (Figure 2). Well-engineered bearing housing seals (Figure 3) represent another layer of protection.

Oil viscosity and moisture contamination are primary concerns and, while higher viscosity lubricants are generally preferred, lubricant viscosities greater than ISO VG 32 cannot be properly applied with oil rings strictly designed for process pumps.[9] The detrimental effects of moisture contamination are well known and even trace quantities of dissolved water in oil can drastically shorten bearing life.[10,11] By the time free water is drained from a bearing's housing, most of the damage has been done. Many researchers have documented this fact in the past six decades.

Bearings: A Never-Ending Subject

Unlike API recommended pump bearings, which petrochemical companies often specify for an L10 life of 40,000 hours, ANSI pump bearings are

selected on the basis of a life expectancy of 24,000 hours. Nominally, this means that 90 percent of the ANSI pump bearings should still be serviceable after approximately three years of continuous operation. However, failure statistics indicate that conventionally lubricated ANSI pump bearings do not even approach this longevity.[5] Lack of lubrication, wrong lubricants, water and dirt in the oil and oil ring debris in the oil sump all cause bearing life expectancies to be lower than expected. It can be assumed that similar findings by other major users of ANSI pumps prompted the search for lifetime lubricated rolling element bearings. However, except for power inputs below five horsepower, lifetime grease lubrication is not usually considered a viable choice for process pumps.

Problem incidents caused by dirt and water have been substantially reduced by the pressure differential at the bearing housing seal provided by oil mist lubrication.[7] Nevertheless, failure risk can escalate by certain specification practices, including some contained in API 610.

Part 2 will touch upon some of the reasons for bearing life reductions and list several observations that should be considered when preparing a modern pump specification.

References

1. Bloch, Heinz P., "How to Select a Centrifugal Pump Vendor." *Hydrocarbon Processing*, June 1978.
2. Bloch, Heinz P., "How to Buy a Better Pump." *Hydrocarbon Processing*, January 1982.
3. Bussemaker, E.J., "Design Aspects of Base Plates for Oil and Petrochemical Industry Pumps." *Institution of Mechanical Engineers (IMechE) paper, C45/81, pp.* 135-141.
4. Bloch, Heinz P. and Johnson, Don, "Downtime Prompts Upgrading of Centrifugal Pumps." *Chemical Engineering,* November 25, 1985.
5. Bloch, Heinz P, "Optimized Lubrication of Antifriction Bearings for Centrifugal Pumps." *ASLE Paper 78-ASLE-1-D-2*, April 1978.
6. Bloch, Heinz P., "Upgrading of Centrifugal Pumps: A Status Report." *Hydrocarbon Processing*, February 1992.
7. Bloch, Heinz P. and Budris, Allan R., *Pump User's Handbook, 4th Edition*. Lilburn: Fairmont Publishing Company, 2014.
8. Bloch, Heinz P., *Machinery Reliability Improvement*. Houston: Gulf Publishing Company, 1982.
9. Bloch, Heinz P., *Practical Lubrication for Industrial Facilities, 2nd Edition*. Lilburn: Fairmont Publishing Company, 2009.
10. Eschmann, Paul; Hasbargen, Ludwig; and Weigand, Karl, *Ball and Roller Bearings*. New York City: John Wiley & Sons, 1985.
11. Bloch, Heinz P. and Geitner, F.K., *Introduction to Machinery Reliability Assessment*. New York City: Van Nostrand-Reinhold, 1990; revised 2nd Edition, Houston: Gulf Publishing Company, 1994.

Heinz P. Bloch has had long-term assignments as Exxon Chemical's Regional Machinery Specialist for the United States. He has authored or coauthored over 730 publications, among them 21 comprehensive books on practical machinery management, failure analysis, failure avoidance, compressors, steam turbines, pumps, oil mist lubrication and optimized lubrication for industry.

How to Improve Your
PM Program in
10
STEPS
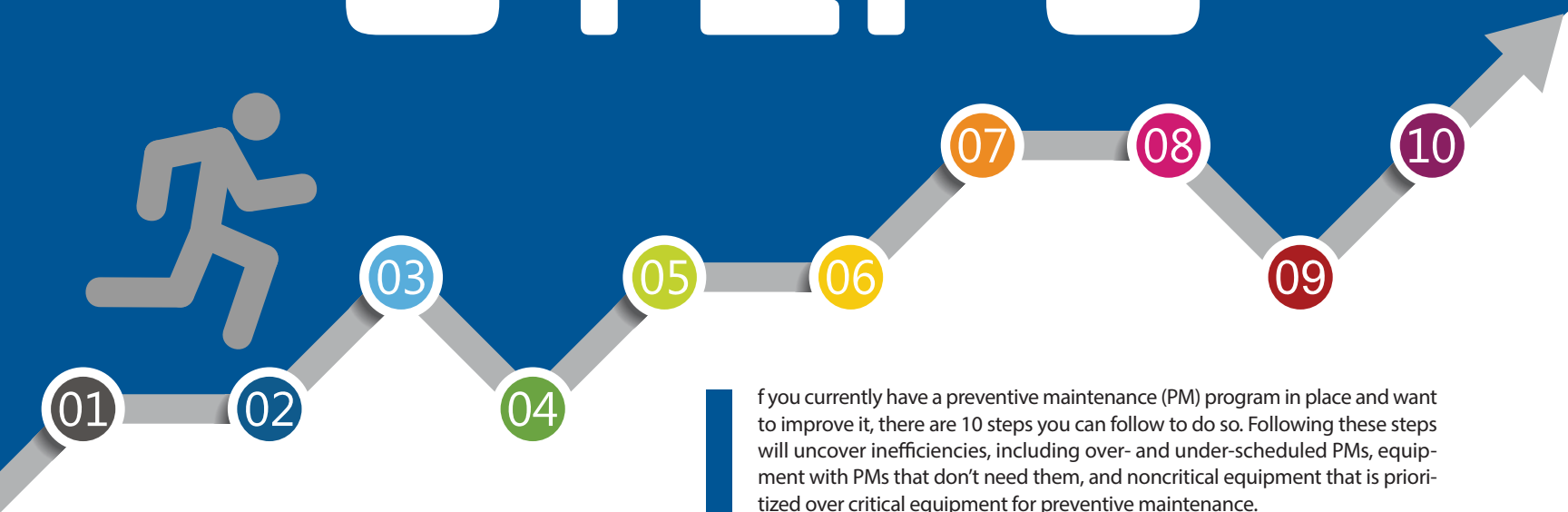
Ryan Chan

f you currently have a preventive maintenance (PM) program in place and want to improve it, there are 10 steps you can follow to do so. Following these steps will uncover inefficiencies, including over- and under-scheduled PMs, equipment with PMs that don't need them, and noncritical equipment that is prioritized over critical equipment for preventive maintenance.

While an optimized PM program should not replace a formal reliability-centered maintenance (RCM) program, it's a respectable solution for improving reliability in the short term. At some later time, you can perform an RCM analysis to corroborate the applicability of the scheduled PM tasks.

Here are the 10 steps, along with an explanation on how to perform each of them to improve your PM program.

STEP 1
CREATE AN OPTIMIZATION TEAM

To add accountability to improve the existing PM program, it helps to select three or four teammates to head the project. These teammates should be from maintenance and operations so that the improvements that are made benefit the overall business, rather than just the key performance indicators (KPIs) of one department.

STEP 2
CATEGORIZE EQUIPMENT

To determine which equipment to optimize the PM program for first, categorize equipment by critical, very important, and important. Again, having people from maintenance and operations involved will produce a more objective understanding of which equipment should be prioritized.

STEP 3
SELECT A CRITICAL ASSET

To get your feet wet in optimizing PM programs, select one critical asset to start. The whole optimization team should focus on improving the program for this single asset. Later, the team can be distributed to optimize PM programs for numerous assets simultaneously.

After the critical asset is selected, run a report in your computerized maintenance management system (CMMS), if you have one. This report should show all historical PM activities that have been conducted on the asset.

STEP 4
IDENTIFY THE FAILURE MODE

To effectively edit existing PMs and implement new ones, you need to understand how the asset fails. For starters, it helps to group the asset into one of two failure categories: age-related or non-age-related.

STEP 5
DETERMINE TASK TYPES

Using the report generated in Step 3, audit the various PM tasks associated with the asset. Also assign a label to the different tasks. Here are some different labels you can use:

- Inspection of equipment for on-condition task;
- Inspection for a hidden failure;
- Restoration/overhaul task;
- Discard task for equipment with a safe life or economic life limit.

After this, determine whether the task type lines up with the assigned failure mode. For instance, if the asset has a non-age-related failure mode, a restoration task should not exist.

STEP 6
REVIEW TASKS IN THE CMMS

If technicians judiciously use the CMMS to perform maintenance, the optimization team needs to verify that every PM is accurately detailed in the system. After all, this is the system that has the checklists and guidelines that technicians reference when they are performing maintenance.

Also, if you assign estimated times for task completion in the CMMS, make sure enough time is allotted for technicians to perform quality work. This helps planners and schedulers with their job, too.

STEP 7
REVIEW TASK FREQUENCY

Are PMs overscheduled or underscheduled? Or are no PMs being performed at all and the asset is breaking down at unscheduled times? The team's combined knowledge of the asset and the maintenance record can help you answer these questions.

STEP 8
PERFORM CHECKS ON OTHER EQUIPMENT

For the other assets you perform maintenance on, go through steps four through seven. Identify the failure mode, determine the types of PMs being performed, review the tasks in the CMMS, and review the frequency of those tasks while making necessary updates.

STEP 9
SET A GOAL

To ensure greater accountability and the timely performance of the PM optimization exercise, goals should be set. For instance, keep the team accountable to reviewing a certain number of assets and PMs per week. At the end of the week, generate a report for the team to review.

STEP 10
DETERMINE COMPLIANCE FOR COMPLETION

For the PMs you review and optimize, you need to make sure they actually get done. For calendar-based PMs, in particular, work with your maintenance planner/scheduler to optimize the calendar for this. Also, take a look at your current schedule compliance. Another goal should be to improve this percentage. You can attach compliance to the goal percentage.

Editor's Note: A version of this article was first published by UpKeep, a mobile-first CMMS solution, and written by Jim Borowski, a maintenance professional and UpKeep advocate.

Ryan Chan *is CEO and Founder at UpKeep Maintenance Management. Ryan started UpKeep out of passion and frustration by the lack of mobility in today's maintenance management software. He was named one of Forbes 30 Under 30 for Manufacturing in 2018.*
www.onupkeep.com

IMPROVING ASSET CONTRIBUTIONS TO THE

BOTTOM LINE

Okey Okoli

"What are your contributions to the bottom line?"

Many asset managers are often put in an awkward position when confronted with this question, which refers to the triple bottom line of people, planet and profit. This question is not necessarily demanding to know the asset manager's individual contributions to the bottom line, but the contributions and input of the maintenance system and the assets he or she manages to the overall bottom line.

Assets remain value-adding investments managed by the maintenance team and are expected to continually remain valuable and positively impact overall business profitability. The asset manager, therefore, becomes directly responsible for realizing this objective. Sustainability and availability of assets are the complete responsibility of the asset manager and the entire maintenance team. Assets, however, do not just exist to be maintained, but must be available to make contributions to the bottom line.

An asset manager, who as expected is a maintenance reliability professional, will have ready answers to the bottom line contribution question, from uptime trends to availability to reliability of the asset(s) being maintained. Creating value for the company through efficient asset management that is strengthened by effective maintenance strategies undoubtedly ensures that assets contribute significantly to the bottom line. The entire maintenance unit must be involved in improvement measures for asset performance. Involving the entire team not only ensures improvements are achieved rapidly, it also ensures achieved improvements are sustained. Among other measures, the following would considerably bring about desirable improvements:

- Communicate expectations and goals;
- Effective change management;
- Skills development;
- Documentation of improvements;
- Periodic review of performance.

Communicate Expectations and Goals

Often times, expectations are conceived by top management that may include the asset manager, but members of the team at the shop floor are not fully acquainted and carried along on the prevailing expectations. Plans are usually made, but not effectively cascaded to the entirety of the team. Consequently, improvements achieved become difficult to sustain because the entire team is not fully familiar with the overriding goals and expectations.

The maintenance unit head or manager who drives the improvement measures must clearly express performance expectations in team briefings and during job execution. In addition, the strategies and processes required for achieving the improvements must be well articulated and clearly communicated. Misconceptions and grey areas are usually addressed when adequate priority is given to the communication of expectations and goals. Communication is key to rallying support for maintenance goals and a reorientation on an unproductive work culture. A clearly communicated expectation is the critical first step toward achieving set goals. The team ultimately aligns with the goals of improvements, imbibes the expectations in the work culture and becomes part of the performance targets. Clearly communicated and understood expectations make for coordinated and motivated efforts toward realizing improvements to the bottom line.

Effective Change Management

Efforts and measures to improve the assets' contributions to the bottom line will likely come with significant deviation from the norm, changes to work processes, organizational culture and work habit. These changes may encounter strong resistance. However, change is usually inevitable if meaningful improvements must be made. Therefore, necessary changes have to be made to certain unproductive work processes, as well as inefficient work habits.

Change management usually entails leading an organization, group of people, or a team through a series of guided steps to meet a defined goal. Changing a status of poor performance and low contribution to the bottom line requires a structured approach to change that will enable the entire team to make the desired transition from poor to high contributions to the bottom line. Strategies for effecting changes should be clearly defined. Where new technologies are introduced, a proper management of change should be on the ground. As previously stated, clearly communicating changes increases the understanding as to why changes are needed and how it relates to the company's vision. The asset manager or head of the maintenance unit must, out of necessity, be a change agent. Implementing the desired changes requires resourcefulness, ownership of the change process and inspiration to keep team members engaged and committed to implementing the desired changes.

Skills Development

A skills gap poses a major drawback in maintenance improvement strategies. Identifying the skills gap and developing the right skills are necessary tools for successful improvements in asset care. Therefore, to continuously and effectively add value to maintenance, there has to be a deliberate plan for skills development and skills upgrades for the maintenance team. Improvements in skills of the maintenance team will ultimately lead to improvements in asset care. Efforts to improve the assets' contributions to the bottom line may include the acquisition of new technologies or an upgrade of existing facilities, gadgets and equipment. Applying technology to enhance maintenance will necessitate the acquisition of the right knowledge and skills. This must be factored into improvement plans. Specialized training and continuing education for the maintenance team are essentials for skills and knowledge upgrades. Undoubtedly, a team of skilled people with the right motivation will bring about enormous improvements to the contributions assets can make to the bottom line.

Documentation of Improvements

Documenting and keeping track of improvements guarantee that the successes achieved can be reviewed and/or replicated. Gradual and significant improvements should be noted and recorded. This not only serves as motivation for more efforts, but as a reference for reviewing the effectiveness
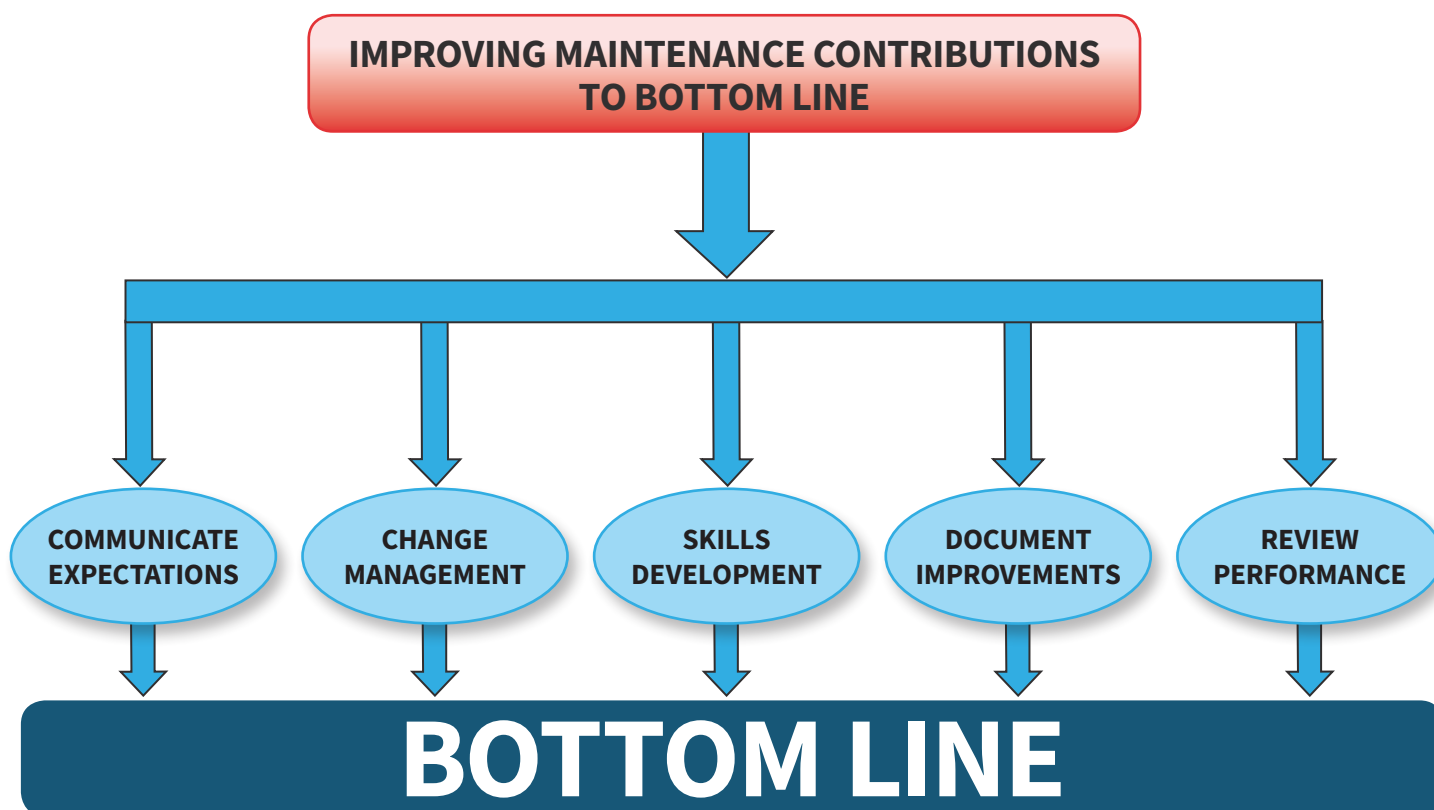

Figure 1: Strategies for improving maintenance contributions to the bottom line

of the improvement strategies. Also, achieved improvements in work processes, designs, equipment and machineries should be properly documented. A clear documentation process needs to be established where one does not exist or where an existing process is inadequate. Never let any improvements go undocumented.

Periodic Review of Performance

The effectiveness of improvement measures, including successes achieved, cannot be adequately strengthened, reinforced and sustained if there is no periodic review. Similarly, poorly performing measures can only be improved when they are appraised and reviewed periodically. The asset manager and maintenance team seeking to significantly and sustainably increase the overall contributions of assets to an organization's bottom line must subscribe to periodic appraisals and performance assessments. Reviewing performance and improvements provide more opportunities for further improvements.

Furthermore, periodic reviews of performance strengthen the foundation upon which improvements are recorded. Robust and sustainable contributions to the bottom line require a deliberate plan for periodic review. Reviews of performance may, as a necessity, extend to other departments or sections that directly or indirectly impact maintenance operations.

Several standardized metrics are available for evaluating and benchmarking performances. The entire maintenance team must not lose sight of the key performance indicators. Performance indicators must be defined and acceptable to the entire team. This ensures that all efforts are aligned and directed toward a common goal.

Conclusion

If assets are seen and managed basically as cost centers, their potential to contribute to profitability and the drive to manage them so they contribute to profitability are diminished. Assets are investments, and sometimes huge investments are made on assets. These assets are expected to yield returns in the form of performance, availability, reliability and an overall value addition to business operations. These returns on investments in the assets are achieved and sustained through the maintenance strategies deployed. The role of the asset manager and the entire maintenance team, therefore, becomes critical in ensuring appreciable value is derived from assets and the returns on investments in the assets are realized.

Asset care must be seen beyond routine activities, meaning the technical and managerial actions performed during the lifecycle of an asset in order for it to continue to perform required functions. Assets must remain viable contributors to the bottom line during their entire lifecycle. Maintenance plans should be deliberately tailored toward contributing to the profitability and sustenance of an organization. Asset managers, among others, must focus on maintaining and utilizing assets to maximally achieve appreciable contribution to the overall bottom line. Embracing maintenance strategies that promote efficient maintainability and utilization of the assets is paramount. By doing so, assets do not remain cost centers, but become useful drivers for improved contributions to the bottom line.

Okey Okoli is a seasoned maintenance and reliability professional with extensive experience in machinery maintenance onboard vessels. He is currently the head of Mechanical Maintenance at Fymak Marine Limited. Okey supervises the planning, scheduling and execution of maintenance across the company's fleet of vessels. www.fymakmarine.com

THE IMPACT OF
FEDERATED
MANUFACTURING
ON THE INDUSTRIAL SECTOR

Eitan Vesely

When considering the future of production in the era of Industry 4.0, there is a truism that applies to any revolution: It is much easier to recognize when it starts than to predict how it will end. Within the hype zone of digitalization, the topic of federated manufacturing has, thus far, gained relatively little attention.

What Is Federated Manufacturing?

In 2017, the research and consulting firm Frost & Sullivan, in collaboration with Intel and GE, released a white paper titled, Vision 2030: The Factory of the Future. The authors suggest that "the future state, in the next 10-plus years, is for the establishment of so-called micro-factories that, for example, will enable significant levels of personalization using 3-D printing and digital manufacturing techniques."

Federated manufacturing is the next phase of the new industrial revolution; the move away from centralized manufacturing based on cost savings from economies of scale to an on-demand model based on the application of big data.
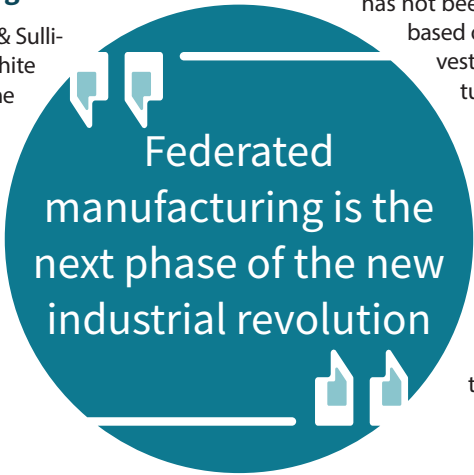
From Mass Customization to Additive Manufacturing

In 1997, James Gilmore and Joseph Pine wrote an article in the *Harvard Business Review* titled, "The Four Faces of Mass Customization." At the time, mass customization was considered a breakthrough concept and the article received overwhelming acceptance in both the academic and business worlds.

More than two decades later, it is clear that Gilmore's and Pine's vision has not been actualized. This is because mass customization is based on the erroneous assumption that consumers will invest their time to willingly collaborate with the manufacturer and manually select each feature of a product. This model of bespoke tailoring is suitable for the purchase of a new computer, but has not been widely applied.

Today, with advances in machine learning and artificial intelligence, manufacturers can access big data and use learning algorithms to customize a product without the customer's direct input or even knowledge.

With additive manufacturing, customization can occur in real time. Manufacturers will find ways to shorten the production and delivery cycle, obviating

> Federated manufacturing is the next phase of the new industrial revolution
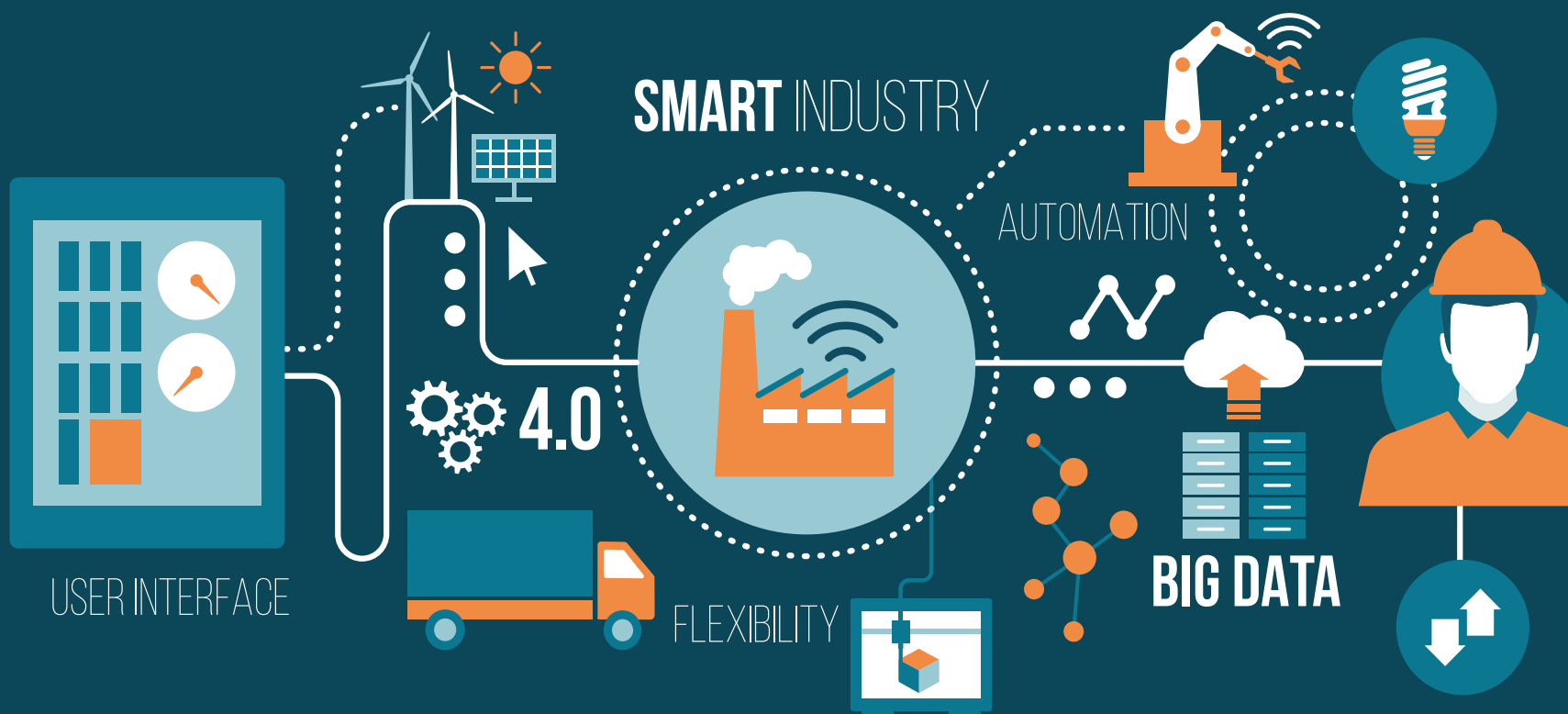
the need for large centralized manufacturing facilities. In the traditional mass manufacturing model, a significant amount of production is done at offshore locations, after which finished goods are transported via freighter ship. With federated manufacturing, on-demand additive manufacturing can be done at small production facilities that are located close to the consumer and products can be transported by drone.

New Maintenance Model: Hardware as a Service

In many manufacturing verticals, the benefits of Industry 4.0 and federated manufacturing can outweigh the economies of scale that are gained from centralized production in low-cost locales.

There is already evidence of changes to operations and maintenance (O&M) models that will enable federated manufacturing.

More original equipment manufacturers (OEMs) are exploring or migrating to hardware as a service (HaaS). With HaaS, the OEM leases the industrial machinery to the manufacturing plant and services its own equipment. This is similar to what engineering company Rolls-Royce did back in the 1960s with its licensing model. Instead of selling its engines to aviation customers, it offered them the ability to lease the engine as part of a subscription agreement. Rolls-Royce retained ownership of the engine and also the responsibility for reliability and maintenance.

> **More original equipment manufacturers (OEMs) are exploring or migrating to hardware as a service (HaaS)**

OEMs offering HaaS need the ability to track the performance of equipment that is widely distributed. One company is addressing this with remote monitoring facilities that cover a multitude of production plants.

With the precipitous reduction in the cost of connectivity, storage and computational power, machine learning is applied to sensor generated big data. Algorithms are trained to detect anomalous sensor behavior that is indicative of evolving asset failures, allowing the OEM to dispatch technicians prior to the occurrence of unplanned downtime.

One of the drivers to HaaS that is enabling remote monitoring is an innovation in the machine learning discipline called automated machine learning (AutoML). With AutoML, machine learning algorithms replace cer-

tain laborious data science tasks, such as data preprocessing and algorithm selection. As a result, OEMs can significantly increase the industrial analytics coverage of leased equipment, thereby scaling their O&M operations cost-effectively.

Federated Manufacturing: Winners and Losers

As federated manufacturing is incorporated into Industry 4.0 plans, who would benefit from this?

According to a Deloitte survey, almost half of the representatives from the Swiss manufacturing sector indicated that Industry 4.0 will lead to a slowdown in the trend toward relocating to low wage countries. Only eight percent of survey respondents completely disagreed.

On a superficial level, a shift in production from developing economies to mature markets is a win for survey respondents who disagreed with the slowdown at the expense of the Swiss manufacturing sector. The reality is far more complex. In an interconnected global economy, it is a mistake to view shifts in production as a zero-sum game.

Let's explore this scenario in more detail.

First, many mature economies are plagued by tight labor markets and aging workforces. An increase in demand for industrial sector jobs could result in wage inflation. Another possibility is that the industrial sector may become reliant on migrant workers, thereby creating other social and political challenges.

The second issue is that a slowdown in the economies of emerging markets would hurt many of the global multinationals that are reliant on these markets to fuel their growth. In 2018, banking executive Peter Wong wrote an article in the *South China Morning Post* that compares the growth of the middle class in Asia to the post-World War II growth of the middle class in the West:

"The rise of the Asian consumer will be a dominant economic theme for the next several decades. By 2030, it is forecasted that two-thirds of the global middle class will be living in Asia. In contrast, North America and Europe will together account for only a fifth of the world's middle-class population, down from more than half in 2010."

Although populism and economic isolationism seem to be the flavor du jour in a surprisingly large number of countries, over the long term, a disruption in the growth of the middle class in Asia could hurt both mature and emerging economies.

Conclusion

Industry 4.0 is still in its nascency and the consequences will likely be far-reaching on the supply chain, environment and energy market. As with any revolution, old elites are replaced by new centers of power. Even if it is too early to forecast the full impact of federated manufacturing, industrial producers should be cognizant of its implications when planning and investment in new production facilities.

Eitan Vesely is the CEO of Presenso, an artificial intelligence driven industrial analytics company. Eitan is the coauthor of the upcoming book with the working title, *Maintenance 4.0 Implementation Handbook*, soon to be published by Reliabiltyweb, Inc. *www.presenso.com*

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OnePM is an innovative asset strategy management (ASM) solution that helps organizations:

- Avoid significant risks by eliminating poor strategy changes. One-PM enables governance and visibility to monitor reliability strategy compliance and ensure that any modifications to procedures go through an approval process.
- Spend significantly less on reactive maintenance by applying risk and cost justified strategies to all assets, ensuring assets are not over-maintained.
- Reduce the likelihood of repeat incidents of like-assets by incorporating RCA into your ASM process.
- Get the most out of your EAM systems by developing high quality master data that your system needs to be effective.
- Get the most from your asset performance management (APM) system by implementing, maintaining and improving strategy that delivers performance that APM can monitor and provide protection around.

OnePM supports the REM and WEM Uptime Elements, making reliability a reality with optimal strategies, on every asset, all the time.
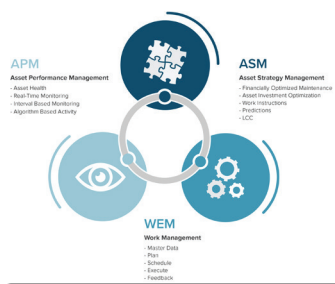
Benefits:

- Reduce safety risks by 10-30% and reduce costs by 5-30%
- Reduce strategy deterioration and drive continuous improvement
- Improve productivity and performance by leveraging best practice strategies across like-assets

Asset Management

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- Siemens APM takes data from all sources and applies Siemens domain and analytical expertise into a single APM solution, seamlessly integrating with the CMMS/EAM.
- Siemens Design, Operations and Maintenance experience and expertise is built-in, proprietary asset models with predictive analytics and situational intelligence to deliver timely insights and automated decision making, which also allows for quick start-up.
- Siemens APM provides asset criticality assessment and multiple risk-based reliability strategies for maintenance.
- Siemens APM is powered by MindSphere, the leading IoT operating system and data environment. APM on MindSphere connects your infrastructure and assets to all of the data, service, and analytic possibilities of the cloud, offering unprecedented transparency, speed, and new insights to optimize plant performance.
- The balance of plant models can be applied in any plant type for improved performance.

Benefits:

- Optimized reliability-focused maintenance planning
- Reduced outages
- Increased reliability and efficiency of the power plant

Asset Condition Management

IRIS MX

The **Iris MX** from RDI Technologies expands upon its revolutionary Iris M product to open up the world of Motion Amplification to high-speed applications. With up to 1400 FPS in HD resolution, you can now amplify and communicate virtually every displacement in the scene in real time. Leveraging a high-speed camera for frame rates over 10,000 fps, the Iris MX's most unique capability is the ability to amplify and show motions up to 5,000 Hz and produce an infinite amount of absolute measurements within the scene. The Iris MX enables the user to see the fault by visualizing the motion of the entire machine, its structure and base, and surrounding environment to determine the root cause. This enables the users to quickly and comprehensively diagnose machinery in a simple and easy-to-understand video. This video can be used to close the communication gap between technical and non-technical resources and empowers them to fix problems. The Iris MX is high-level analysis in its simplest form.

Benefits:
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Benefits:
- Full color screen displays timewave/fft for in-the-field analysis
- 10 minutes acquisition time for machines turning less than 1 RPM
- focUS mode samples data at 256k/s for high-resolution defect identification

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DIVERSITY IN RELIABILITY AND ASSET MANAGEMENT

HACKATHON

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The Association of Asset Management Professionals (AMP) is excited to announce the first Diversity in Reliability and Asset Management Hackathon. This weekend project is for reliability and asset management enthusiasts who want to create new approaches, technology, applications and ideas to build and promote greater diversity in the reliability and asset management community. The material will be provided to the community under Creative Commons (open source) license at no cost.

HACKATHON

A portmanteau of the words "hack" and "marathon," where "hack" is used in the sense of exploratory development, not its alternate meaning as a reference to violating computer security.

THE ISSUE

It is generally acknowledged that there is a lack of diversity of all types (gender, race, age, background, physical ability, etc.) that could provide many benefits for organizations seeking to advance reliability and asset management.

THE CONCEPT

Hackathons have typically been aimed at technology; however, we think this collaborative concept can work to advance all diversity possibilities, some of which may be technology-based, others not.

Produced by the names you trust.

SCHEDULE:

FRIDAY, DECEMBER 6 • 3:00pm

- Opening presentations and overview

- Team selection and breakout (participants will form teams based on individual interests and skills)

  The main work of the diversity hackathon begins. Teams work for several hours, some even pulling an "all-nighter." Meals are informal with participants often subsisting on foods like pizza and energy drinks. Sleeping can be informal, too, with some hackers catching a few zzzs in sleeping bags or heading next door to the Best Western to get a few hours of rest!

SATURDAY, DECEMBER 7 • 3:00pm

- Team presentations and demonstrations

  To capture the great ideas and work-in-progress, people can post a video of the demonstrations, blog about results with screenshots and details, share links and progress on social media, and generally make it possible for people to share, learn and possibly build from the ideas generated and the initial work completed.

- Evaluation and judging of presentations

  Panel of judges - AMP officers, chapter leaders, book authors and sponsors

- Awards and prizes

  Winning ideas will be presented at IMC-2019, the 34th International Maintenance Conference.

BRING YOUR TEAM! There is no cost to participate; however, advance registration is required, and space is limited. To get more details on signing up or supporting this exciting event, email: **crm@reliabilityweb.com**

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Minnesota's Xcel Energy and Chemist, Seth Carlson, take a stand against reactive maintenance by overhauling an outdated lube room and improving maintenance culture. Read about Xcel Energy's journey towards predictive maintenance, how they redesigned the lube room utilizing Des-Case products, and where they are today.

Continue Reading at:
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