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JUNE/JULY 2015

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Can you find the Uptime logo on the cover? uptime

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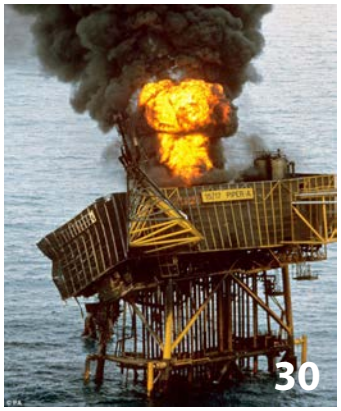

Elements

Editorial

Dinner with Albert Einstein and W. Edwards Deming

I had the weirdest dream a few nights ago. It was one of those dreams that was so vivid and detailed that you think it is really happening.

I was at a small Italian restaurant in the East Village of New York City eating dinner with the Physics genius Albert Einstein and Quality Management guru Dr. W. Edwards Deming.

The odd thing was that we were engaged in a very intense conversation about Uptime Elements and the Reliability Leadership Framework. These guys were both true inspirations and spoke authentically (in fact they spoke in very famous quotations).

I have recreated the evening in script form as accurately as I can recall so you can follow the conversation. The full script is published at Reliabilityweb.com and on my LinkedIn page.

Opening scene – Italian restaurant, East Village, New York City, Round Table.

TO: Do you think it is important to have a written strategy for reliability and asset management?

AE: You have to learn the rules of the game. And then you have to play better than anyone else.

TO: We are very excited to map the Uptime Elements Reliability Framework to the new ISO55000 Asset Management Framework. It is amazing to me that it all boils down to everyone understanding value (assets) and to coordinate activities that deliver value. Getting everyone on the same page to understand organizational objectives seems so simple but there are a number of barriers.

WED: What we need to do is learn to work in the system, by which I mean that everybody, every team, every platform, every division, every component is there not for competitive profit or recognition but for contribution to the system as a whole on a win-win basis. Sub-optimization is when everyone is for himself. Optimization is when everyone is working to help the company. Management's job is to optimize the whole system. When we cooperate, everybody wins.

TO: Our focus is to engage and empower leaders at every level of the organization to ensure a focus on value through asset management and reliability.

AE: It is the supreme art of the teacher to awaken joy in creative expression and knowledge.

WED: It's management's job to know. A leader must have knowledge. A leader must be able to teach. A leader's job is to help his people.

TO: There are advantages to using a framework for reliability and asset management

WED: People need to know what their jobs are. The emphasis should be on why we do a job. People need to know how their job contributes.

TO: Guys we have known the answers for reliability for over 40 years and we still struggle with achieving high levels. What is stopping us from solving this problem?

AE: We can't solve problems by using the same kind of thinking we used when we created them. Insanity: doing the same thing over and over again and expecting different results. Intellectuals solve problems; geniuses prevent them.

WED: Stamping out fires is a lot of fun, but it is only putting things back the way they were. Rational behavior requires theory. Reactive behavior requires only reflex action. Manage the cause, not the result.

TO: There is a big difference between knowing and doing.

WED: Best efforts will not substitute for knowledge.

AE: Knowledge of what is does not open the door directly to what should be. Information is not knowledge.

WED: The problem is that most courses teach what is wrong. People learn in different ways: reading, listening, pictures, watching.

AE: The only thing that interferes with my learning is my education.

TO: My work has shifted from supplying answers to working in the form of enquiry to create even more possibilities.

AE: The important thing is not to stop questioning. Curiosity has its own reason for existing.

WED: Without questions, there is no learning.

AE: Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning.

WED: Information is not knowledge. Let's not confuse the two. If you do not know how to ask the right question, you discover nothing.

TO: Many of the managers seem to focus on Key Performance Indicators as the road to improvement.

WED: The most important figures for management of any organization are unknown and unknowable.

AE: Not everything that can be counted counts, and not everything that counts can be counted.

WED: 3% of the problems have figures, 97% of the problems do not.

TO: We just released a report on asset management that showed organizational culture as the biggest single obstacle for asset performance. Top management can benefit from providing constancy of purpose for the people who work in the organization.

AE: Concern for man and his fate must always form the chief interest of all technical endeavors. Never forget this in the midst of your diagrams and equations.

WED: All anyone asks for is a chance to work with pride. If someone can make a contribution to the company, he feels important. Innovation comes from people who take joy in their work.

At that point in the conversation I noticed Mr. Einstein staring at the cover on the latest issue of Uptime Magazine when he suddenly pointed with delight that he finally found the hidden Uptime logo in the image at which point I suddenly woke up.

Weird….

Warmest regards,

Terrence O'Hanlon, CMRP
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CRL Workshop and Exam
Fort Myers, FL

Aug. 3-7, 2015
Solutions 2.0
CRL Workshop and Exam
Houston, TX

Sept. 16-17, 2015
ReliabilityTours
Cincinnati MSD
CRL Workshop and Exam
Cincinnati, OH

Sept. 28-Oct. 2, 2015
RLI Uptime Elements
CRL Workshop and Exam
Fort Myers, FL

Nov. 7, 2015
CRL Workshop and Exam
London, England

Nov. 10-12, 2015
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Dec. 7-11, 2015
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CRL Workshop and Exam
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The Certified Reliability Leader (CRL) is traveling the world and offering a variety of locations and events to choose.

4-Day CRL Preparatory Course offered at Reliability Leadership Institute (RLI) located in Ft. Myers, Florida. The week includes an in-depth discussion of the Uptime Elements and how each element enhances and fits into this framework. The first workshop was held May 4-8th. At the end of the week, the CRL exam was offered with an impressive pass rate – **90%**!!

ReliabilityTours is a 2-day CRL workshop held at a facility that is currently using the Uptime Elements. See first hand how organizations are implementing the Uptime Elements and how they are putting this framework into practice in their own company. Attendees are treated to a private tour and an overview from the company's key players in reliability. The CRL Exam is offered to close off this one-of-a-kind experience!

Conferences and special events can range from a 4-hour workshop overview to a 4-day in-depth discussion with the option of the CRL exam. This provides a unique opportunity to tailor your needs to an event or learning environment you desire.

To learn more and register, visit
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I've Been Everywhere

Song by Johnny Cash

Reliabilityweb.com version by Terrence O'Hanlon

I was toting my pack along the long dusty Reliability road
When along came a semi with a high canvas covered load
If your goin' to Reliabilityweb.com, Mack, with me you can ride
And so I climbed into the cab and then I settled down inside
He asked me if I'd seen a road with so much dust and sand
And I said, "Listen! I've traveled every road in this here land!"
I've been everywhere, man
I've been everywhere, man
Crossed the deserts bare, man
I've breathed the mountain air, man
Travel, I've had my share, man
I've been everywhere
I've been to,

Stillwater (OPMUG)
Vegas (Reliability 2.0)
Cleveland (RELIABILITY Plant)
Pretoria (Aladon Meeting)
Dubai (Certified Reliability Leader)
Everett (Fluke's Measure of Innovation Summit)
Nashville (FLIR's Inframation)
Columbia (Maximo Utility Working Group)

I've been everywhere, man.
I've been everywhere, man.
Crossed the desert's bare, man.
I've breathed the mountain air, man.
Of travel I've had my share, man.
I've been everywhere.

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CONGRATULATIONS

Why Drones Are the Next Internet

by Terrence O'Hanlon

Drones are a game changer and hold vast potential for streamlining and reducing the cost of inspection and monitoring tasks associated with reliability and asset performance.

Back in the mid-nineties, I worked with a small group of 10 engineers at AT&T's Bell Labs in Murray Hill, New Jersey, that eventually became AT&T Worldnet Services. Back then, the possibilities of today's Internet were in their first minute and it was exciting to be part of it.

Fast free connected information, easy to use communication tools, image sharing, online video and social connection tools are now ubiquitous and seem normal in our everyday lives.

Imagine if you had been part of the first minute of the Internet. What would you have created? Even if you are old enough, you may have missed it because things that change our everyday lives are hard to imagine before they actually create the change.

Woody Allen says that 80 percent of success is showing up, and now you have a second chance to show up during the first minute of a technology that will change the future in a big way. I am referring to drones. Drone technology has been democratized and it's now fast, cheap and out of control. It's like the Internet all over again.

Once the Federal Aviation Administration's (FAA's) rules for using drones commercially are approved, the Association for Unmanned Vehicle Systems International estimates the economic impact of the industry could reach $13.6 billion in the first three years and climb to $82.1 billion by 2025. Part of that impact will be the addition of 103,000 jobs, paying a minimum of $40,000 for those involved in manufacturing the drones, and more for the engineers and operators. Equipped with new capabilities, such as integrated audio and text with real-time video feeds and the ability to overlay images over existing footage through augmented reality, next generation drones could have significant commercial value for businesses across industry segments.

While commercial and civil aviation are tightly regulated, inexpensive, sophisticated drones are being built and sold online by the thousands.

According to Chris Anderson, CEO of 3D Robotics, Inc., drones are not just remote controlled aircraft; instead, they're computer controlled unmanned aircraft capable of autonomous flight following GPS waypoints and otherwise executing pre-programmed missions and controlling onboard cameras. A decade ago, this was the sole domain of the military. Today, you can buy one for less than $550.

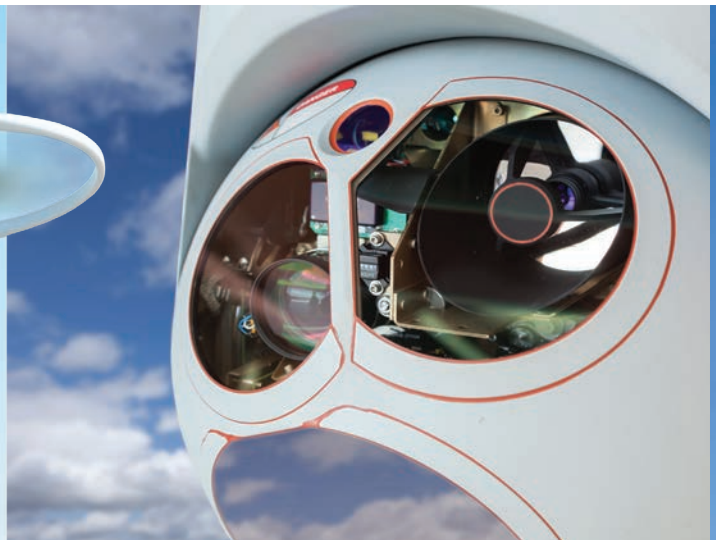
There are several kinds of drones, including helicopters and airplanes.

Airplanes fly missions that require longer time periods and operators must know how to land successfully. Helicopters are great for close-up inspections and monitoring that requires stationary views.

Drones like Gimball are designed not to be disturbed by collisions. It uses obstacles to find its way instead of avoiding them, offering a simple solution to a complex problem.

Gimball can safely fly indoors and in complex environments, is easy to fly and can be operated close to humans. It solves multiple challenges in inspection of industrial facilities!

There is even a pocket drone, a collapsible, three rotor aerial vehicle by AirDroids that folds up small enough to easily fit in a backpack, but its three independent propeller motors are powerful enough to carry a GoPro camera.



These key features are available on most drones:

- They are lightweight units, typically ranging from two to 15 pounds, with the ability to easily fit in the back of a car.
- They have highly efficient propulsion systems that enable quiet hovering capability and flight durations typically ranging from 30 to 200 minutes.
- They can include dual forward and side-look high resolution color and thermal imagery cameras with image stabilization, which is ideal for video recording during day and night.
- They have a line of sight ranging from 0.5 miles to 10 miles.
- They require minimal use of runway strips, with options for vertical takeoff and landing.
- Data connectivity is typically through low power, digital, wireless and video links.

As sales of drones gain traction and they are used by more companies, is demand for talent skilled in drone manufacturing, technology, or operation also growing? In January, there were 164 job openings that refer to the term "drones," according to data from WANTED Analytics. While that may not seem like many, this is a 32 percent increase when comparing January 2015 to January 2014.

Embry-Riddle Aeronautical University's Daytona Beach, Florida, campus is one of a small but growing group of colleges and universities offering a degree in unmanned aircraft systems. The program started only three years ago with about 11 students and that has grown to about 230 students since.

Industrial Applications for Drones

Recently, the FAA approved BP and California-based manufacturer AeroVironment's request to fly the Puma AE UAS (unmanned aircraft system) at BP's Prudhoe Bay Oil Field on Alaska's North Slope. It's the first time the FAA has authorized the commercial operation of a UAS over land in the U.S. The Puma is a radio-controlled, fixed wing vehicle 1.4 meters (4.6 feet) long with a wingspan of 2.8 meters (9.2 feet).

Made of ultralight Kevlar, it weighs less than seven kilograms (13.5 pounds). Other fixed wing UAVs are autonomous, which means their route, speed and height are all pre-programmed ahead of flight. Both versions can fly for around three-and-a-half hours and remain stable in winds of up to 50 kilometers (31 miles) an hour. This makes them ideal for checking pipelines and mapping land outcrops for exploration purposes.

> "there were 164 job openings that refer to the term "drones," according to data from WANTED Analytics."

There are also radio-controlled, multi-rotor UAVs – effectively mini helicopters – that are smaller and have a shorter range. These are perfect for checking vertical structures, such as flare stacks and cooling towers, as well as flat roofs and electrical lines. BP is also investigating their potential use inside vessels and tanks. The beauty of a multi-rotor UAV is that it can collect accurate data from a structure at a distance of seven to nine meters (23-30 feet), without having to shut it down.

Bentley Systems Inc.'s Acute3D (see sidebar) develops and sells Smart-3DCapture®, a software solution allowing you to produce high resolution 3D models from simple photographs of as-built 3D models of your facility captured by a drone with a camera in a simple and inexpensive way.

> "drones are also being used for the thermographic inspection of inaccessible buildings or electric power lines, as well as for firefighting and law enforcement jobs."

According to FLIR Systems, Inc., thermal imaging camera drones are also being used for the thermographic inspection of inaccessible buildings or electric power lines, as well as for firefighting and law enforcement jobs.

The days of small plane flyovers for infrared roof inspections and underground steam pipe mapping and leak detection are certainly numbered as drones make a powerful economic argument for their use.

The Electricity Research Pool at Finnish Energy Industries and Sharper Shape Ltd. have demonstrated drones with advanced sensors in public test flights as part of a research project.

The robotic copter is equipped with a laser scanner, cameras and aviation safety systems and has the capability for long-distance beyond visual line of sight (BVLOS) inspection flights. The laser scanner maps the terrain and forms an accurate 3D model of the components of the power network, as well as the surrounding buildings, forest and vegetation.

The purpose of the study was to demonstrate the technical viability and cost-efficiency of drone-based inspections to the electric industry. Drones enable the advanced collecting of needed data for identifying and mitigating risks in power distribution.

Drones from a company called Skycatch, Inc. and more established companies are monitoring power lines, inspecting oil and gas pipelines, checking wind turbines for defects and pinpointing malfunctioning solar panels.

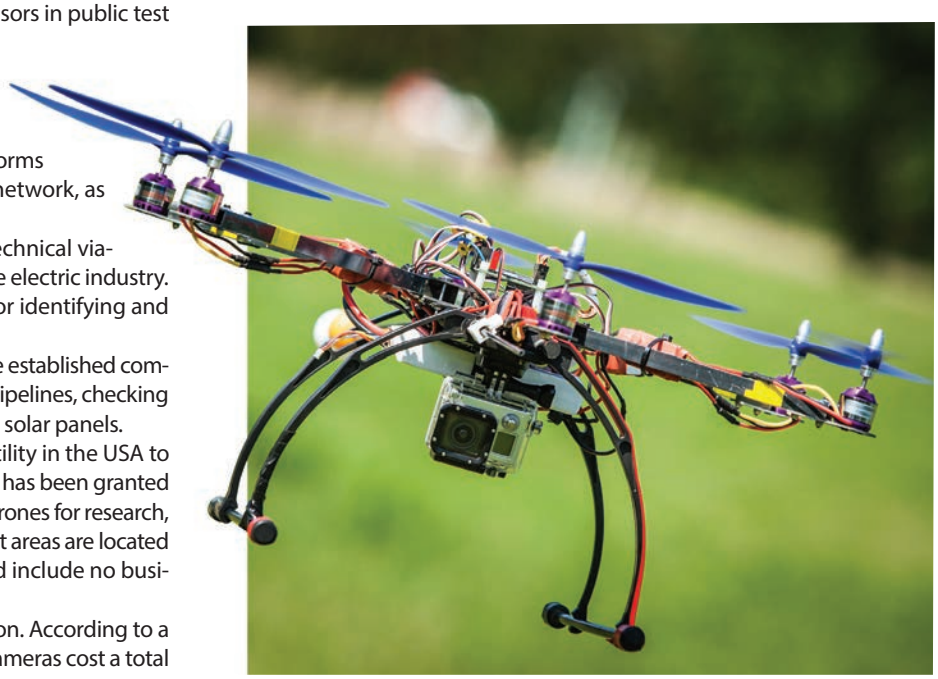
San Diego Gas & Electric (SDG&E) became the first utility in the USA to gain approval from the FAA to test-drive drones. The utility has been granted a special airworthiness certificate that allows it to operate drones for research, testing and training flights in eastern San Diego County. Test areas are located in zones measuring 2.5 miles long by a half mile wide and include no businesses or residences.

When comparing costs, helicopters are no competition. According to a local San Diego news station, two drones equipped with cameras cost a total of $6,000. Leasing a helicopter would require $2,000 per hour.

Are you getting a sense that this article is not even scratching the surface when it comes to the potential for drones in industrial inspections and applications where humans were previously in harm's way or the cost and time of using existing transport were cost prohibitive?

As Woody states, success is achieved by showing up. How do you plan to show up for the quickly passing "first minute" of the exciting new technology revolution?

Meet Emmanuel de Maistre, CEO and Co-founder of Redbird, an information company capturing and analyzing data using small civilian drones. *See page 62.*



Terrence O'Hanlon *CMRP, is the CEO and Publisher of Reliabilityweb.com®, RELIABILITY® Magazine and Uptime® Magazine. Mr. O'Hanlon is the acting Executive Director of the Association for Maintenance Professionals (AMP) and was a voting member of the US TAG (PC251) for ISO 55000 - ASTM E53 Asset Management Standards Committee. Terrence is certified in Asset Management by the Institute of Asset.*

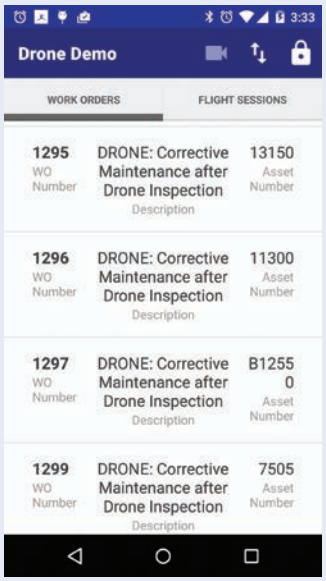
Drone Inspection for IBM Maximo

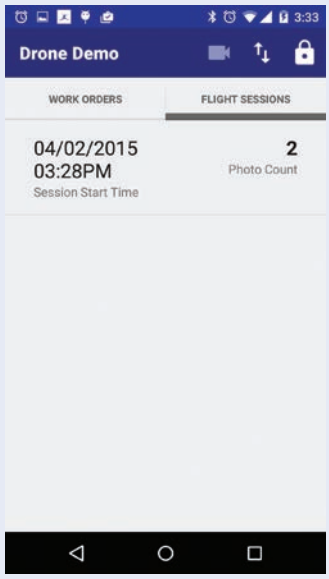
by Stacey Miller

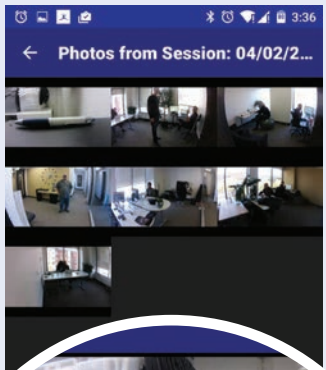
When one thinks of drones, images of unmanned aircraft systems (UASs) in military situations typically come to mind. The technology of these unarmed aircraft, such as camera feeds, GPS and vertical landing system equipment, creates opportunities to use them in practical maintenance applications, such as inspections of hard to reach and/or cost prohibitive to reach valuable assets. By obtaining Federal Aviation Administration (FAA) approval to use drones, asset-intensive companies, such as BP and San Diego Gas & Electric (SDG&E), are exploring drones as the answer to certain maintenance applications. Interloc Solutions, an IBM premier business partner focused on Maximo consulting and mobile solutions, believes this is the optimal time to put drone applications into practice with Maximo.

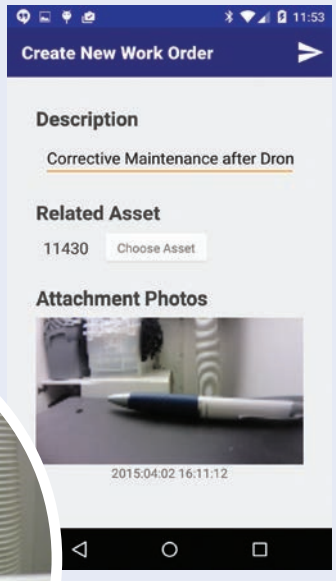
To that end, Interloc has brought together its extensive Maximo and mobile expertise with its industry asset maintenance knowledge and developed a purpose-built drone inspection for Maximo application. This application uses Maximo and the Interloc mobile informer solution with the technology features of the DJI Phantom 2 unmanned aircraft.

The unmanned aerial vehicle (UAV) provides three-axis camera stabilization, on-screen real-time flight parameters and an integrated GPS autopilot system. The mobile informer is native to Maximo and to iOS, Android and Windows devices, including tablets, phones, wearables and drones. The applications work both online and off-line, with no middleware needed.









Mobile informer's simple, purpose-built drone inspection for Maximo application allows inspectors to stay safely on the ground, yet see exactly what the UAV sees directly from their mobile device. The drone inspection for Maximo application also provides inspectors with the video camera feed from the UAV, allowing them to take a picture of a specific asset by tapping on the screen and creating work orders by tapping on the image needing attention. The work order will contain the image of the asset and provide its GPS coordinates, allowing for concise and detailed inspections. And, because the mobile informer application is native to Maximo, all inspection data is pushed directly to Maximo in real time.

This simple, purpose-built drone inspection for Maximo application has many business uses. From wind turbines to bridges, buildings and transmission lines to cell phone towers and aerial land surveys, inspections become a whole lot easier, less costly and safer. No longer do inspectors need to use or incur the cost of traditional discovery methods, such as scaffolding erection, sky climbers, or rappelling. The combination of Maximo, mobile informer and drones provides inspectors the ability to not only perform visual inspections with pinpoint accuracy and high definition clarity, but also creates work orders that are directly within Maximo.

About the Author
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www.interlocsolutions.com/mobileinformer

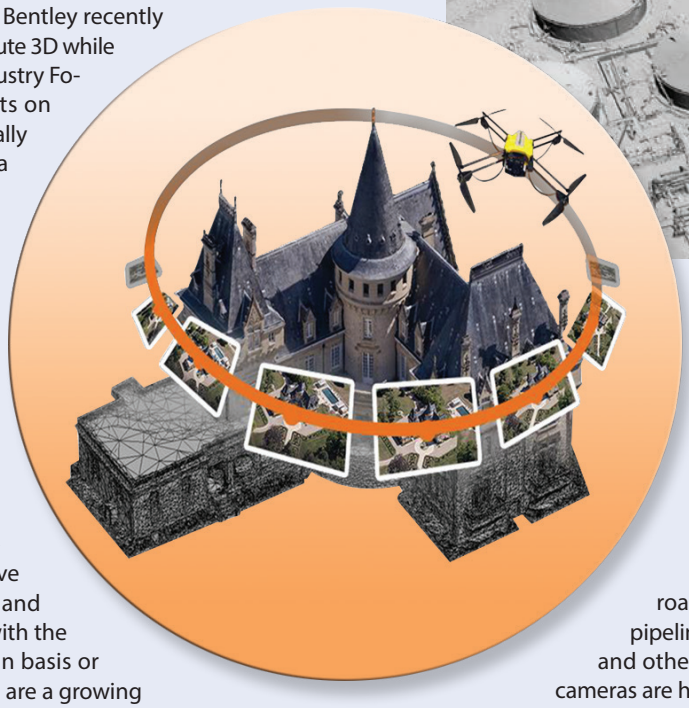
Breakthrough Technology for Maintenance Inspections:

A Drone in Every Maintenance Organization!

by Sandra DiMatteo

Sustaining infrastructure requires good design, construction and handover, but ultimately, it's the operating context and the inspection and asset care program that dictate how well an asset will perform over its lifetime and how long it will last. Know what the latest breakthrough in technology for maintenance inspections is? Drones!

Bentley Systems CEO Greg Bentley recently announced the acquisition of Acute 3D while at the ARC Advisory Group's Industry Forum. Bentley shared his insights on how this software can dramatically enhance productivity, turning a simple series of digital photos taken with a smart camera mounted on a drone into a 3D reality mesh model. The result is a compact, intelligent representation of the asset in its current operating context. He confidently predicted there will be a drone in every major infrastructure maintenance organization by 2016. Using unmanned aerial vehicles (UAVs) and normal digital photography, inspectors can observe existing conditions, then track and trend the condition over time with the ability to compare to the design basis or any point in its life. In fact, there are a growing number of uses of drones in industrial maintenance, reliability and integrity inspections.



Creating 3D Plant/Asset Drawings

Many existing plants have no information model, no accurate records and possibly some unreliable or outdated 2D drawings. If you are operating in an existing plant with poor engineering records, today you can now capture a precise 3D model using simple digital photographs taken from UAVs using software to render an information model that you can maintain going forward. It's called reality modeling. You can then take updated photos to observe current state and compare them to the model as time goes on. To model a given plant/asset, the image acquisition process requires a minimum of three sharp overlapping photographs. Anyone following this rule will be able to capture suitable imagery data sets, whether using a smartphone, a compact digital single-lens reflex (DSLR) camera, or a high resolution professional camera like those used for airborne acquisition.

Conducting Inspections on Infrastructure Assets in Hard to Reach Areas

From structural integrity issues on bridges and roads to wind turbine blades and rig inspections to pipeline monitoring for wall thickness, welds, corrosion and other structural integrity issues, UAVs with mounted cameras are helping maintenance organizations to more easily and cost-effectively observe these out of reach conditions. Bridge and road inspections, especially as regulatory guidelines move towards reliability-based inspection practices, will require flexibility as the frequency of inspections changes based on operating context. Water and power utilities are benefiting from unmanned drones using high definition sonar to conduct subsea inspections. All in all, the use of drones can make what used to be a difficult and costly task an easier and more cost-effective one.

Drones and reality modeling can and should be part of every maintenance organization and every proactive maintenance workflow to dramatically enhance productivity and safety in infrastructure asset inspections.

About the Author
Sandra DiMatteo leads the marketing strategy and positioning for Bentley's asset management and operations products. www.bentley.com

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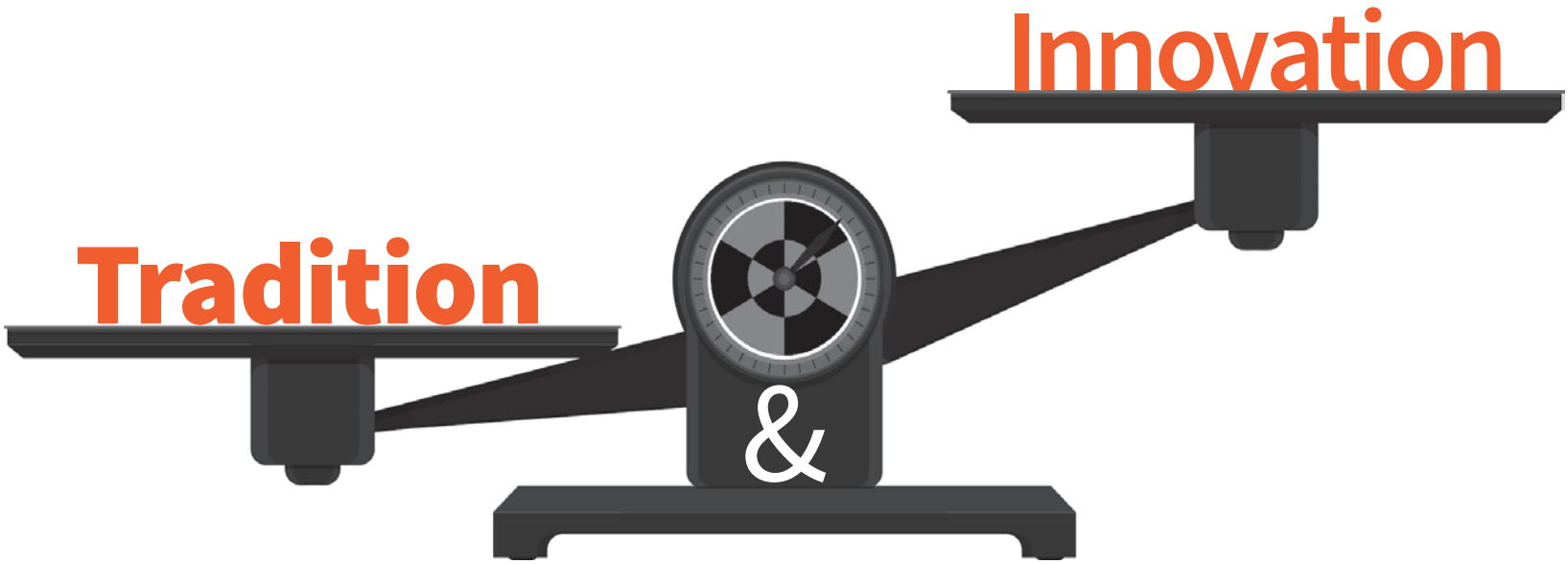


by Heinz P. Bloch

Process pump reliability logically involves a combination of fluid-related performance and design decisions that focus on engineering materials and the configuration of mechanical components. Recent case studies have pointed out improvement opportunities in the relative design conservatism found in certain process pump models. Combined with deficiencies in the training of personnel, it can be argued that pump reliability has not made as much progress as it perhaps could. This view is supported by repeat failures of process pumps. It is evident that whenever random or repeated failures occur in process pumps, the true root causes of these events have not been uncovered. In many instances, tradition favors treating the symptoms or, just as inappropriately, doing nothing at all.

Tightened Specifications Often Inappropriate

A closer look at the issue of unidentified repeat failures shows another worrisome trend. Tradition-bound reliability engineers look at pre-existing specifications and decide to make the new specification tighter. The fallacy of simply tightening a specification is best shown in four case histories. Each deals with fluid machinery and illustrates that tighter specifications do not automatically translate into better and truly life extending specifications. Well-focused specifications increase safety, equipment reliability and bottom-line profits. Tight specifications may fall far short of reaching the goal.

Case 1

Case 1 and high temperature pump lubrication. Many years ago, a Canadian consulting engineer was impressed by a well-designed API-style pump at a refinery in Trinidad. He fully understood the merits of pure oil mist lubrication which, in this instance, benefited a visbreaker heavy fuel oil pump that processed flammable hydrocarbons at 750 degrees F. For many years, the pump and its rolling element

> *Well-focused* specifications increase **safety**, **equipment reliability** and **bottom-line profits**

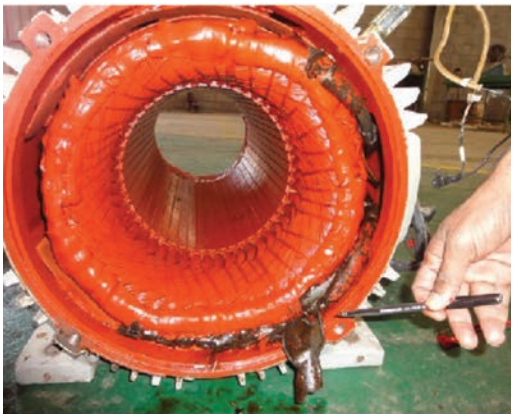


Figure 1: Swollen T leads in an electric motor

bearings ran safely, successfully, dependably, flawlessly and reliably. Later, in the early 1980s, the same reliability-focused machinery engineer learned more about pumps in pipestill bottoms service with fluid temperatures of 740° F at many U.S. oil refineries. For decades, dozens of these high temperature process pumps have been lubricated by pure oil mist, again, successfully, dependably and flawlessly.

Next, fast-forward to several specifications issued by less informed engineers in 2012. What's particularly troubling is that some of these recent specifications were issued on behalf of world-scale oil refineries. One of them, or its design contractor, now limits oil mist to pumps with pumping temperatures below 450° F. Even more astounding is a specification from another contractor. It stipulates a 300° F pumpage temperature as the cutoff for oil mist lubricated rolling element bearings. A few recent specifications call for "heavy service factor reclassifiers," although no such "heavy service factor" reclassifiers (i.e., oil mist flow orifices) were ever found necessary for process pumps in the 40 years from 1973 to 2013.

Limiting oil mist applications to pumping services not exceeding 300° or 450° F begs an important question: What lube application method will best serve pumps with 600° and 740° F operating temperatures? Other than the outstandingly well-proven pure oil mist, only liquid oil sprayed directly into the cage of a rolling element bearing is a suitable option for the reliability-focused machinery engineer. Reverting back to liquid oil sumps with oil rings and constant level lubricators has serious, negative maintenance cost impact. An even worse potential scenario exists with conventional lubrication and inadequate maintenance. In the case of inadequate maintenance, the equipment owners must surely brace themselves for adverse safety and reliability outcomes.

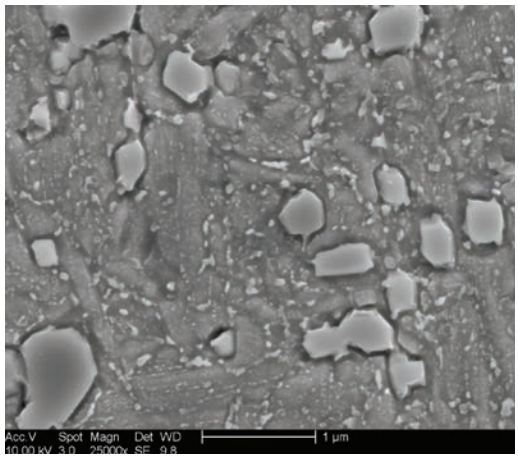


Figure 2: A surface before diffusion conversion treatment

Case 2

Case 2 and the implications of continuous pump operation at 25 percent of design point flow. Another recent oil refinery pump specification requires all process centrifugal pumps to be continuously operable at 25 percent of the capacities shown on their respective design flow plans. If such clauses are enforced, the owner-operators could be locked into purchasing highly inefficient pumps or would have to elevate pump suction vessels high into the process unit to gain available net positive suction head. Alternatively, the pumps might have to be provided with variable frequency drives, automatic bypass valves, or whatever. It's just another example that shows a surprising lack of understanding. The cure would be to read a few of Igor Karassik's old pump texts or, as of 2015, study some of the now 31 years' worth of Texas A&M University's International Pump Symposium Proceedings. But, simply tightening a specification will have serious cost consequences up front, serious failure consequences later, or both.

Case 3

Case 3 and disregarding favorable experience with oil mist on electric motors. Only very recently have there been reports of electric motor terminal wires swelling. After noting swelling of the insulation on terminal wires (i.e., "T" leads) of relatively new electric motors, one would be concerned that cooling air flow at the motor's stator ends might be impeded (see Figure 1). But the T leads on thousands of motors have never swelled *prior to* a prominent manufacturer recently changing the insulation materials on them. The manufacturer had begun using a material with a swell rate in excess of 10 percent at 50 degrees C while the decades-old satisfactory precursor material had swell rates of only 1.8 percent at the same operating temperature. And of the motors equipped with the precursor materials, over 26,000 were commissioned in the four decades leading up to 2010. In fact, about 1,000 of these had been installed in Texas from 1975 through 1978 and lubricated with pure oil mist. Many were still operating flawlessly when last checked with the user in 2012. In other words, as of 2012, these motors had been in successful service for 34 years.

At one petrochemical plant in 2012, the response to T lead swelling in motors was to advocate a return to grease lubrication. But, grease lubrication needs to be done periodically and correctly. The maintenance intensity and personnel training requirements for grease lubricated electric motors far exceed those of motors lubricated with pure oil mist. A professionally superior approach would be to question the motor manufacturer to fully understand what caused the T leads to swell. Cooperative motor manufacturers will readily assist with the analysis and implement the right remedial action without delay. Remedial directives are available from the better electric motor manufacturers and from the Reliability Services Resource Center (*colfaxcorp.com/tlm)*, offered by an experienced provider of plant-wide oil mist systems. These manufacturers would be among those able to explain that T leads coated with well-proven, low swelling materials, such as irradiation cross-linked polyolefins, should not have been abandoned in favor of new T leads with a much greater swell rate. And reverting to grease lubrication will rarely qualify as 21st century reliability engineering. Instead, insistence on the type of T leads that have served well for the past 34 years would seem appropriate.

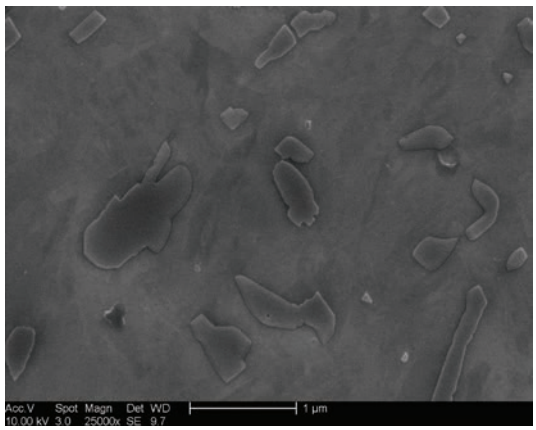


Figure 3: The surface after diffusion conversion treatment

It is worthy to note that reliability engineers at true best-in-class companies are obligated to ask questions whenever equipment manufacturers

change to newer materials. Such questioning has been around for a long time; it's called management of change. In this instance, the new material was the key and comparing its properties to those of the T lead insulating material that served well in the previous 34 years would have disqualified a new material with six times the swell rate of insulation material that had been in successful use for decades.

Case 4

Case 4 and lubricating vertical electric motors for pumps. On a presently active project for a petrochemical plant in the U.S. Gulf Coast region, vertical pump drive motors were specified with oil mist lubrication. Four vendors were invited to bid and all of them claimed their motors were not suitable for oil mist lubrication. It was found extremely noteworthy that a world-scale competitor in the same area has used oil mist lubrication on 107 of its vertical motors since 1977! A number of these have never experienced bearing failures in the past 37 years.

If, then, the motors for the active project are purchased as offered with part grease/part liquid oil lubrication, the new project is saddled with maintenance handicaps from Day 1. Its expenditures will far exceed those of the competition with its 37 year technologically more advanced motor lubrication.

Wear Improvement Through Diffusion Conversion Based Technologies

There are unique diffusion conversion based technologies that improve both the chemical and physical characteristics of steel. These improved characteristics transform lower cost materials so they can either match or outperform more costly exotic alloys in high wear applications. Many hundreds of thousands of truck diesel engine exhaust turbochargers are using the technology to great advantage.

By modifying the crystalline lattice of steel to a depth of 50 to 75 micron, diffusion conversion techniques often prove superior to traditional surface coating methods. Traditional coatings usually add a layer of high strength material which, in many cases, is prone to inadequate bonding, brittle fracture and spalling. Diffusion conversion does not alter the dimensions of the treated component. The surface hardness of diffusion conversion parts can reach 67 on the Rockwell C scale, while the underlying bulk hardness remains unaffected. When an abrasive particle or opposing surface strikes a diffusion converted surface, the wear energy is adsorbed and dissipated throughout the surrounding steel. Figures 2 and 3 show the before and after surfaces with 25,000x magnification.

> A few 21st century operating companies are developing a questioning attitude. They demand fact-based answers from reliability engineers.

This technology has the potential of solving wear problems in slurry pumps and abrasive-containing crude oil services. There is also a strong possibility that certain hot service pump impellers will live longer after the diffusion conversion treatment. At present, a forward-looking pump user is needed to make cost comparisons and share his or her findings with the industry.

Specify With Forethought

These and other regressive case histories indicate a mid-20th century, stuck in the past mind-set. Tightened specifications are often misguided and ill-defined efforts to improve equipment reliability. Fortunately, there are opportunities for a new crop of smart competitors to move ahead of the rigid traditionalists. A few 21st century operating companies are developing a questioning attitude. They demand fact-based answers from reliability engineers. Their managers refuse to act on mere opinions and recognize that wild guesses are unproductive at best, and dangerous, at worst.

Indeed, thoughtful industry leaders emerge from the haze and fog of trial and error engineering. Best-in-class companies are aligning their specifications with best available practices; they manifest and practice leadership at all levels. True leadership is conduct that convinces others to accept a course of action that, although not initially perceived as beneficial by the tradition-bound, is ultimately a far-reaching benefit to a business entity. Translation: Do some reading before you become a party to specifying counterproductive requirements. Speak up. It can be done tactfully, but decisively and authoritatively as well. Make your contributions based on factual information. Join the trend set by motivated reliability professionals who favor pursuing a 21st century mind-set.

__Heinz P. Bloch__ began his professional career in 1962, which included long-term assignments as Exxon Chemical's regional machinery specialist for the U.S. He has authored over 600 publications, among them 19 comprehensive books on practical machinery management, failure analysis, failure avoidance, compressors, steam turbines, pumps, oil mist lubrication and practical lubrication for industry. Mr. Bloch holds BS and MS degrees in mechanical engineering.

LEAN THINKING Maintenance, Repair and Overhaul Jobs

by Robert Crotty

Large maintenance, repair and overhaul jobs (MRO) can be significantly improved in terms of safety, cost, downtime and quality by applying lean thinking.[1] At Luminant, we applied lean thinking to our power plants, mines, construction and rail operations, along with our supply chain.

Improving safety is our number one priority. One of the principles of lean thinking is respect for the individual. This can be demonstrated in several ways, as shown in Figure 1, in the lean thinking house of quality that we adapted for maintenance, repair and overhaul.

At Luminant, safety for the individual is one of our key approaches to the principle of ***respect for people***. An example is a recent switchyard upgrade and overhaul. At one of our power plants, we were building a new plant next to the existing plant while conducting a major retrofit of the existing plant. Additionally, another power plant company was tearing down three old units adjacent to our unit, along with maintaining smelter operations.

This required a redesign and upgrade of the electrical switchyard. Given the danger of the high voltages present, our overall objective for the job was safety. Secondly, we could not interrupt the smelter operations for very long without risking irreparable damage to the pot lines.

The lean thinking approach we use is a combination of 5S[2], process mapping, eliminating the seven wastes[3] and best practices wrapped in the Single Minute Exchange of Die (SMED)[4] method.

SMED started as a technique to reduce die changeover time to less than 10 minutes on machines that processed a variety of parts.

For example, it typically would take eight to 16 hours for a changeover from left-handed to right-handed door panels. The long changeover time drove the economic need to produce enough units to amortize the downtime cost across the parts produced. Large batch sizes dramatically increased lead time and inventory costs.

Dr. Shigeo Shingo, an industrial engineer, originated and perfected the SMED technique over time by applying it very successfully in the Toyota Production System (TPS). Applied systematically, it lowered the cost of vehicles and created shorter lead times to deliver cars, giving Toyota a market advantage.

We took the SMED approach and adapted it for MRO jobs with a variation on the goal. Our objective was to ensure safety and a 12-hour max changeover. There wasn't a large economic payoff for reducing the downtime.

If an accident occurred handling the high voltage, it could be fatal or cause serious injury. Not being able to repower the pot lines would render them useless, while requiring extensive equipment replacement and lost production.

The total duration for most MRO jobs can be divided into the following task categories:

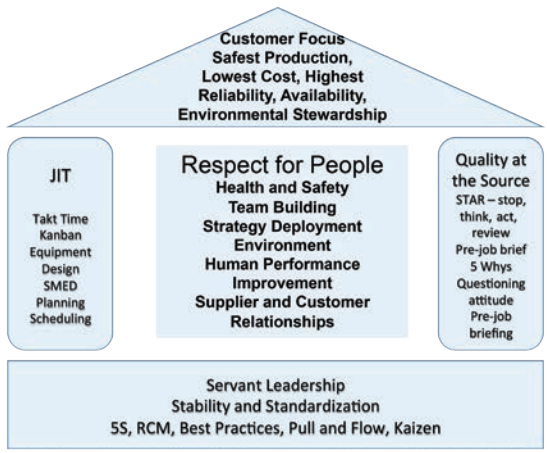
1. Gather necessary parts, tools, instructions and equipment.
2. Shutdown/start-up, remove/replace covers, guards, or get access.
3. Replace parts.
4. Adjust, test and align parts, material, or equipment to be production ready.

In many cases, the majority of the time is spent on items 1, 2 and 4. SMED divides all tasks into two categories:

1. Tasks that can be done while the equipment is running are considered ***external***.
2. Tasks that only can be done when the equipment is down are considered ***internal***.

The process we adapted from SMED for MRO is these six steps:

1. Measure total time to complete the job.
2. Separate internal and external tasks.
3. Convert internal tasks to external tasks.
4. Streamline internal and external tasks.
5. Assess risks and identify countermeasures.
6. Document and maintain new procedure.



Dr. Yoji Akao originally developed QFD house of quality in Japan in 1966, adapted for MRO.

Figure 1: Lean thinking house of quality adapted for MRO

STEP 1:

Measure total time to complete the job

Since we had not completed the switchyard upgrade job before (in many cases, MRO jobs can be one-offs or done infrequently), we had to process map the job via a brown paper approach. We worked with the team who would be performing the job, along with the engineers, project manager, supply chain and other supporting groups.

The brown paper approach is essentially a critical path network and process map combination with labor and durations of tasks.

1 Measuring total job time – using brown paper process mapping work breakdown structure

Source: *Luminant Outage Playbook, page 18, Dallas, Texas, 2007*

The brown paper facilitates discussion and can be changed easily as the team thinks through how the job would be done. It also gives an estimated idea of how long the total job time will be.

For repetitive jobs, the job change over observation sheet is a great way to document the job.

1 Measure total job time by documenting job steps and time

Date:
Machine: Die Exchange

Job change Observation Sheet

Change from:
To:

No	Step by step action elememt	Can be split Int	Can be split Ext	Timing Unit	Observations
1	Get tool bag			12	
2	Find wrench, loosen screw			18	No designated location for wrench. Operator lost time searching for wrench
3	Loosen tool			3	
4	Put down tool				
5	Receive tool			8	
6	Problem: loosen screw, key			45	
7	Find wrench			10	
8	Loosen and lift tension arm			15	
9	Insert new tool			4	
10	Find measuring stick			5	No designated location for measuring stick. Operator lost time searching for stick
11	Set tension arm			105	

Define job steps

Document time

Source: *Single Minute Exchange of Dies (SMED), page 11, Luminant Academy, Dallas, Texas 2005*

STEP 2:

Separate internal and external tasks

Next, we wanted to identify which tasks can be done while on line before and after the job (external tasks). For example, gathering tools, parts and job instructions are all tasks that can be done before going off line.

2 Separate internal and external tasks

Date:
Machine: Die Exchange

Job change Observation Sheet

Change from:
To:

No	Step by step action elememt	Can be split Int	Can be split Ext	Timing Unit	Observations
1	Get tool bag			12	
2	Find wrench, loosen screw			18	No designated location for wrench. Operator lost time searching for wrench
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4	Put down tool				
5	Receive tool			8	
6	Problem: loosen screw, key			45	
7	Find wrench				
8	Loosen and lift tension arm			15	
9	Insert new tool			4	
10	Find measuring stick			5	No designated location for measuring stick. Operator lost time searching for stick
11	Set tension arm			105	
12	Centre tool			55	
13	Tighten tension arm			7	
14	Exchange raw material			28	
15	Adjust per instruction from inspector			35	
	Total:			352	

Internal task:
Can be done only when the equipment is not producing

External task:
Can be done while the equipment is producing

Source: *Single Minute Exchange of Dies (SMED), page 12, Luminant Academy, Dallas, Texas 2005*

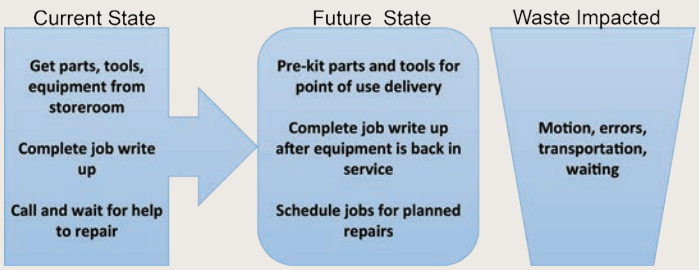
Cleanup could be done after going on line or in parallel with the job. A good approach to this would be applying 5S.

STEP 3:

Convert internal tasks to external tasks

The next step was to look at tasks that are internal and convert them to external tasks. For example, we may be able to pre-assemble some components while on line. In our example, we had some of the connector fixtures pre-assembled.

3 Convert internal tasks into external tasks wherever possible



STEP 5:

Assess risks and identify countermeasures

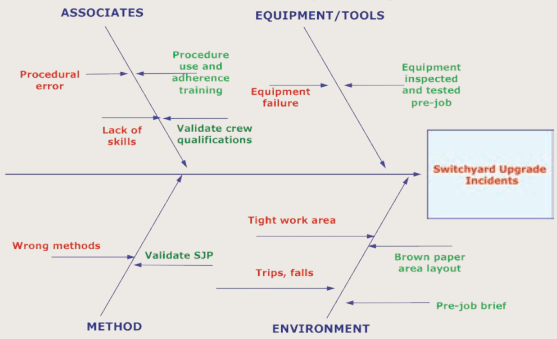
In this step, we are identifying risks and countermeasures to mitigate the risks. The approach is to take each of the major tasks and ask questions about what could go wrong. Then, we ask what we can do to mitigate the risk.

Where the risk was high, we needed to determine countermeasures. For example, if it rains and we are past the point of no return, we either have to stop working or put up tarps. We would then dry off the equipment with portable heaters. Of course, checking the weather forecast before starting the job would be the first countermeasure.

A great tool for evaluating overall risks or specific tasks is a cause and effect diagram[5] modified to show countermeasures (in green).

5 Assess risks and identify countermeasures

Causes and countermeasures for potential job incidents

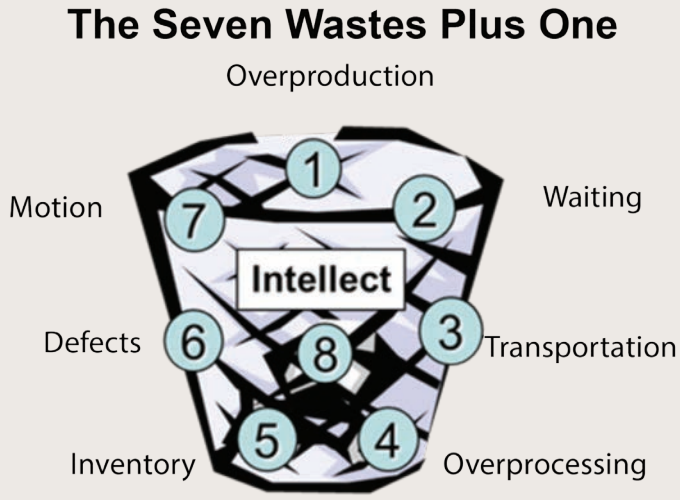


STEP 4:

Streamline internal and external tasks

Streamlining internal tasks:

Tasks that only can be done while the equipment is down should be streamlined where possible. One approach would be to look at the seven wastes plus one, intellect, and eliminate them or reduce where possible.



Source: *Lean Concepts, Luminant Academy, Page 13, Dallas, Texas 2005*

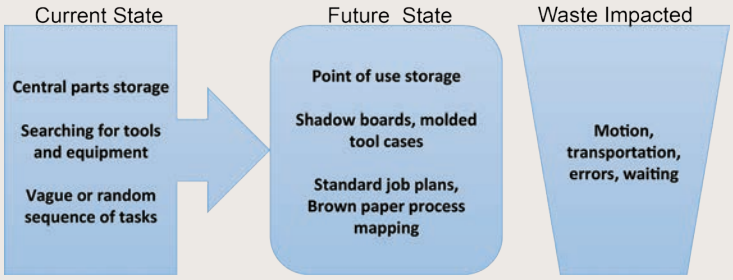
For example, there may be excessive motion or transportation activities during the job. This could be improved by predetermining where tools, fixtures, materials and parts will be located for efficiency.

In our example, since the switchyard was a tight space, we took a layout of the yard and simulated the locations for the parts, tools and equipment. The goal was to reduce walking and improve safety by avoiding tripping hazards.

Streamlining external tasks:

Any task that is external where you can eliminate waste or improve the flow will reduce the cost of the job. For example, we pre-kitted the parts and materials for delivery to the job site versus organizing them when they got to the site.

4 Streamline external tasks where possible



STEP 6:

Document and maintain new procedure

Once the new process is established, the job needs to be documented. This can be implemented via the computerized maintenance management system (CMMS) or enterprise asset management (EAM) system and standard job plans.

In our example, this was a one-off for the organization as it was a job driven by building a new power plant and tearing old ones down. For this situation, we standardized our approaches for pre-kitting, brown paper and risk assessment for future jobs that may be similar.

6 Document and maintain new procedure

Examples of eliminating waste using best practice procedures

Measure and communicate repair or change out operations

Last	Best
6:30 hours	4:00 Hours

Create best practice procedures for MRO jobs

Changeover Standard Procedure Sheet – Minutes

No.	Step	Planned	Actual	Remarks
1	Shut down machine	2:00	1:75	
2	Remove cover	1:00	1:00	
3	Remove part	2:25	3.00	
4	Insert new part	1:00	1:00	Difficulty aligning
5	Replace cover	0:50	1:00	Too many bolts and tight clearance
6	Load new material	1:25	1:00	
7	Restart machine	1:25	1:00	
8	Start production	0:75	0:50	
Totals		10:00	10:25	

Document New Procedure and Sustain
- Create standard job plan and document in CMMS or EAM system
- Standard time to perform job and task sequence
- Standard tools, parts, consumables and equipment needed
- Standard parts and tools kit
- Health, safety and environmental precautions identified
- Procedure use and adherence
- Train all involved

Source: *Single Minute Exchange of Dies (SMED), page 16, Luminant Academy, Dallas, Texas*

TYPICAL RESULTS FOR MRO JOBS

While the switchyard example's focus was related to safety and completing the job within a specified time period, this technique can be used to reduce the overall downtime and cost. Here are some examples:

EXAMPLE 1

Application in a nuclear power plant
Comanche Peak Nuclear Power Plant in Texas reduced its refueling outage duration from 75 days to 55 days, setting a world record.

EXAMPLE 2

Application in mining operation
The duration for a dragline swing shovel ring changeover was reduced from 204 hours to 36 hour an 82.4% downtime reduction.

EXAMPLE 3

Application in fossil fuel power plant
A power plant boiler feed pump downtime duration was reduced by one day out of a scheduled six days. This included unexpected rework, costing an additional 96 hours.

Summary

The lean thinking approach can be used successfully on any type of MRO or construction job. The jobs can be one time, highly repetitive, or infrequent. In any case, the benefits are improving overall availability, safety and cost.

The SMED method is a proven approach to applying lean thinking for improving MRO or construction jobs. The key advantage is the use of the collective knowledge of the individuals who do the work to create an improved process.

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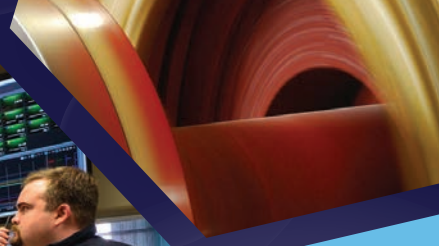
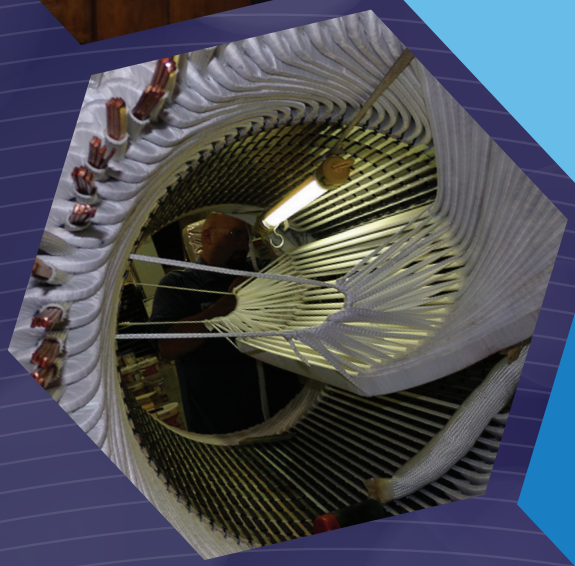
Robert Crotty *is a Director for the Luminant Generating Company's Nuclear Supply Chain. He has been practicing lean thinking for over 30 years.*



Small to Large

Electric Motor Repair & Load Testing



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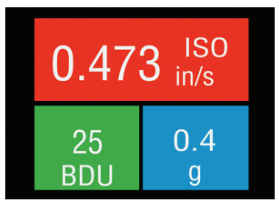
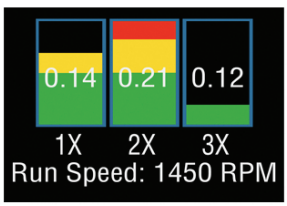
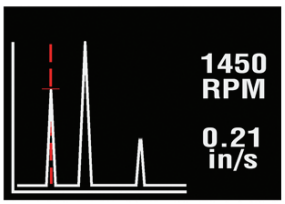


Color coded to ISO alarm levels
› Overall velocity
› Bearing damage
› Acceleration



Diagnose
› Unbalance
› Looseness
› Misalignment



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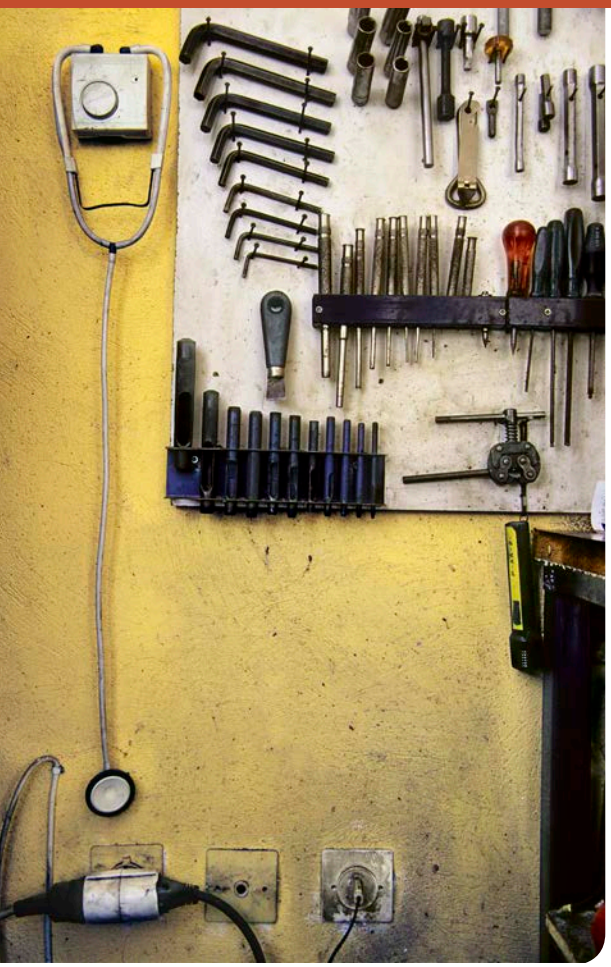
Practical Implementation of Acoustic Emission Technique in Machinery Fault Diagnosis

by Hamid Karimi and Mohammad Moshtaghi



Vibration analysis is a valuable technique in machinery fault diagnosis. Although lesser time is spent on the acoustic emission technique (AET) in comparison to vibration to make it applicable in industries, many years ago, listening to machine sounds using a screwdriver or a sound scope was the first step a technician took to detect a fault in machinery. This article is the result of three years' experience of corrective maintenance (CM) experts in a petrochemical plant trying to explain implementation methods, obstacles, advantages and disadvantages of acoustic emission technique. It compares the vibration and acoustical data gathered from different machines in order to find similarities and differences.

Implementation Method

For implementation of AET, a variety of instruments have been introduced to industries. The measuring device in this petrochemical company is able to record the sounds and transfer the frequency range from 15 kHz to 197 kHz to the human hearing frequency range of 20 Hz to 20 kHz. This device is compatible with both sound and ultrasound sensors; the former evaluates ultrasound in terms of dBμV, while the latter evaluates sound pressure level in dB terms.

To utilize this device, measuring points of ultrasound should be marked on machines to minimize possible errors. Hence, data can be acquired, stored and analyzed. Subsequently, any abnormal evidence, such as an increase in measured data, can cause machinery to go under precise supervision. There are some notes related to data gathering that should be considered:

Data acquisition should be done preferably by a specified individual due to applied pressure to the sensor.

Measuring points and time interval should be carefully respected.

The amplification setting in the instrument.

The effect of noise in a noisy environment.

It's highly recommended that acquired acoustic and vibration data be analyzed together. This may lead to finding some similarities, as well as differences, between AET and vibration. Likewise, before issuing any work order for dismantling a machine after tracking the fault, AET data should be gathered for future analysis.

To make acoustic data quantitative, it's necessary to calculate some acoustical parameters. These parameters help verify the severity of the defects so necessary action can be taken to manage the lifetime of the defected part. Parameters are well used for detection of faults in roller element bearings and life management of them as well.

There are various parameters for evaluating an acoustic wave:

RMS: This is defined as the formula:

$$\mathrm{AErms} = \sqrt{\frac{1}{N}\int_0^{\Delta T} \mathrm{AE}^2(t)dt}$$

Where ΔT is integration time and N is the number of discrete data within ΔT.

Integral: Numerical integration of a certain part of the signal.

SNR: The ratio between noise and overall signal power. SNR is defined as the power ratio between a signal and background noise, where A is RMS of amplitude.

$$SNR = \frac{P_{Signal}}{P_{Noise}} = \left(\frac{A_{Signal}}{A_{Noise}}\right)^2$$

SNR is often expressed using logarithmic dB due to the wide dynamic range of signals.

$$SNR_{dB} = 10log_{10}\left(\frac{P_{Signal}}{P_{Noise}}\right) = 20log_{10}\left(\frac{A_{Signal}}{A_{Noise}}\right)$$

MARSE: Stands for measured area under the rectified signal envelope, which can be clearly seen in Figure 1.

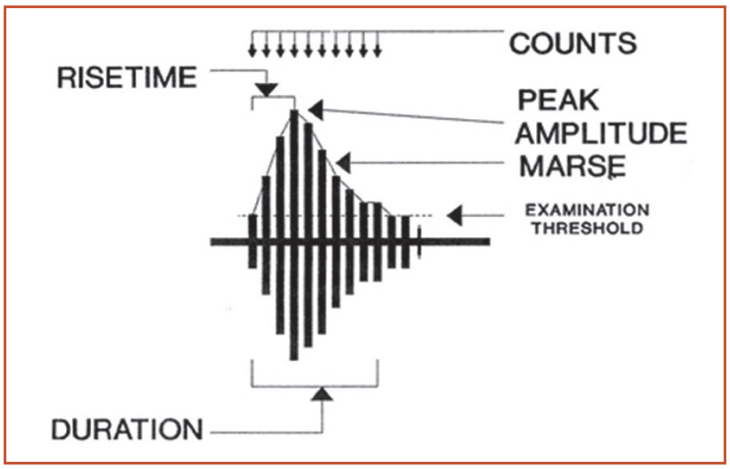


Figure 1: An illustration of MARSE

Kurtosis: A parameter that describes how a probability density function is distributed. Kurtosis can be defined using the formula:

$$Kurt\ (x) = \frac{\sum[(x-\mu)^4]}{\sigma^4}$$

Where x is signal, μ is average and σ is deviation.

Spectrum: One of the most popular analysis methods using Fourier transform function.

SVL: Stands for sound voltage level and is calculated using the formula:

$$SVL = 20log\frac{V}{V_0}$$

Where V_0, reference voltage, is considered 1μV.

Disadvantages of AET

There are some obstacles users face with acoustic emission technique. They are:

The effect of noise on recorded sound waves.
The importance of how and in which direction a sensor should be held.
Difficult analysis of recorded sound waves.
Exaggeration of problems.
Disproportionality between defect development and some AET parameters.

Figure 2: False brinelling effect on bearing

At the beginning of implementing AET in machine diagnosis, once the SVL was increased, it seemed that a serious defect existed in the equipment. Accordingly, several electric motors (about 3-4 motors) were dismantled in order to check and replace the bearings. Although the ultrasonic sound level was very high and there seemed to be a severe defect in the bearings, the only problem discovered was a false brinelling. There was no need to change the bearings (Figure 2) at that time and it was able to be in service more. False brinelling happens in these cases:

- The machine is stored in a warehouse for a long time, exposing it to the influences of humidity.
- A machine is out of service for a long time period, causing induced vibration.

Advantages of AET

One of the most important advantages of AET is the early detection of faults in machines. Other advantages are:

Insensitive to structural resonance;
Detection of growing cracks;
Low needed test time;
Evaluating the lifetime of parts.

As mentioned before, early detection of faults, especially in roller element bearings, is one of the most important advantages of the acoustic emission technique. This will be discussed later in this article.

Study and Findings

Air cooled exchangers (ACEs) are the machines under supervision of AET in the Zagros Petrochemical Company (ZPC) plant. Figure 3 shows an installation schematic of these coolers.

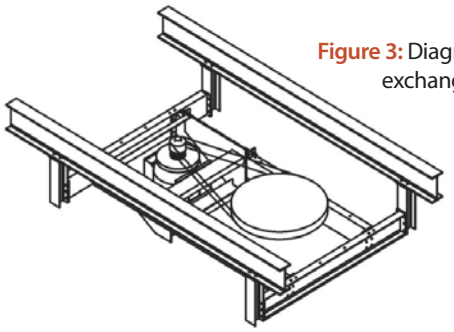


Figure 3: Diagram of air cooled exchangers in ZPC plant

Table 1: Studied electric motors calculated parameters

Tag No.	FFT				Time Waveform				SVL
	Measured Parameter				Measured Parameter				
	Integral	Kurt.	RMS	SNR	Integral	Kurt.	RMS	SNR	
AM2	68900	10427	23.2	24.5	11.8	2.78	6224.5	47.5	21
BM15	69352	10378	21	25.8	-2.1	2.8	5745.5	48.5	23
BM7	95760	23223	29.9	24.9	-23.2	2	7988	46	24
DM1	67994.34	87094.37	35.18728	23.2894	43.41553	0.864283	9599.191	48.01303	25
BM5	398538	24712	64	24.7	-3554.9	-0.5	17312	35.7	35
CM3	252127.5	65752.21	59.72888	25.83924	-3920.85	-0.45973	16267.63	37.8711	38
DM10	632452	365.2827	70.22272	22.34934	-1643.93	-0.327	19078.48	24.9426	39
AM16	456873	3924.5	60.1	25.4	-3699	-0.48	16301.5	31.8	41
DM15	499660.4	2139.964	60.8966	23.761	-6488.93	-0.17984	16558.69	29.5235	42
AM7	660684	1691	75.7	21.5	-2824.3	-0.25	20656.2	29	47
BM14	685597	3091	79.1	20.7	-2478.1	-0.18	21510	29.5	49

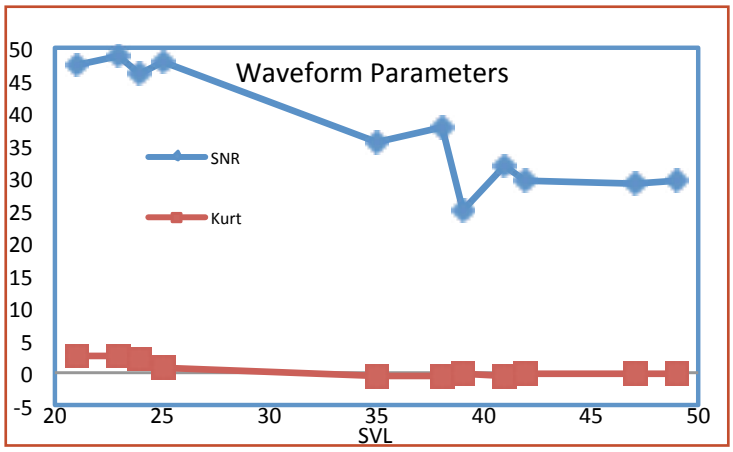


Figure 4: Waveform parameters' changes trending

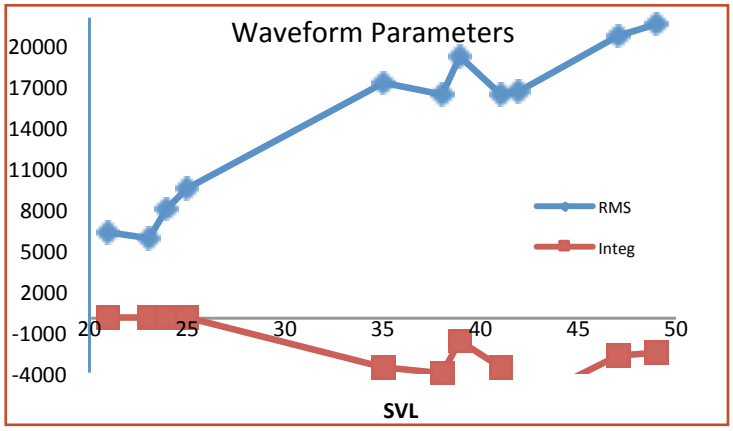


Figure 5: Waveform parameters' changes trending

The ultrasonic sound level of these electric motors is acquired monthly. Accordingly, these motors are categorized into four groups based on the sound voltage level. They are:

Group 1: SVL<20 dBµV

Group 2: 20<SVL<30 dBµV

Group 3: 30<SVL<40 dBµV

Group 4: SVL>40 dBµV

Table 1 show the AET parameters values of 11 studied coolers. Note that the SVL is ascending downward.

In Figures 4 and 5, the values of various parameters versus the changes in SVL are shown. It's implied from this curve that *as the SVL increases, the values of Kurt and SNR decreases. Likewise, increasing the values of SVL results in increasing the RMS and absolute values of integrals* (Figure 5). Note that these parameters are calculated in a certain time period (10 seconds).

This phenomenon was seen in several machines and the same results obtained as well.

Bearing deterioration consists of several steps or phases:

- **Initial stage** - increase in ultrasound level.
- **Second stage** - large increase in ultrasound.
- **Third stage** - very high increase in ultrasound.
- **Final stage** - gradual decline in ultrasound.

In Figure 6, trending of ultrasound levels (SVL) in the bearing of an electric motor is shown in a bar chart in which an envelope curve has been set along with bars.

This process is also common in vibration analysis. Figure 7 illustrates the trend of bearing condition unit (BCU) in a bearing at the same time period.

Note that fault diagnosis should not be done using AET alone. In fact, defects have to be detected early using AET and controlled and monitored in order to postpone bearing replacement as much as possible.

Statistical Investigations

ZPC includes two separate methanol plants. There are three sets of air cooled exchangers, with a total number of 106 fans in each plant (Figure 8). These fans are electric motor driven, in which power is transmitted by timing belts. Because of its vicinity to the Persian Gulf, ZPC is located in a hot and high humidity coastal area. As such, two main parameters play important roles in the operation of these machines: humidity and temperature (Min: 15°C and Max: 50°C).

Humidity: The relative humidity percentage in this region varies from 20 to about 95 percent during a year. Moreover, injected steam into a tower (T-1501) (Figure 8), which comes out from the top, dispenses around the ACE and enters into electric motors due to an existing draft at the bottom of the air cooled exchanger.

Temperature: All the electric motors are erected vertically below the exchangers, so the drive end (DE) side of the bearing is too close to the finned tubes exposed to high temperatures.

According to the defined routine, ultrasonic sounds of electric motors are recorded, saved and analyzed monthly. The results of these data are analyzed statistically as well. Figure 8 shows the plant layout and potentially contaminant machines that are affecting the air cooled exchangers.

According to Figure 8, the cooling tower in plant 2 and the T-1501 in both plants are the main contaminant equipment. Likewise, the direction of wind in this region causes the outlet vapor from the T-1501 and the humidity from the cooling tower to move toward the ACEs and enter them.

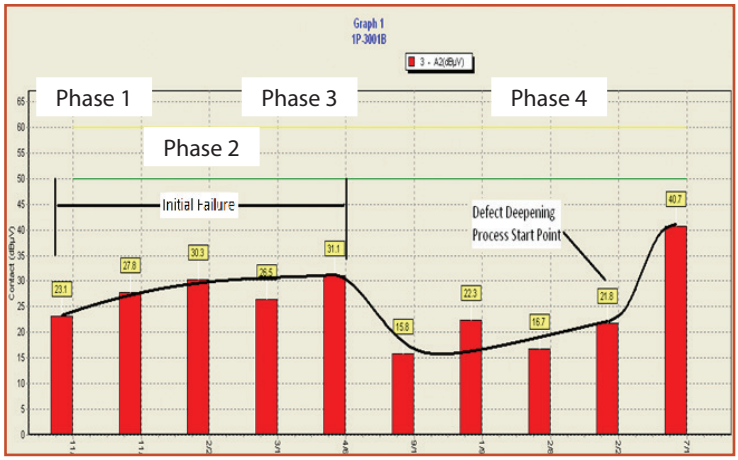


Figure 6: Defect developing in a bearing versus SVL

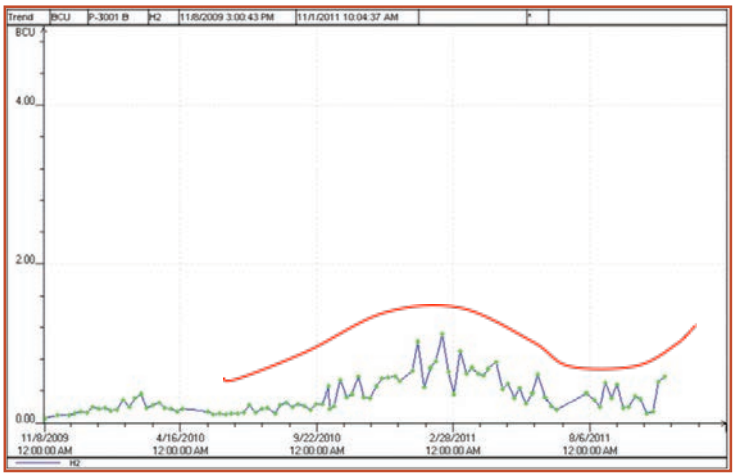


Figure 7: Developing defect in a bearing

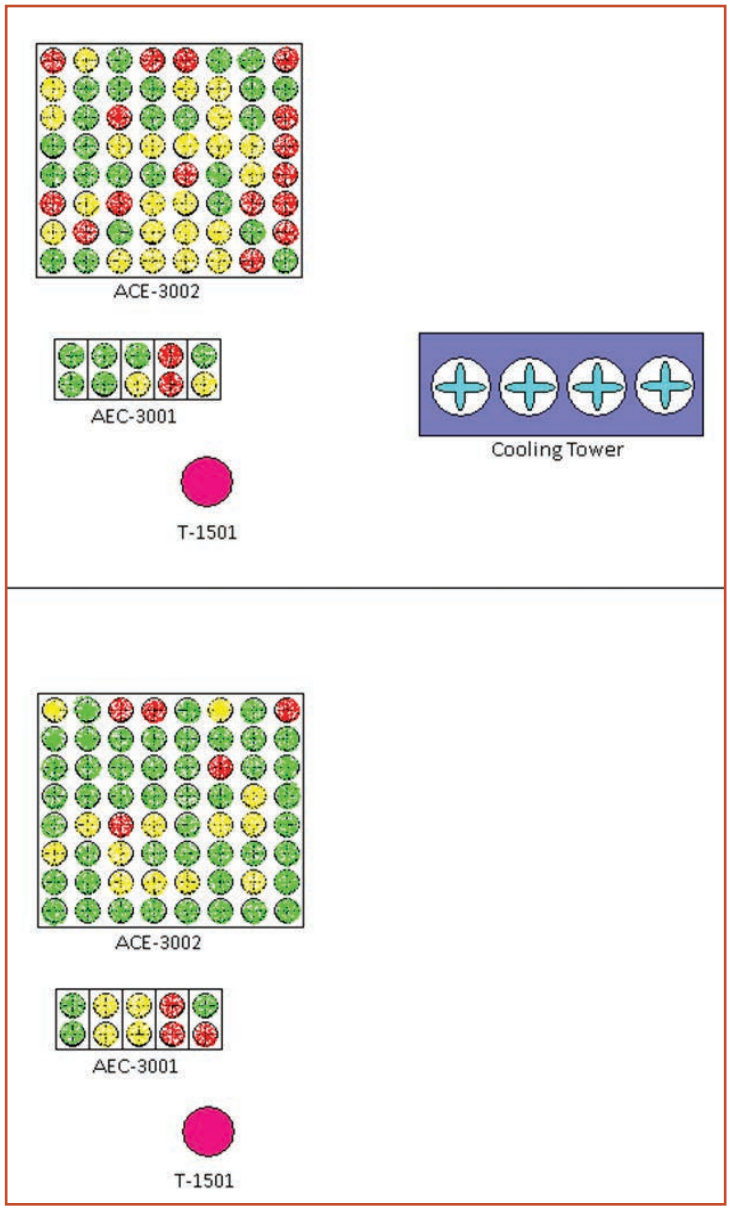


Figure 8: Plant layout

These fans are equipped with two lubricating nozzles through which grease can be injected into the bearings. One of these nozzles is exposed to the polluting substances. These polluting substances can be entered, along with grease, into the bearing and cause deterioration of it.

Naturally, the electric motors closer to the source of the contaminants have the worse conditions. Hence, some information was gathered through the computerized maintenance management system (CMMS) about the electric motors, including:

- The number of routines issued for regreasing (Routine A).
- The number of routines issued for replacing the belt, leveling the skid, adjusting the belt tension and so on (Routine B).
- The number of routines issued for replacing the bearings (Routine C).

SVLs for all electric motors are also recorded using an acoustic emission (AE) instrument.

Results

The results of the collected data showing the overall conditions of the electric motors are shown in Figure 8 using different colors. The red color

refers to the defected machine, the yellow color represents those electric motors whose bearings are in the initial stage of defect and the green color points out a normal condition. Analyzing the data proved these results:

- The closer the electric motors to the contaminant equipment, the more vulnerability. As demonstrated, the red circles show defective fans, which are closer to the cooling tower.
- The electric motor's DE side bearing is more vulnerable than the non-drive end (NDE) side due to the exchanger's high temperature, as well as pollution.
- Since there is no cooling tower in plant 1, no regular deterioration was seen on the ACE-3002 in this plant.
- Although plant 1 was commissioned about three years earlier than plant 2, the number of defected electric motors in plant 2 are more than those in plant 1. In other words, the cooling tower is the main contaminant equipment in plant 2.

Conclusion

Acoustic emission technique is a valuable technique in machinery fault diagnosis, but unfortunately, is not used widely in industrial plants. Many written papers related to AET are the result of lab investigations. Although it cannot be claimed that without implementing AET machine diagnosis will face problems, but using this valuable technique will remarkably help with more accurate diagnosis and defect tracking. However, it should be noted that the nature of AET is somehow investigative not only in labs, but also in production plants.

Timely fault detection is one of the main advantages of acoustic emission technique. Sometimes, an equipment fault, especially in roller element bearings, can be detected, monitored and tracked several months before it will be seen in vibration spectrums. It could be said that there are some techniques, such as the envelope technique, which helps detect the fault in a timely manner. But the fact is that AET is famous due to its high sensitivity. Once a fault is timely detected by AET, some maintenance activities can be executed in order to manage the defect growth process and reduce its decline.

> Timely fault detection is one of the main advantages of acoustic emission technique.

One of the main ways for reducing defects in anti-friction bearings is timely regreasing. Of course, the amount of injected grease into the bearings is of the essence. However, regreasing intervals also can be defined using acoustic emission technique.

Acknowledgment

The authors dedicate this article to Mr. Aliakbar Abbaspour, maintenance manager at Zagros Petrochemical Company, whose managerial method and strategy in maintenance is knowledge based and admirable.

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Safety Devices

By Gordon Mains

When developing a maintenance strategy, the usual suspects are always at the forefront of time-based maintenance (TBM) activities in a periodic maintenance program (PMs), such as PMs for motors, pumps, compressors, diesels, valves, etc.

In reviewing current maintenance practices at three companies, it was interesting to see how the maintenance reporting structure was put together to track history on these particular assets. There were also the criticality assessments that prelude the development of the strategy and the subsequent coding of "CRITICAL ASSETS."

Without entering into a discussion on critical assets, it is safe to say that right off the bat, safety devices are "Number One" on the list.

> "History is cataloged with the reminder that things actually do happen and will happen with the most horrific consequences."

Safety Device: Its Function

There appears to be varying definitions for safety devices across the board, from the Canadian Standards Association (CSA) , Health and Safety Executive (HSE) in the United Kingdom and the U.S. Chemical Safety Board, however, the intent is the same:

- **To alert operators to abnormal conditions (e.g., warning lights, etc.).**
- **To shut down equipment in the event of a failure.**
- **To eliminate or relieve abnormal conditions (e.g., rupture discs, safety valves, etc.).**
- **To take over as a backup (e.g., redundancy, standby, etc.).**
- **To prevent dangerous circumstances from arising.**

You probably know all too well what can happen if these devices are not maintained, or if even the awareness that they actually exist on your systems is not known. For example, the following disasters come to mind:

- **Piper Alpha**
- **Bhopal**
- **Texas City Industrial disaster**

History is cataloged with the reminder that things actually do happen and will happen with the most horrific consequences. The knock-on effect is usually far greater than the short-term impact. Families are devastated for years, communities are impacted financially and emotionally, environmental issues, and the company's reputation is irretrievably damaged.

With this in mind, there is still a desire to either ignore the warning signs or feel unable to do something about it.

Regulatory Maintenance

One thing that is easy to include in your 100 percent compliant PM program is regulatory maintenance. The code makes it easy for you to dictate what should be done over what is less important. The regulatory PM is the minimum requirement and should be the building block for all maintenance strategies.

You can communicate regulatory PMs easily with your staff as they are non-negotiable, the law of the land. Some examples of the governing bodies and the regulation are:

- **Overpressure Protection Systems – CSA Z662, API, etc.**
- **Pressure Vessels – Alberta Boilers Safety Association (ABSA), Approved Code of Practice Safety of Pressure Systems (United Kingdom), API, ASME**
- **Pressure relief devices – ABSA, API, etc.**
- **Fire protection equipment inspections – National Fire Protection Association (NFPA), British Standards Specification, etc.**

If these are considered first level protection not just for the equipment, but for the company, the second level of protection would be your existing safety devices, which are non-regulatory, but by no means any less important.

This level of protection can be considered not only for the company, but for the manager of the assets and the safety of the personnel. In Canada there is Bill C45, in the United Kingdom the corporate manslaughter bill was passed in 2007, for the first time companies and organizations can be found guilty of corporate manslaughter, in the United States it is known as the collective knowledge doctrine. These legislations establish new legal duties for work-

Which 33% Are You?

place health and safety, and a good Occupational Health and Safety (OH&S) code, which states that management is responsible for including these listed examples:

- **Providing a safe and healthy workplace, including the necessary equipment systems and tools which are properly maintained.**
- **Providing information, training, instruction and supervision, and facilities to protect the health and safety of workers.**

Safety Devices

Fitted on most systems are myriad protection devices, ranging from ultimate highs to overspeed trips, from low-low level switches to lower explosive limit (LEL) detection. The list is large, so how can you identify what they are, where they are fitted and what they do?

In reference to the Reliability-Centered Maintenance (RCM2) publication by John Moubray, it was stated that approximately 33 percent of protection devices are not maintained properly, 33 percent of operators are unaware of what maintenance to carry out and 33 percent of crews aren't sure of the safety device's function or existence.

Assess your equipment on a system by system basis or by a criticality ranking of the system, whichever is more suitable to your needs or the company. Equally, if there is the process for reporting incidents, you could go back through old reports involving safety devices (e.g., emergency shutdown (ESD) devices). These can be used to build the starting point of the device you want to analyze first. It also may be part of a greater asset management improvement strategy.

Another area to consider is documentation. Do you have relevant and up-to-date piping and instrumentation diagrams (P&IDs), process flow diagram's (PFDs), control narratives, shutdown keys? During the process of collecting the information, it may flag other areas of opportunity. Even by updating or redlining drawings and you will begin to put together a more reliable source of information that will lead to a safer workplace.

Figure1: The Piper Alpha oil production platform disaster – July 1988

With the information gathered, look at which devices fall into which category.

- **Devices that will let you know they have failed.**
- **Devices that do not alert the user that they have failed while in service.**
- **Devices that are covered by a regulation.**

Decide which process you will use to determine the frequency of the inspection and the task to be performed.

There are many products on the market or information available to assist supervisors or asset owners with determining their maintenance program for these particular types of assets. The key is finding a methodology that allows you to determine the minimum maintenance requirements of your safety devices. The focus should be on ensuring the devices are functionally tested at an interval where the probability of failure is reduced to a tolerable low level to the likely victim.

Reliability centered maintenance (RCM) provides a solution to derive such ***failure finding intervals*** based on set equations that are applicable to the asset being analyzed.

The failure finding interval is like a P-F curve, but it determines the frequency at which a safety device can be functionally tested to ensure a probable level of protection to the user. The P-F interval, on the other hand, is used to determine the detectability and degradation of an asset over a period of time in order to detect the onset of a potential failure condition.

With the intervals calculated, look at the impact they will have on your system to carry out the functional test. There always will be a compromise between management and operations as to what is practical. Equally care must be taken when testing the device that it's not left in a failed state or may compromise the safety of

the system during testing. These hazards must be identified upfront prior to carrying out the work.

As an example, the interval may be calculated as three months to test the emergency shutdown devices; however, the plant is on a four month shutdown program, so it makes sense to move the frequency to four months. But, the reason for doing this has to be documented as to why the frequency has changed. It is important to communicate with the Operations, Engineering, Reliability, Planning and Scheduling group the frequency calculated in order to reach a consensus to limit the impact on operations, with respect to production loss and risk of changing to the frequency to fit.

Implementation and Validation

Be sure to implement the new maintenance tasks and frequencies, and communicate them with the staff at all levels. Ensure that they understand what has been done and why.

Track the devices on the PM program and code the PM type to reflect the work being carried out. This will help in terms of follow-up work and scheduling priority.

Figure 2: The Texas City industrial accident – March 2005

Failure coding on follow-up work can be reclassified to reflect failure effect and failure mode. Reports can be run in the computerized maintenance management system (CMMS), which looks at any asset of a safety type that has been found to have functionally failed while in service.

When developed this way, the maintenance program also can be used as information for insurance companies when documentation is required to prove what measures are in place to ensure the safety of the equipment and personnel. The documented safety device program can be easily printed, along with a report on associated work orders.

Summary

When evaluating systems to determine what maintenance to carry out, it is important that the 'safety devices' are assessed using a defensible and rigorous program, such as RCM. Ensuring the basics of functionally testing and inspecting safety devices will, at the very least, give the user, the asset owner and management the knowledge that they have done everything possible to ensure their devices function as required and may only be in a failed state for a reasonably tolerable period of time. In doing so, this may well save lives, reduce impact to the environment and limit damage to the company's public image.

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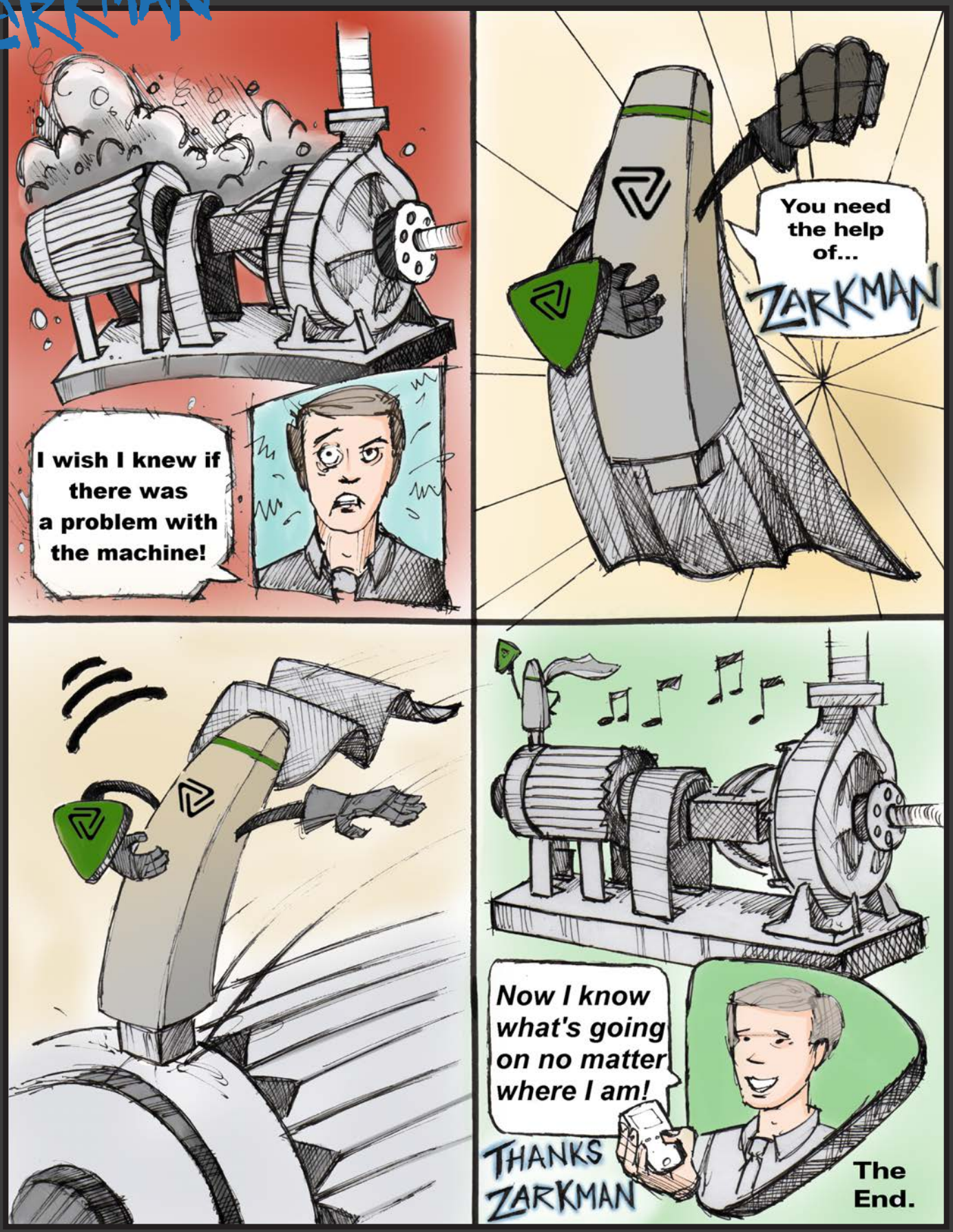
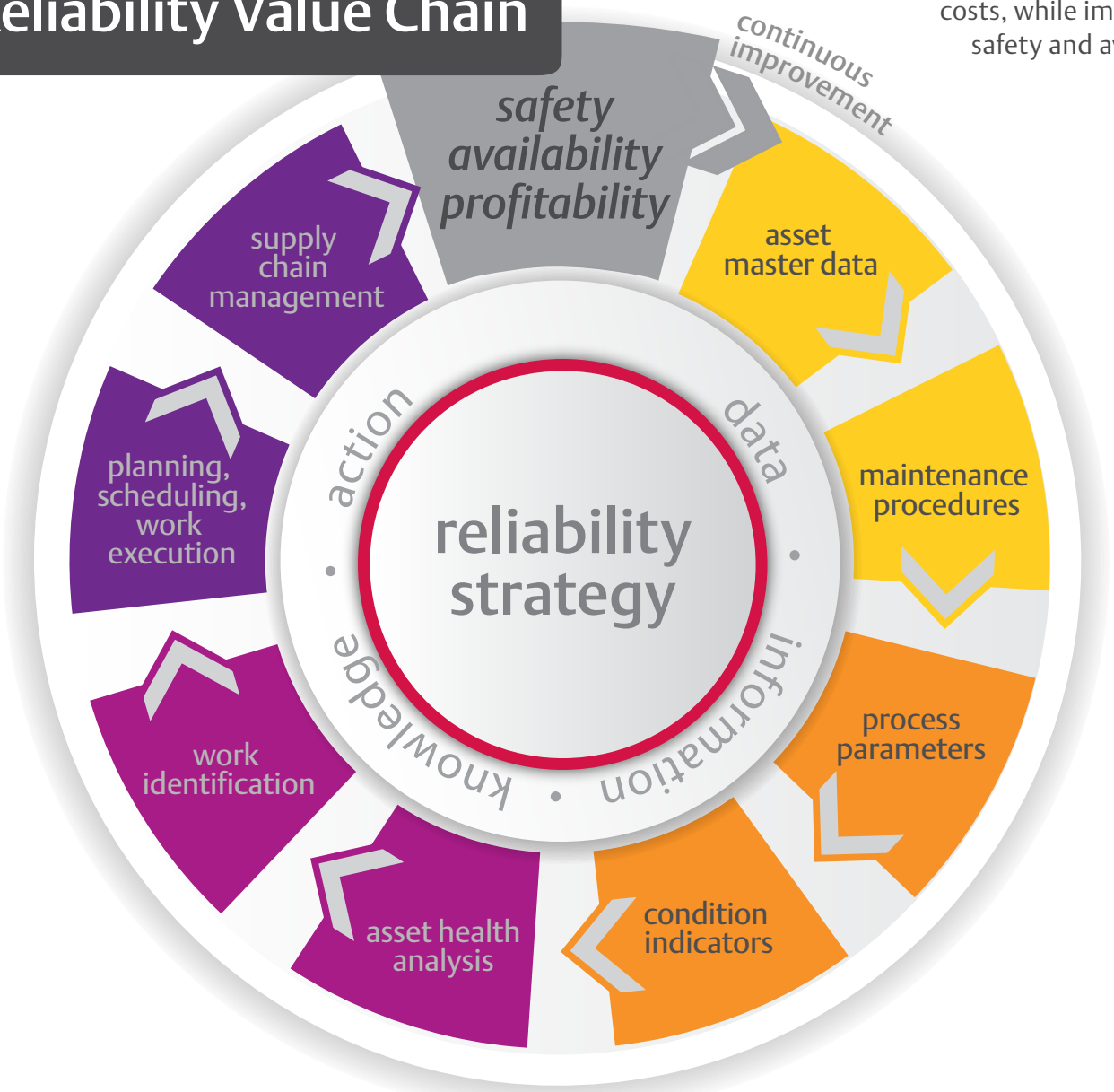


4 STEPS TO IMPROVE YOUR

The Reliability Value Chain – Top performing companies understand that reliability is a chain of activities that reach across the organization. Transform your reliability program to drive down maintenance costs, while improving safety and availability.

Reliability Value Chain



RELIABILITY

1 CLEAN YOUR DATA HOUSE

The best reliability programs are data driven. Without a solid data foundation, the integrity of your decisions will always be questioned. Invest in a robust data foundation which includes asset master data, failure codes, and maintenance procedures.

2 STEP UP YOUR INFORMATION

Deriving information from asset-condition data has long been used as the indicator of asset health. Now, top quartile performers are leveraging process-parameter data to get deeper insight into the health of their assets. Putting these two together in a robust dashboard view provides the complete picture of asset health. And, adding process-parameter data has never been easier with wireless technology.

3 PUT IT ALL TOGETHER TO CREATE KNOWLEDGE

Knowing what is good, what is normal, and what needs attention is critical to your reliability program. That knowledge comes from the union of data, information, and experience. Otherwise, your reliability program is just collecting useless information. Reach outside of your organization to get best-in-class experience.

4 TAKE THE RIGHT ACTIONS AT THE RIGHT TIME

The time for maintenance needs to be the right time for the maintenance department and operations. Top quartile-performers get their operations team and supply chain involved in order to minimize disruption, labor, and parts costs. Their maintenance spend decreases, and by eliminating emergency repairs, their plant availability increases.

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The Art of BALANCE

BALANCE is a necessary part of keeping production running and preventing unplanned shutdowns.

Balance in critical equipment isn't an optional goal for manufacturing facilities. It is a necessary part of keeping production running and preventing unplanned shutdowns. It's particularly important for facilities with high demand for products, as is the case with the Oman India Fertilizer Company S.A.O.C. (OMIFCO). OMIFCO is a joint venture business established to operate a state-of-the-art, two train ammonia-urea fertilizer manufacturing facility in the Sur Industrial Estate in the Sultanate of Oman. The plant produces 1,750 tons per day of anhydrous ammonia and 2,530 tons per day of granular urea. Its products help meet the growing agricultural demand in India.

The company's goal is to produce fertilizer 365 days a year. As a result, the company has focused extensively on ensuring reliability. Its strategy includes building in redundant equipment for all critical assets, performing predictive maintenance based on vibration, flow, pressure and temperature monitoring, and completing routine preventive maintenance.

Each year, OMIFCO is able to meet its targets. The highest production values came in 2013 with 1.38 million tons of ammonia and 2.15 million tons of urea.

SAVES $100,000

by Ankit Niranjan

Choosing the Right Tool and Technique

Since 2012, OMIFCO has relied on a portable vibration analyzer as a key tool in ensuring reliability. Engineers routinely use trending peak waveform to assess various bearing faults. They began using the analyzer to gather vibration data from heavy-duty boiler feedwater pumps, which produce steam used in processing ammonia and urea. The data is uploaded to asset management software for detailed analysis. Using peak vibration analysis technology, OMIFCO technicians quickly identified a potential problem in a turbine thrust bearing. The impacting faults were readily visible in the peak waveform long before any significant increase in overall vibration was noticed. As a result, OMIFCO engineers began to carefully monitor that machine.

In February 2013, a sudden 50 percent increase in peak value spectrum and waveform was observed, followed a few days later by another large increase. At this time, a slight increase in turbine horizontal vibration velocity was evident for the first time. The machine was taken out of service to check the thrust bearing, which was found to be severely damaged with large pitting in the inner race and small pitting in the ball bearings. After the thrust bearing was replaced and the machine put back into service, all the vibration readings returned to normal levels.

As experience with the portable analyzer increases, so do the ways it brings value. The maintenance inspection team began using the analyzer for in situ balancing of fans. The team used dynamic balancing, a two plan balancing method. With more than 12 uses of this application, the results have been fast and accurate. In situ balancing was performed for a variety of fans, including the granulator scrubber fan, the fluidization air fan and the dedusting fan in the granulation unit. These fans are all large in size and driven by 1350 kW, 1600 kW and 90 kW motors, respectively.

A persistent problem with a motor led the maintenance inspection team to add vibration monitoring to their routine. In each ammonia plant, there are three ammonia booster compressor drivers that pressurize ammonia. These compressors are powered by electric motors. To run the process, two out of the three motors are required to run at all times. One particular motor had a history of high bearing temperature and high vibration. The maintenance team monitored the motor closely with data on vibration and temperature captured every two weeks. This particular motor also required frequent rotor balancing. Each time, the problem would stop for a short period and then start again.

After the third incident of high vibration and temperature, the motor was removed and brought to the vendor's maintenance shop. The vendor found damage in the journal area. Using metallic spray and a lathe, the vendor repaired the issue. The part was returned to the motor and the balancing was done in the maintenance shop.

The motor was reinstalled, but the analyzer still indicated a high vibration. To determine the root cause, the maintenance team performed a number of tests. The results of an impact test on the motor's non-drive end and drive end vertical position showed no sign of resonance. The

OMIFCO relies on a portable vibration analyzer as a key tool in ensuring reliability

team checked the cross phase on the motor's foundation, foot and casing, but didn't find any looseness. The phase difference between horizontal to horizontal was found equal +/- 20 degrees with vertical to vertical, which is within the normal range.

With high demand for its products, ensuring smooth operation of critical equipment is a top priority for OMIFCO

In short, the tests indicated that the only issue was with non-balance. The vendor had already balanced the motor at its maintenance shop, so that option had already been attempted. Yet, risk was still high, as if the rotor was not repaired. Catastrophic damage could occur, resulting in a safety threat and loss of ammonia and urea production.

The management team was resigned to replacing the rotor at a $40,000 cost. But, the internal maintenance team had an inkling that they could balance the motor in situ, using the portable analyzer.

Balancing a motor in situ had never been attempted. The perception was that it would not be easy. As there had been no previous cases where such a large motor balancing had been attempted on-site, it was difficult to select the weight planes considering the limitation of space.

OMIFCO saved a total of $100,000.

Yet, even knowing the potential difficulties, the team was confident the approach could work. Eventually, management became convinced of the benefit of letting them try.

Once they had the motor cage open, the maintenance team used the fan as plane 1 and coupling as plane 2 and added trial weight calculated by the vibration analyzer. After the start-up of the machine, the analyzer calculated the correction weight that had been applied at both weight planes. Within four hours, team members were able to get the vibration to a normal level by removing 45 grams of trial weight and adding 1,159 grams in plane 1 and 612 grams of correction weight in plane 2. The balancing data was entered into the predictive maintenance software and the appropriate reports were generated. The entire balancing operation was wrapped up in less than a day. In comparison, removing the motor would have taken it out of commission for up to three days.

With the in situ balancing approach, OMIFCO eliminated the cost of replacing the rotor, manpower costs in removing the equipment and reinstalling, and paying the vendor for a second round of balancing. In total, OMIFCO saved $100,000. Confidence in the technicians increased and the skeptics among the management team congratulated the team on its success.

Using the portable vibration analyzer made balancing simple and saved OMIFCO time and resources. In addition, the maintenance team's increased experience using the portable analyzer has made in situ balancing a viable option for an increasing number of assets. For OMIFCO, practicing the art of balance is now a key part of the solution to ensuring production availability.

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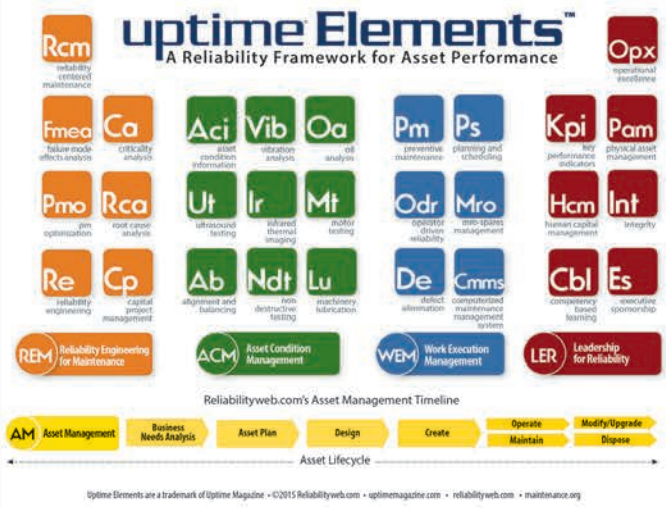

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Safety

by Dr. Jeffrey Dutschke and Jason Kong

One of the most frequently used methods for electronically storing maintenance data is a computerized maintenance management system (CMMS). CMMS systems hosted on the Internet (the Cloud) are becoming more and more common. But is your maintenance data safe when it is hosted on the Cloud and how does this compare to maintenance data stored on a local computer? In this article, some of the techniques used by cloud-based CMMS companies to ensure your data is secure are described and compared with the security of a local installation. While the security of local installations varies wildly, in most cases, the data on a cloud-based CMMS is more secure than on a locally hosted CMMS.

Where Is Your Data Stored and Is It Physically Safe?

Reputable cloud-based CMMS companies will store your data in an advanced and dedicated data center. The only business model of these data centers is to provide secure data storage and move this data safely to and from customers. These data centers are run by some of the biggest companies on the Internet, such as Google and Amazon. The expertise of these companies in storing their own data safely and securely led to the formation of new businesses that provide these services to other customers, including CMMS customers.

Data centers are typically nondescript buildings within major city centers. Inside, they have banks of computers. These computer banks are secured like a bank of money. All people, including data center staff, need to pass through multiple levels of security authentication to gain access to the computers and the supporting infrastructure.

Compare this physical security at the data center with a solution hosted on your own computer. A local installation is probably stored in an insecure room that is accessed by many people, including a cleaning crew. Alone. At night.

Data centers are incredibly secure in comparison.

> CMMS systems hosted on the Internet (the Cloud) are becoming more and more common.

Data Loss

Data loss can occur due to several reasons. Data can be physically stolen, deleted, or overwritten. None of these losses are realistic for a reputable, cloud-based CMMS run from a reputable data center.

First of all, the physical security measures in data centers essentially guarantee that theft of data storage devices from a good data center is impossible.

Second, data centers run multiple redundant backups of all data in several geographically distinct buildings. In effect, a backup hard drive containing the same information (but in a different building) would be ready to go almost instantly if data were to be lost for reasons including breakdown, theft, or environmental hazard.

in the CMMS Cloud

Addressing Concerns About Cloud-Based CMMS Solutions

In addition to the multiple redundant backups, a cloud CMMS solution will never permit the CMMS to be accidently uninstalled, nor will it need to be reinstalled when you upgrade your desktop computer.

With all these measures, you can be virtually assured that the data cannot be stolen, lost, or accidently overwritten with a reputable, cloud-based CMMS company.

Data Availability

Your data availability is the percentage of time your data is available, ready for access. This is a critical parameter because there is nothing worse than having a CMMS unavailable when it is needed.

For a cloud-based CMMS, part of the data availability calculation is the data center's availability. Most data centers guarantee a minimum uptime percentage of 99.95 percent. Most perform much better than this.

Another component of cloud-based CMMS availability is the application availability. This is the amount of time the CMMS is available, excluding the small amounts of time when planned system upgrades are performed overnight. Reputable CMMS companies will record these outages and be happy to tell you their performance over the previous year. For example, in 2013, a leading provider of cloud-based CMMS solutions had a 99.991 percent availability over the entire year. Does your locally hosted CMMS achieve availability this high? Do you even measure it? When you do measure it, make sure it is a fair comparison by including all of the unplanned unavailability of the local system.

Furthermore, because a cloud-based CMMS is viewed over the Internet, it can be accessed at anytime from anywhere with an Internet connection. If you really want to, you can check your CMMS on your mobile phone while at the beach!

Web Security Against Hackers

Security against hackers is a critical element of any cloud hosted program. Data centers have systems in place to record and stop all classes of hacker attacks, including attacks based on denial of service (DoS), man-in-the-middle, IP spoofing, port scanning and packet sniffing. Furthermore, exceptional CMMS companies will use irreversible hashing algorithms to protect sensitive data, like passwords, from being viewed in plain text by anyone. These measures combine to protect your data from thieves.

Data Sent Via the Web to the Data Center

Cloud-based CMMS providers also need to protect your data while it is being sent to and from the data center. Banks and other important Internet services, like e-mail, face a similar problem and they use a secure sockets layer (SSL) encryption technique to guard against it. Good CMMS companies use exactly the same technology with the same level of encryption. You will notice a padlock symbol in your browser when SSL is being used by your CMMS to stop hackers from observing the data being sent.

Access Control

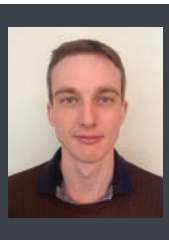
The last security vulnerability that exists in both cloud and locally hosted CMMS systems is access control. On some locally hosted CMMS versions, anyone can use the computer on which the CMMS is installed and make changes to the CMMS. This is not permitted in a cloud-based CMMS. Users have to log in before they have any access to the CMMS. Then, because they are logged in, their actions are recorded. As a consequence, in the future, you will be able to determine who did what and when.

Conclusion

Cloud-based CMMS systems are incredibly secure. The data is stored in physically secured locations, with highly secured access controls. There is always a live backup of your data at another data center ready to take over in the case of a system failure in the primary data center. Furthermore, there are frequent historical backups of all data for protection in the unlikely event of a catastrophe. Hackers are thwarted using the latest techniques and your data is encrypted while being transmitted to the data center using the same methods adopted by the world's largest financial institutions. In addition, because your users have to log in to their system, you will have a record of every change made in the system and by whom.

If you are still worried about using a cloud-based CMMS, you need to compare these security measures with a locally hosted system. Is your computer physically secured from other people? Do you have a live backup and regular historical backups? Do you have protection from hackers? And what about availability, can you guarantee a 99.95 percent uptime and access from anyplace with an Internet connection?

When you do a fair comparison, it is likely your own security measures will need improvements to match those provided by a reputable, cloud-based CMMS provider.



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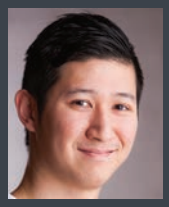


Jason Kong *is a Software Engineer and API Specialist at Maintenance Assistant Inc. Mr. Kong has experience architecting and integrating APIs in a wealth of industries, including healthcare, social media, industrial & manufacturing and pharma regulatory. www.maintenanceassistant.com*

Part 2

Reliability through Optimized Setup and Changeovers

by Dan Miller

This is Part II of the article featured in the April/May15 issue of *Uptime* magazine addressing these topics:

- The motivation behind Shigeo Shingo developing single-minute exchange of die (SMED) concepts at Toyota.
- How the changeover process can affect reliability of an asset.
- Adding setup and changeover elements to failure mode and effects analysis (FMEA).

Changeover greatly affects asset reliability and its impact is often neglected when improving changeover times. Today's changeovers in manufacturing have followed the same formula as Shingo and Toyota, and many industries have benefited with an increase in uptime and production line capacity and a reduction in finished goods inventory. Equipment manufacturers have successfully added versatility to their product lines; many machines are able to produce dozens of sizes and shapes of products for their customers' needs. Operational-driven initiatives by Six Sigma, 5S and visual factory methodologies have refined the changeover process on the production floor to help keep conversion times to a minimum. Additionally, original equipment manufacturers (OEM) and aftermarket businesses have eliminated many of the assembly fasteners and replaced them with revolutionary clamps, slides and twist locks.

Reliability Centered Maintenance Principles Relating to Changeover

The principles of reliability centered maintenance (RCM) cannot be ignored when changing over an asset for the next product. When evaluating an organization's changeover program, these RCM principles need to be upheld:

Preserve System Function – The function of the system does not change with changeover. For example, a tablet press must still produce tablets meeting the same criteria regardless of raw material or size.

Identify Failure Modes That Can Defeat the Function – Both parts and methods need to be evaluated for their impact on system function. Part wear and improper task execution can lead to failure.

Prioritize Function Needs – The importance of each function needs to be assessed and the interaction each has on another must be considered to assure system function is unaffected. Take, for example, a changeover from a smaller bottle size to a larger bottle size. If the stated function of speed (bottles per minute) is maintained, it is quite possible a quality function (e.g., net contents, foaming, etc.) will suffer.

Select Applicable and Effective Tasks – Any manipulation of the equipment to convert it to run the next product inserts a potential risk to functionality. Eliminating unnecessary steps also eliminates an additional risk to performance.

DEFINITIONS

Reliability: The probability that an item will perform its intended function for a specific interval, under stated conditions (Mil-Std 721C).

Failure Mode and Effects Analysis (FMEA): A technique used to examine an asset, process, or design in order to determine potential ways it can fail and the potential effects of that failure, and subsequently identify appropriate mitigation tasks for the highest priority risks.

Changeover: The total process of converting a machine, line, or process from running one product to running another.

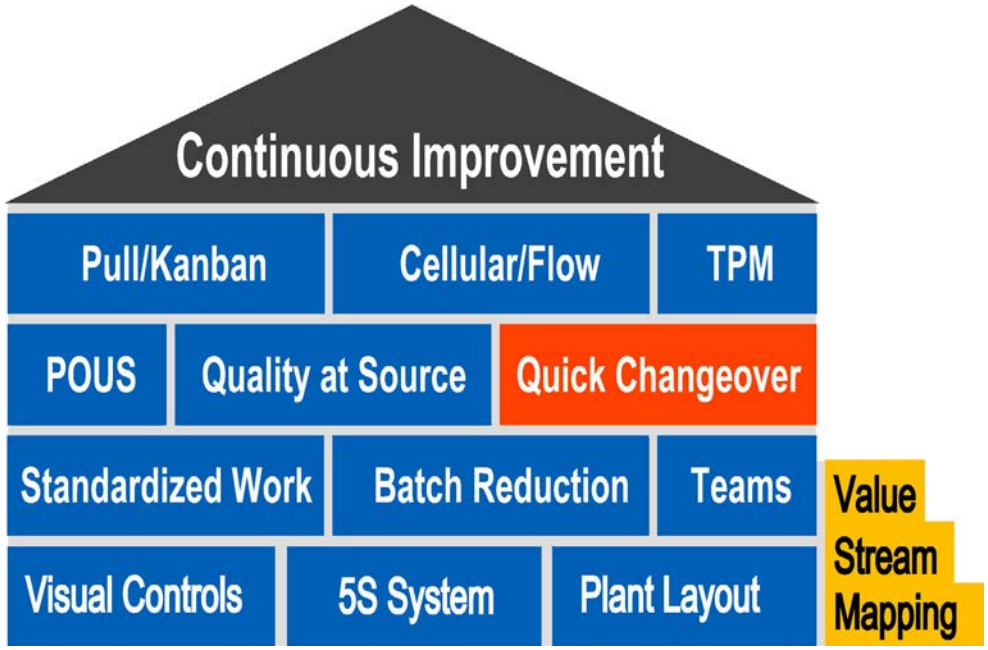


Figure 1: Continuous improvement

The Changeover Process

Technically and specifically, an asset's changeover encompasses all steps necessary to run the next product, from the last product unit from the previous batch to the first production product unit for the next batch.

There are four categories of changeover steps:

1. **Preparatory Steps:** Steps occurring prior to the completion of the batch preceding the changeover.
2. **Cleanup:** Removal of all materials from the previous lot, as well as all cleaning and housekeeping tasks.
3. **Setup:** The physical conversion of the machinery to run the next product.
4. **Start-Up:** The period of time after cleanup, setup and all other changeover tasks have been performed and the line begins producing, but before it has settled down into normal operation.

The proper sequence of steps in the process also must be taken into consideration. Optimizing changeover steps may require that steps in one category precede steps from the next category. For instance, the changeover parts for a filler may need to be removed and partially disassembled before it can be cleaned. Disassembly is a setup step/task that would be performed prior to a set of cleanup steps in this case.

Changeover Steps

Preparatory Steps: Includes any staging, inspection, inventory, stocking, or planning/coordinating.

Cleanup: These steps include:

- **Closeout** – All paperwork for the previous batch is completed. The product is weighed and accounted for and removed from the room/production line. Any waste or scrap is also segregated, accounted for and separately removed from the area.
- **Actual Physical Cleaning Steps** – These include any physical cleaning, whether light surface cleaning or more detailed master cleaning.
- **Washroom Steps** – These are any cleaning steps that are extensive, usually away from the production line and in a specifically designated/designed cleaning room.
- **Filter Replacement** – Because filters generally contain residue from the previous batch, replacing filters should be considered as part of the cleanup steps. However, in some instances, it may be more appropriate to change filters during the setup or start-up steps.

Setup: Setup steps contain:

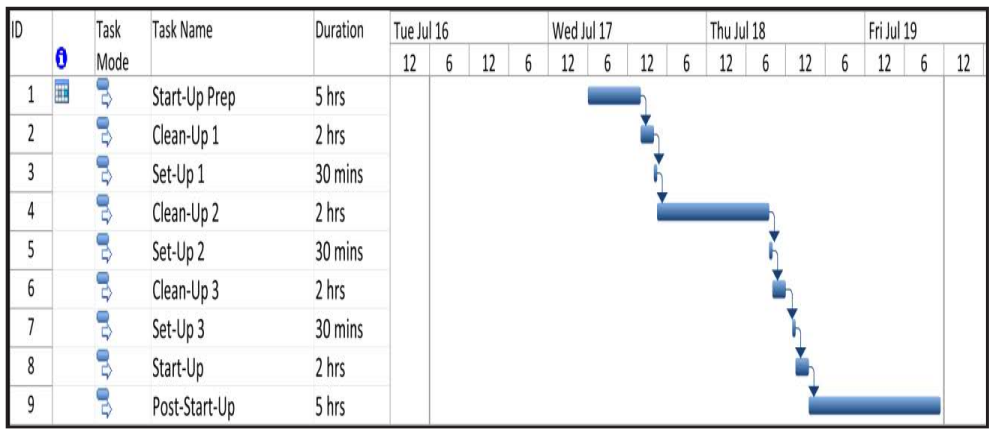
- **Disassembly** – Before proper equipment cleaning can occur, the change parts most likely will be removed from the machine, cleaned and put in their proper, predesignated place.
- **Preventive/Predictive Maintenance** – Any PM/PdM work orders that are due and can be performed during changeover should be planned and scheduled appropriately.
- **Change Part Replacement** – All changeover parts are stored appropriately on carts, hooks, or other pre-assigned locations. Next product parts, which may be the same parts as the previous batch, totally different parts, or a combination of the two, are installed on the applicable equipment.
- **Wear Part Replacement** – Wear strips, belts, hoses, etc., are replaced.
- **Setting Start-Up Parameters** – This is done on the equipment's control panel and the spin test is performed in two phases.
- **Manual Steps** – They involve rotating the asset by hand looking for interference and fit-up issues. Steps done via the control panel involves slowly increasing the speed with manual speed control.

Start-Up: These are steps that affect runability or steps to ensure the machine can input raw materials and output product. Speed and quality are not factors in these sub-steps, which include:

- **Pre-Production** – Produced product passes all associated quality criteria, but the machine is not yet at normal operating speed.
- **Production** – The press is running at normal operating speed meeting all quality criteria.

SMED Applicability

Once a specific changeover has been stabilized, meaning it can be performed over time repeatedly and consistently, a SMED process can be used to optimize the changeover.



ID	Task Name	Duration
1	Start-Up Prep	5 hrs
2	Clean-Up 1	2 hrs
3	Set-Up 1	30 mins
4	Clean-Up 2	2 hrs
5	Set-Up 2	30 mins
6	Clean-Up 3	2 hrs
7	Set-Up 3	30 mins
8	Start-Up	2 hrs
9	Post-Start-Up	5 hrs

Figure 2: Sequence of changeover steps

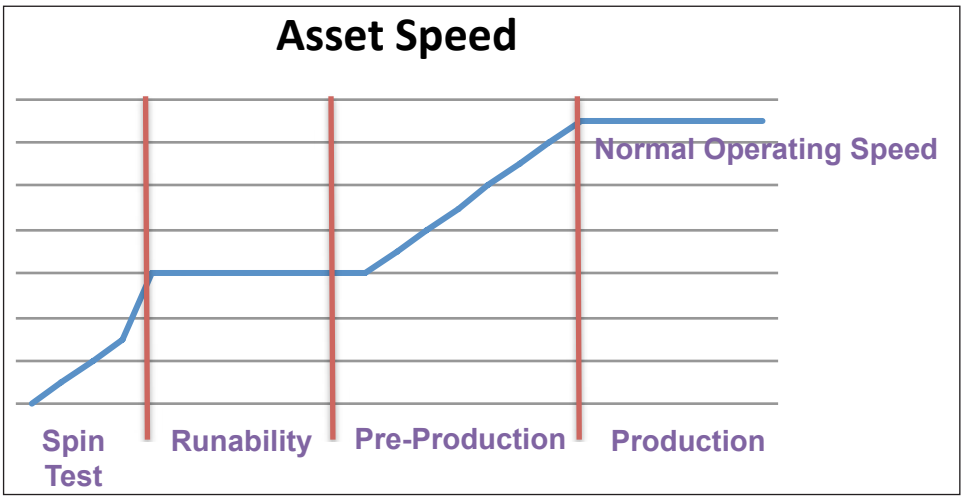


Figure 3: Asset speed

Reduce Intrusion/Trauma: Begin with the end in mind. Evaluate whether a part needs to be removed at all. If removal is necessary, consider how it can be removed and reinstalled with as little impact as possible.

Reduce Variability: Serialize all parts so they can be tracked to each asset, by product and associated to any specific setup criteria, such as tooling used in a tablet press or an embosser/coder for differently configured bottle sizes for a liquid filler, for each changeover. Look for opportunities to inject consistency into the process. If a method can be developed where a part can be only slid in one way every time, regardless of the installer or conditions, then variability and compensation for it also will be reduced.

Optimize Time of Changeover: It is important to be as efficient as possible, but if a faster speed is achievable with no injuries or associated adjustments only 10 percent to 15 percent of the time, target a speed that is achievable 80 percent to 90 percent of the time, even if the new time is longer than the original time. An effort to reduce the changeover time always should be coupled with a performance measure, such as measuring the asset's performance in the first hour after start-up. The new time should be established not as a goal to beat, but as an indication that the step was performed flawlessly.

Eliminate/Reduce Impact of the Environment: Minimize or eliminate the use of water. It is hard to manage and the equipment always requires extra effort and time to dry. Also minimize or eliminate the use of air. Air just redistributes contaminants and only marginally cleans surfaces. Consider a vacuum, where possible, as a last resort. Factor in temperature differences between the machine and the change parts, especially where tight tolerances are critical. If possible, match temperatures prior to and during installation by allowing the parts to acclimate.

Calculate Separate Run Times/MTBF/FMEA for Each Product: Establish tracking processes that enable a differentiation of performance data based on product recipe, product size and machine at a minimum. Create reports that help predict functional failures. Establish criteria that clearly identify performance trends.

Minimize/Eliminate Non-Run Related Wear: Devise installation and removal techniques that minimize contact or abrasive conditions related to the parts or the machine. Ensure all parts have a specific location, such as a change cart or shadow board, that protects all critical dimensions. Train and educate associates in proper handling methods.

Eliminate Unnecessary Steps: Wasted steps add time and complexity to an already difficult event. Challenge previous ways of completing tasks. Combine steps and devise tools, jigs, bridges, alignment marks/indicators and go/no-go gauges to eliminate rechecks and inspections.

Externalize Non-Run Required Steps: Concentrate on pre-changeover steps, moving anything possible to a time prior to the end of the current production run. Move steps that can be accomplished after the next batch is running to a time outside the changeover period. Build in non-adjustable dimension settings and install alignment pins, clamps and lips/collars that allow precise placement of parts and reduce the variety of fasteners.

Rewrite the Standard Operating Procedure (SOP): Separate the steps into the changeover categories of preparatory, cleanup, setup and start-up. Sequence the steps to provide optimal use of resources and time. Allow for continuous improvement of the SOP and any other changeover documents.

Establish a Comprehensive Training Program: Provide background information that addresses reliability fundamentals, SMED methodology and the changeover process. Ensure participants not only understand mechanical principles, but also have the aptitude to perform complex assembly and disassembly tasks. Integrate on-the-job (OJT) techniques into the training program to solidify repeatable behaviors leading to consistent outcomes.

Institute or Expand 5S. Use sort, straighten, shine, standardize and sustain (5S) methods to include changeover parts, tools and equipment.

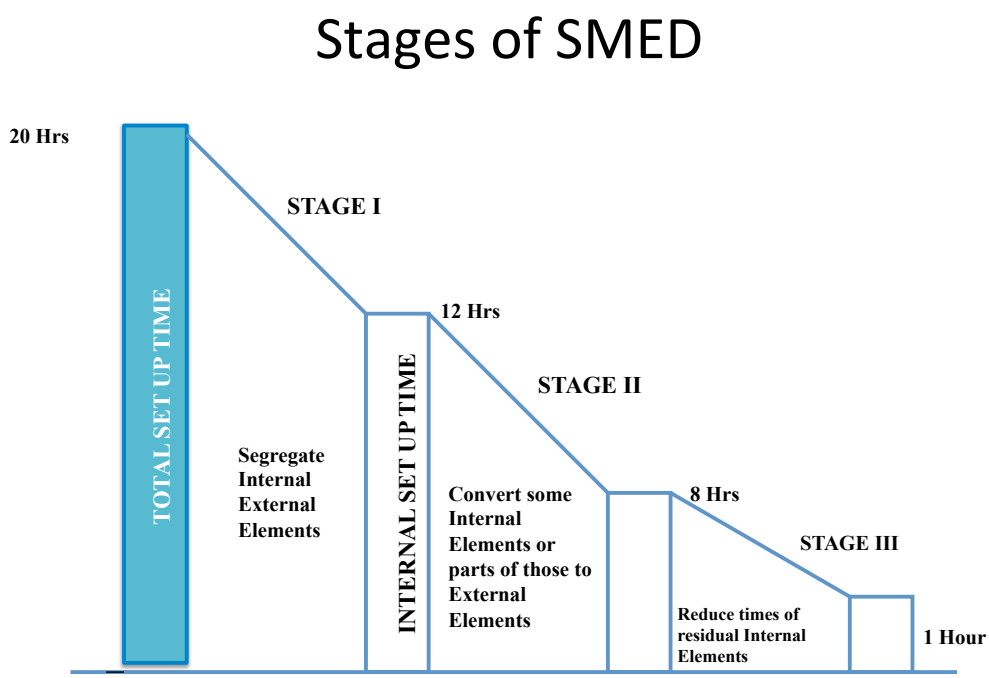


Figure 4: Stages of single-minute exchange of die (SMED)

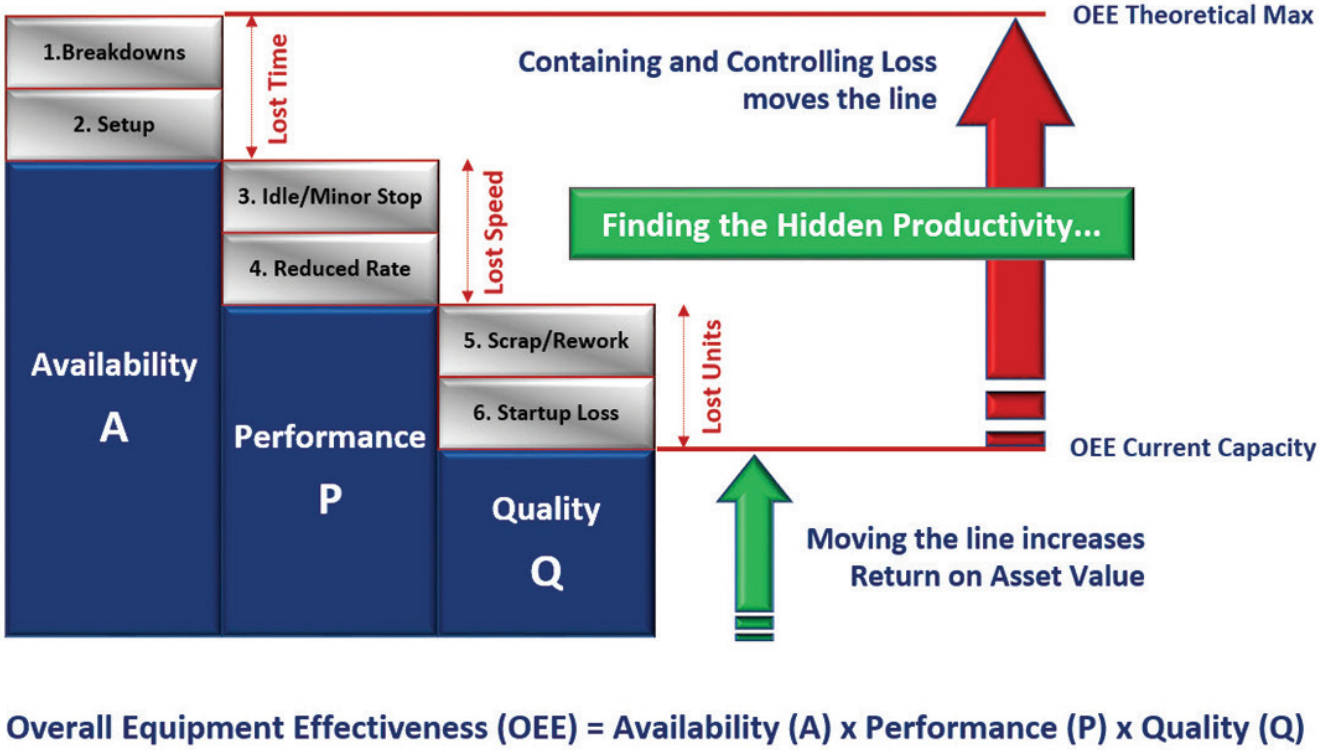


Figure 5: Overall equipment effectiveness reliability

All parts, tools, supplies, documentation and support devices must have their own location when stored, cleaned, inventoried and, if applicable, quarantined. All methods, practices, movements, etc., must be sustainable.

Conclusion

Reliability begins with a well setup machine. Mastering changeovers requires consistent execution of all its elements and leads to better performing equipment, less scrap, higher yields, less downtime, more availability and higher capacity.

Well-running equipment is reliable and leads to better planning and production scheduling, reduced inventories, just in time (JIT) material deliveries and the elimination of manufacturing-based out-of-stocks.

Consistent practices lead to predictable outcomes and process reliability.

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Developing Asset Management Plans

Creating Value From Physical Assets

by Mark Ruby

Asset management plans form the cornerstone of an effective asset management system. The recently released ISO55000 series of standards for asset management clearly defines the importance of asset management plans (AMPs) by indicating that they provide the road map for achieving value from physical assets by optimizing cost, risk and performance across the asset's lifecycle. AMPs define the implementation activities necessary to realize an organization's asset management objectives, which translate the strategic intent of the company. The relationship and interdependencies of asset management policy, strategy, objectives and planning to achieve those objectives clearly demonstrate how important organizational alignment is to the creation of asset management plans.

Getting Started

Compliance versus Performance

Even though ISO55000 has established many of the criteria for creating AMPs, it is not necessary to approach this from a standard compliance perspective. Many organizations are deciding to improve how they manage assets in order to achieve performance gains while postponing the compliance decision. Most companies already maintain other ISO certifications and fully recognize the level of commitment necessary to seek certification. Short of a compelling business case for investing in the compliance journey, they are content to reap the performance gains without necessarily addressing all the management system aspects. This decision may impact the overall approach to creating AMPs and should be considered early on.

> The ***simplest way*** to begin is to ***gather*** all existing data and analyses and ***start*** constructing the ***plan***.

Asset Definition and Selection

Defining assets that can then be filtered through a selection process may not be as straightforward as it seems. From an expanded view of asset management, there are different levels at which an asset can be managed. At a foundational level, assets are viewed individually. This is the simplest and most easily understood approach. Assets also can be defined and viewed in terms of systems. Examples of asset systems include networks, production lines, or facilities systems (e.g., HVAC, wastewater, compressed air, etc.). And finally, a third expanded view can define asset portfolios. Examples include classes of oil rigs, business units, real estate and municipal infrastructure.

Based on how you define assets, they can then be selected for plan development. A defined selection process is the most critical of all concepts in asset management. Assets should be selected based upon their criticality and defined risk to the value stream. A risk-based asset management approach should be utilized that includes a defined process for classifying, analyzing, controlling and measuring the effectiveness of the operating and equipment maintenance strategies.

From a pure process perspective, asset definition and selection are most likely an outcome of the strategic asset management plan (SAMP) and the establishment of asset management objectives. The point is to maintain the linkage for achieving organizational objectives within the asset management plans.

Understanding AMP Maturity Levels

Another important getting started activity involves determining the approach to data collection and analysis. As shown in Figure 1, the commitment to establishing an asset management system capable of providing the necessary information to construct advanced AMPs is often characterized as a true continuous improvement journey.

The simplest way to begin is to gather all existing data and analyses and start constructing the plan. Where data is required but does not exist, use organizational experience and judgment. Fill knowledge gaps with documented assumptions. This approach enables AMPs to be constructed quickly. Implementation momentum builds sooner as the organization develops the necessary awareness and desire required to sustain the new way of doing business. One disadvantage to this simple approach is that plans result in a lower level of reliability, with the potential for suboptimal decision-making.

An alternate approach requires the organization to perform a gap analysis against its existing capabilities and develop a tactical implementation plan for closing the gaps prior to beginning the preparation of the asset management plans. This approach requires additional time and resources, but the data and analysis are more complete and the quality of the decision-making is improved.

There can be benefits in developing the first AMP as an interim plan as quickly as possible using existing information. It helps the organization understand the strengths and weaknesses of current asset management practices and identify priorities for developing future plans. It can also avoid allocating excessive resources for data collection before the needs are fully understood.

Regardless of how an organization decides to proceed, it is certain that the maturity level of the AMP will evolve and improve over time. The AMP development process will identify capability gaps and opportunities for improvement that must be systematically addressed via a continuous improvement loop. As the sophistication of the asset management system progresses, so will the maturity level of the asset management plans.

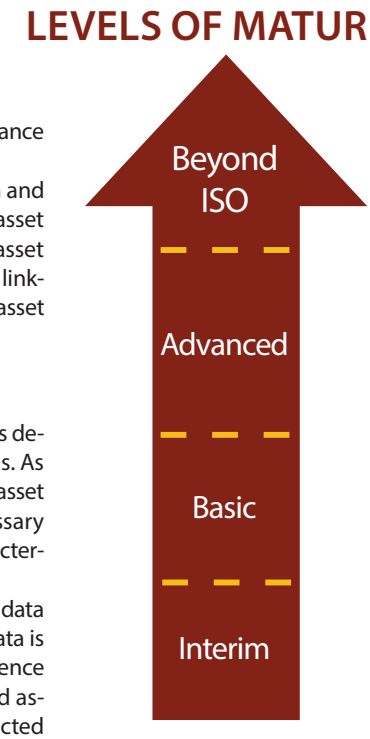

Figure 1: Asset management plan development – a journey not a destination

Constructing the Plan

An asset management plan defines the activities that will be implemented and the resources that will be applied to meet the asset management objectives and, consequently, the organizational objectives.[1] An asset management plan provides the direction to and the expectations for an individual asset, or for a portfolio, group, or class of assets.[2]

Asset management plans should be developed to appropriate time horizons for the organization.[3] The time horizons should meet the organization's needs and take into account the organization's period of responsibility and the life of its assets.[4]

With this in mind, an AMP template will help you define the specific activities, resources and scheduling required for an individual asset or a grouping of assets to achieve the organization's asset management objectives. The maturity level of the AMP and the sophistication of the asset management system may impact which sections of the plan are prioritized over others. Here are the recommended sections your AMP template should include:

Asset Management Plan Overview

The overview section identifies the assets within the plan, how the performance of the assets connects to organizational objectives, the stakeholders and connectivity to other plans or standards. A brief summary of covered assets is also recommended.

Levels of Service

A key aspect of asset management planning is to match the level of service assets provide to customer expectations. It provides the balance between the cost to deliver and the level required. Specific levels of service include cost, efficiency, quality, quantity, reliability, safety and responsiveness.

The level of service section may include a description of how organizational goals and regulatory requirements impact service levels. Current levels of service and targeted

levels of service are necessary to identify gaps that must be addressed in other sections of the asset management plan.

Future Demand

Future demand provides details of forecasted growth and asset utilization. This section also describes demand drivers and how demand changes may impact assets, demand contingency planning and investment planning necessary to meet the demand forecast.

Asset Lifecycle Management

This section should summarize how assets will be managed and operated at the agreed upon service level while optimizing total cost of ownership at an appropriate level of risk. This section is the most important part of the AMP and includes these subsections:

> Where **assumptions** must be made, be sure to **document those assumptions.**

1. **Background Information** – Provides basic asset information, including age, size, capacity, performance, current condition, current value and asset information management summaries.
2. **Risk Management Plan** – Identifies risks that may affect service delivery. Includes what corporate goal or objective is impacted by the risk, how the risks are identified, how the risks are evaluated (e.g., consequences, probability, detectability) and what risk mitigation plans are in place.
3. **Operating Plan** – Includes trends, the decision-making process, defined *operating* strategies and methods to meet required service levels, how *operating tasks* are prioritized, risks associated with alternative strategies and forecasts of planned *operating* costs.
4. **Equipment Maintenance Plans** – Includes trends, the decision-making process, defined *maintenance* strategies and methods to meet required service levels, how *maintenance tasks* are prioritized, risks associated with alternative strategies and forecasts of planned *maintenance* costs.
5. **Recapitalization Plans and Strategies** – Outlines renewal expenditures, which include major work that does not increase the asset's design capacity, but restores, replaces, or renews an existing asset to its original capacity.
6. **Capital Planning and Strategies** – Describes a new investment, which creates a new asset that did not exist previously, or upgrades or improves an existing asset beyond its existing capacity.
7. **Disposal Plan** – Identifies activities associated with the disposal of a decommissioned asset, including its sale, demolition, or relocation. Contains a future forecast of disposal assets, including timing and costs, and a cash flow forecast of income/expenditures from asset disposal.

Financial Summary

This section should include and summarize all financial requirements resulting from the activities in the previous sections. The financial summary represents an important link to other parts of the organization and establishes the value of asset management to the organization by integrating the financial impact of the activities into the company's financial and strategic plans. The summary should include cash flow forecasts for one to five years and provide the necessary details on how expenditures are to be treated (e.g., capital versus expense) in order to determine optimal funding strategies and timing.

Continuous Improvement

This section should summarize the current and future asset management practices and provide details on the planning and monitoring of the asset management plans and any improvements to asset management systems. It should provide a demonstrated link back to the deficiencies noted in constructing the other sections of the asset management plan.

Writing, Reviewing and Maintaining the Plan

Once the assets are selected and the approach defined, it is time to begin writing the asset management plan. Two key points are to always keep the objectives in mind and to rely on the most current and complete data available. Where assumptions must be made, be sure to document those assumptions. In many cases, some sections of the template may provide summary data with references to the exact locations where the data or the analysis is maintained. For efficiency purposes, it is very likely that the AMP will include many such references to specific locations within the asset management system.

Each section of the AMP may be written by different subject matter experts, but should be coordinated by a single point of accountability. The entire team should review the AMP for consistency and accuracy. It also may be helpful to have an independent party review the plan for additional insight and understanding. Finally, the plan should be viewed as a living document that is to be updated and maintained in accordance with the established parameters.

A Note on Compliance

If companies choose to pursue a path of certification to the ISO55000 asset management standard, several key principles must be addressed when writing asset management plans. The key requirements are identified in ISO55001, Section 6.2.2, and are summarized as follows:

Integration – The AMPs must be fully integrated with other relevant planning activities within the organization. For example, cross-disciplinary planning should support AMP resource estimates, outsourcing assumptions, HR training and capital investment planning.

Alignment – AMPs must demonstrate alignment to the strategic asset management plan. Activities contained in the AMP should be traceable to top-down requirements identified in the asset management objectives, policy and organizational plan.

Decision-Making Criteria – Planning processes must include decision-making and prioritization criteria. Evidence should exist on how activities and plans are selected and prioritized.

Whole Lifecycle Approach – Organizations are expected to adopt an asset lifecycle management philosophy with both financial and non-financial dimensions.

Criticality – AMPs must reflect usage of logical business support tools for determining which activities are necessary and the frequency of those activities. The techniques used must be aligned with the criticality of the assets and prescribed actions.

In total, Section 6.2.2 describes 11 requirements that an organization needs to determine and document when planning to achieve its asset management objectives.

In summary, AMPs must clearly contain what is to be done, what resources are required, who is responsible, when it will be completed and how results will be evaluated.

References

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3. Ibid.
4. Ibid.

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Rid Yourself of Routine Oil Changes

by Richard Bierman

It is well-known that the most important properties concerning a lubricant's role are its viscosity and purity. Several turns can be made to ensure that clean, dry oil of the correct viscosity is put into machinery. However, the moment the lubricant is placed into the machine, it becomes contaminated, especially in cases of an equipment rebuild. Managing the oil's condition once it is put into service can be, and should be, a very comprehensive task. Preventive maintenance (PM) schedules, condition monitoring, filter and desiccant breather changing, level checking, leak detection, etc., can utilize a tremendous amount of man-hours. Switching a facility's program to a periodic, partial drain and fill method can make managing the service life of a lubricant much easier and more effective than traditional PM programs.

Creating a lubrication drain and fill method can eliminate your PM backlog in one day. The first step is to add bottom sediment and water (BS&W) bowls to a convenient low point on each machine's sump. This is needed during operator rounds. Any sediment or particles in the fluid will gather in the BS&W bowl where, upon inspection, the operator can determine the appropriate action. Next, create a route in which the sumps are partially drained and refilled with new oil. The objective is to perform this task frequently enough to replenish the volume of the sump in a time period that is consistent with the recommended PM interval. For example, if the oil is to be changed once per year, you could drain 25 percent of the reservoir every quarter. This is an improvement to routine PMs in that the fluid never reaches the end of its service life since the product is constantly replaced or "sweetened" with new stock. Even better, the machine never has to be set up or taken out of service for an oil change. The small, spring-loaded drains located at the bottom of the BS&W bowls simplify this process and ensure the oil is not drained too rapidly, which is important to maintaining a fluid film in machine components.

Managing the oil's condition once it is put into service can be, and should be, a very comprehensive task.

Figure 1: Bottom sediment and water (BS&W) bowl

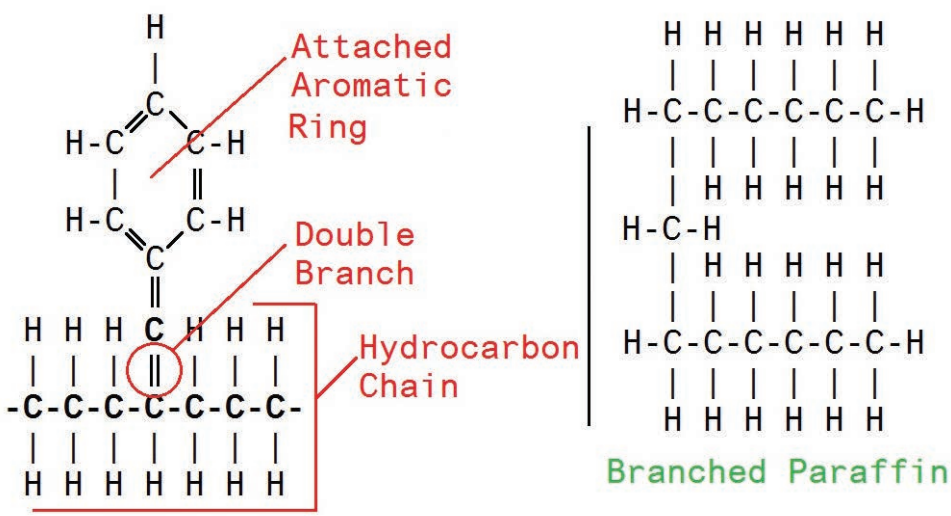
The science behind base oil manufacturing is why this works. Most industrial lubricants used today have near synthetic properties. Crude oil molecules contain 25 to 40 carbon atoms and a complement of hydrogen atoms in various structures and shapes. The double bonds between carbon atoms create aromatic and naphthenic hydrocarbon ring structures. These types of rings allow contaminants, including water, to saturate the oil and mix with the lubricant, causing it to lose its viscosity index, oxidation stability, or otherwise alter its properties, making it ineffective. A simple analogy would be to envision a bubble wand. When the ring end is inserted into the soap, the fluid is retained in the ring. If the handle were to be inserted into the soap, the soap would simply run off it and back into the bottle. The hydrocracking process of crude stock removes contaminants by cracking the double bonds and detaching the aromatics and multi-ring naphthenes, leaving branch chained paraffins. Since the contaminants can no longer bond to the fluid molecules, they simply settle to the bottom of the reservoir. Hence, any contamination or saturated oil molecules (bad oil) will fall into the BS&W bowl, be drained off and replaced with fresh, new oil.

This method can be proven with oil sample analysis. Once this method is in place, samples drawn from the sump of the machine will come back suitable for continued use, even in cases where the BS&W bowl must be frequently drained of water. The results from the sumps also will be better when compared to systems with a traditional PM program.

The benefits of the partial drain and refill PM method are numerous. Not only is it no longer necessary to shut machinery down to change the oil, but it gets inspected more often, allowing you to find issues faster. The BS&W bowl provides an excellent visual of what's inside the machinery. The oil in the sump never reaches the end of its service life and will maintain its viscosity even when shearing occurs. In most cases, since the water is drained off and never emulsifies, it eliminates the need for desiccant breathers. A backlog of PMs will no longer be a concern. Scheduling can be routine without interruption of process. Often, a single person, depending on the size of the facility, can maintain the program, increasing consistency and accountability. Likewise, it can be managed by the existing team of operators, creating ownership. This method will also clean the internals of the machine over time, especially where synthetics are used.

> Not only is it no longer necessary to shut machinery down to change the oil, but it gets inspected more often, allowing you to find issues faster.

All things being considered, there are always exceptions. A routine oil change in certain situations still has its place. For extreme situations, like combustion engines, high temperature applications, or pressurized systems, routine oil changes should still be performed, but may be extended when supplemented with a drain and fill at determined intervals. Oil sampling should be used to determine what is best for the machinery. Manufacturers' recommendations based on practices performed 30 years ago are not always the best guidelines to consider. Technologies, such as that used in oil refining and oil analysis, have enabled improved reliability, as well as improved reliability practices.



Water and other contaminants will bond with naphthenic and aromatic molecules (left), becoming dissolved in the oil. Hydrocracking breaks the double bonds, converting them to paraffins and releasing the contaminates. Branched chains contain no rings for the contaminants to become entrained or dissolved in.

Figure 2: Hydrocarbon bonds

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Safety and Reliability Concepts

A Review of the Pyramid and Swiss Cheese Models

by Ron Moore

The safety pyramid was first proposed by H.W. Heinrich, whose 1931 book, "Industrial Accident Prevention: A Scientific Approach," stated that 88 percent of accidents are caused by "unsafe acts of persons" and put forth what is often referred to as Heinrich's accident pyramid. It illustrates that of 330 accidents in the workplace, 300 will result in no injuries, 29 will result in minor injuries and one will result in a major injury. This is shown graphically in Figure 1.

Heinrich is given much credit for bringing safety to the forefront and beginning the process of linking minor accidents to an increased risk of major accidents and injuries. He is also credited with suggesting that people's unsafe acts cause the vast majority of accidents. But, he was soundly criticized at the time for lack of documentation to back up his theory.

Frank Bird did additional work in the 1960s that was much better documented and received. He concluded that for every 600 near misses or minor incidents, you will have some 30 incidents or accidents resulting in 10 more serious injuries and, ultimate-

Heinrich's Accident Pyramid

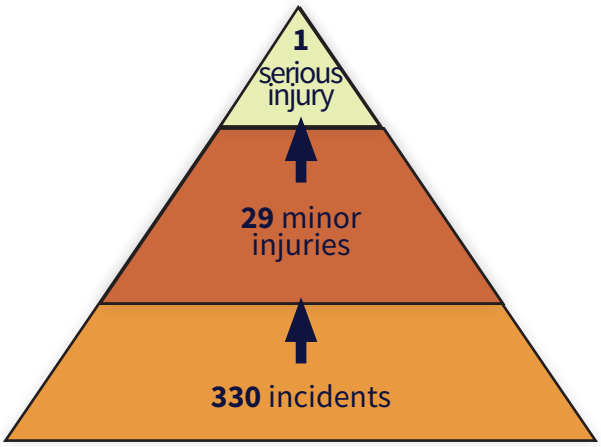

Figure 1: Heinrich's accident pyramid

Defects (Failure Modes) Affect Reliability

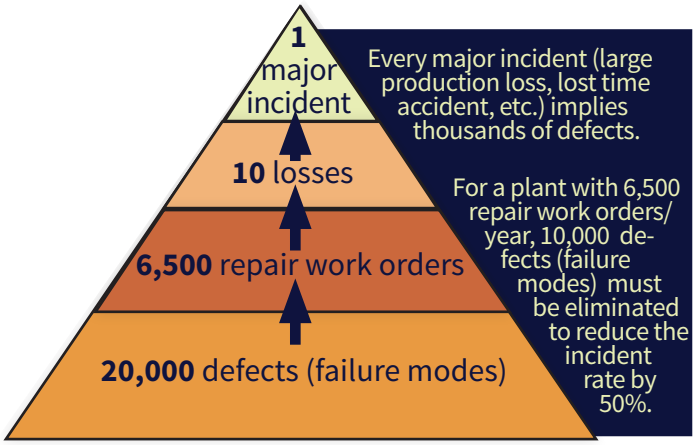

Figure 2: Ledet's reliability pyramid

ly, one major accident or death. Interestingly, these numbers are similar to Heinrich's, despite the criticism he received at the time. Although modern safety experts disagree with some of Heinrich's, and even Bird's, conclusions, both substantially advanced the idea that changing people's behavior can prevent accidents.

More recently, Winston P. Ledet has linked the concept of plant reliability, or unreliability as the case may be, to operating and maintenance practices, more specifically to thousands of minor defects leading to additional repairs, thereby increasing the risk of loss (e.g., production, additional costs, etc.), and ultimately to major incidents, that is, lost time accidents, deaths and/or major production losses. This is shown pictorially in Figure 2.

This author's own data and research from manufacturing plants support Ledet's contention that the more defects you have, the higher the risk of injury, production losses, additional costs and environmental incidents.

Consistently found in numerous operations are:

1. Overall equipment effectiveness (OEE) negatively correlated with injury rate, that is, the better a given operation runs, the lower the risk of injury.
2. A reliable plant is a cost effective plant, that is, the better your operating and maintenance practices, the fewer the defects, thus the lower your costs will be.
3. The greater your reactive maintenance, the higher the risk of injury. Conversely, the more planned and scheduled maintenance, the lower the risk of injury. Incidentally, OEE is also negatively correlated with reactive maintenance. The lower the reactive, the higher the OEE.
4. Plants with higher OEE because of better operating and maintenance practices have fewer environmental releases.

These conclusions, along with the supporting data, are provided in the article, "Is Your Plant Reliable? It's Good for Personal and Process Safety," published in the February/March 2015 issue of *Uptime* magazine.

While all this may sound intuitively obvious, it's comforting to know that the data from operating plants substantiate that a reliable plant is a safe plant, is a cost effective plant, and is an environmentally sound plant. Executives would be well served to take this into account in their decision-making, particularly when it comes to cutting maintenance costs and setting a high standard for operations and maintenance practices. Costs and injuries are a consequence of your practices.

Even more recently, Andrew Hopkins differentiates between personal safety and process safety. He contends that the two, while related and overlapping, are driven by different processes and thus require different approaches in minimizing risk. For example, he points out that so-called "slips, trips and falls" or injuries to individuals relate to personal behavior, which can be addressed through training, standards, personal protective equipment (PPE), etc. These incidents can be thought of as relatively high probability, low consequence. However, Hopkins also highlights that process errors increase the risk of major incidents – catastrophic failures – and result from poor operational discipline. Multilayered approaches and so-called safety nets minimize this risk, but the poorer the operational discipline, the greater the risk of a catastrophe. These can be thought of as relatively low probability, high consequence incidents. This is shown pictorially in Figures 3 and 4.

As shown in Figure 4, these issues influence each other, that is, defects and process errors can have a major impact on reliability, process safety and major incidents or accidents. Thus, the key to minimizing these is operational discipline throughout the organization in ALL practices.

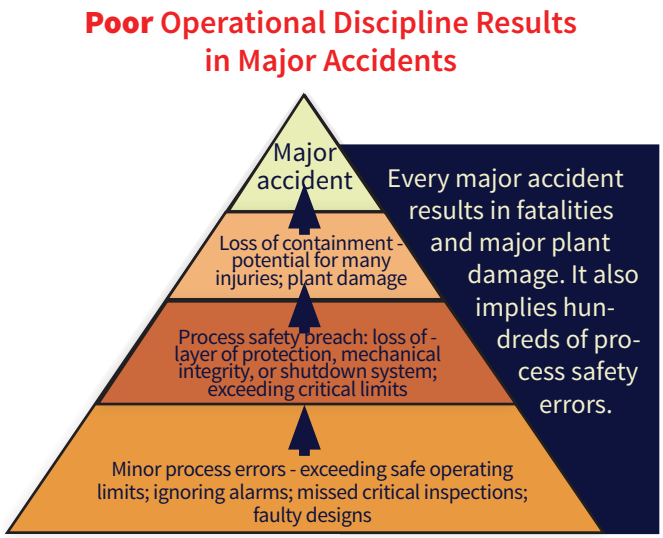

Figure 3: Poor operational discipline results in major accidents

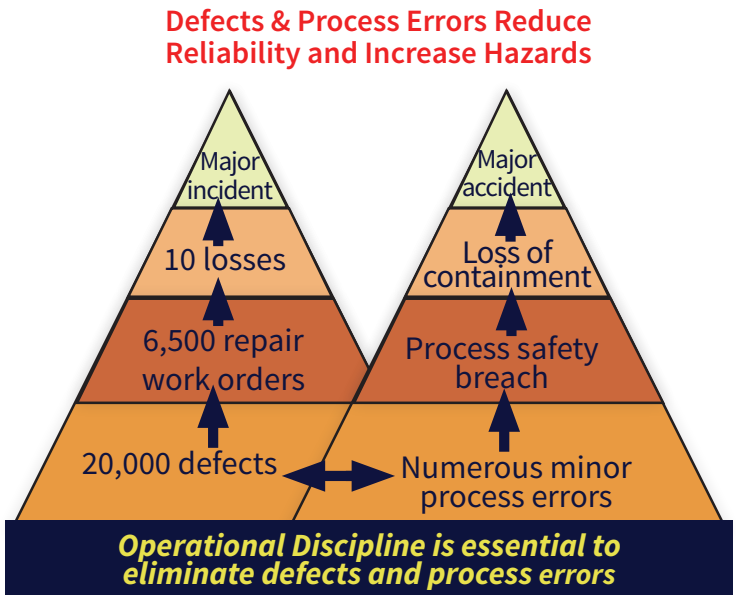

Figure 4: Defects and process errors increase hazards

As you can see, all these graphical models are pyramids, wherein the bottom layer increases the risk of the next greater impact above it until reaching the apex, which represents the worst case of the series of events. The theory, then, is if we can reduce the minor events in the bottom layer, we reduce the risk of major incidents; it's a reasonable assumption. These models serve a good purpose and allow you to visualize the sequence and consequences, and take appropriate action to minimize the risk of major incidents. But, is there a better characterization?

James Reason first proposed the so-called Swiss cheese model around 1990, wherein risks are layered by practices and those practices have holes (e.g., omissions or poor practices), but only when the holes "line up" do the really bad things happen. Reason's model was modified by Gordon Dupont of System Safety Services in Canada, as shown in Figure 5 (see page 54). The holes in the disks of "cheese" represent fallible decisions by senior management that lead to line management deficiencies. Combine them with preconditions, unsafe acts and inadequate safety nets and the result can be a major accident. However, it's likely the holes are moving or changing on a regular basis and since all the holes must line up, it's a statistical probability of uncertain magnitude, but one that increases with the number and size of the holes in each layer. Thus, one of management's critical jobs is to minimize the size and number of holes in the organization's systems by demanding and supporting excellence in **all** practices.

This article proposes an alternative model using the reliability process shown in Figures 6 and 7 (see page 54 and 55, respectfully). It is a blend of Ledet's model – defects create problems and work orders, and the more work orders the greater the risk of losses and major incidents – and what this author calls the reliability process shown in Figure 6. In both models, organizations must eliminate the defects in their systems to improve perfor-

mance. In the alternative model of Figure 7, each layer of "Swiss cheese" is made up of each element in the reliability process and the defects are the holes in the cheese induced by things like poor management and supervision, poor standards, poor training, poor implementation, and so on. The poorer these practices are, the greater the number of holes and, therefore, the risk of both minor and major events (e.g., a catastrophic accident, bankruptcy, etc.). Note, however, that industry experience and data from numerous operations indicate that there are typically more defects, or holes, in functions related to design, installation and start-up, and operation, than there are in maintenance, procurement, or stores.

Thus, the Swiss cheese version of this model might look something like Figure 7.

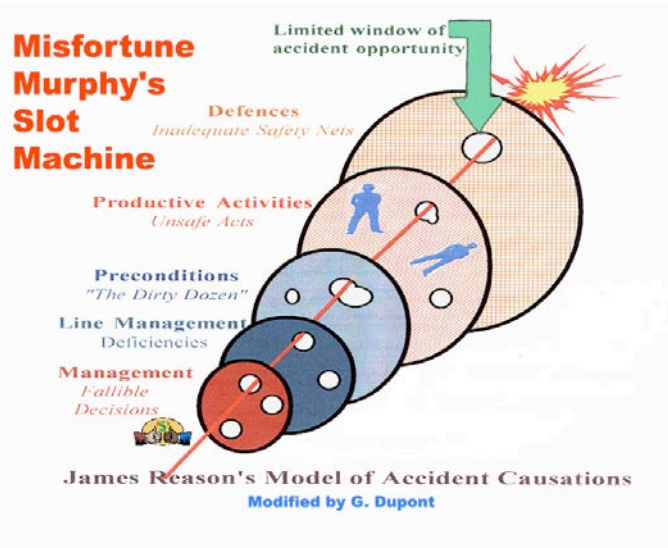

Figure 5: G. Dupont's Swiss cheese model of safety

All the holes or defects in the system allow bad things to happen – injuries large and small, additional costs, lower output, poorer quality, poorer on time delivery, environmental incidents – and, ultimately, sometimes really big bad things, like catastrophes, deaths, or bankruptcies occur. More often than not, the initiating events are contained within the functional area and only lead to small bad things happening (e.g., an extra minor cost, a minor injury, a short disruption, etc.). Sometimes, they make it through to the next layer and the next. Also imagine that the holes are constantly changing, moving from one area to another within a function, or changing in size as people, managers, systems, standards, procedures, training and other things change. And finally, imagine that the discs are spinning round and round, driven by variability within each function. All this makes for a very complex system, but it's only when the holes line up that really big bad things happen.

So the key to minimizing these events, both large and small, is to minimize the size and number of holes or defects in each functional area and to functionally align the goals and practices in all the areas so they work in concert, not conflict, to minimize that risk. These holes or defects typically relate to poor standards, training, procedures and, more broadly speaking and more accurately, to root cause, poor management and organizational culture, meaning a lack of operational discipline. W. Edwards Deming once said that 85 percent of all organizational problems are because of poor management. Just before he died, Deming said he was wrong, that it was 95 percent. Many agree with Deming.

Let's look at a few examples of the defects in each functional area.

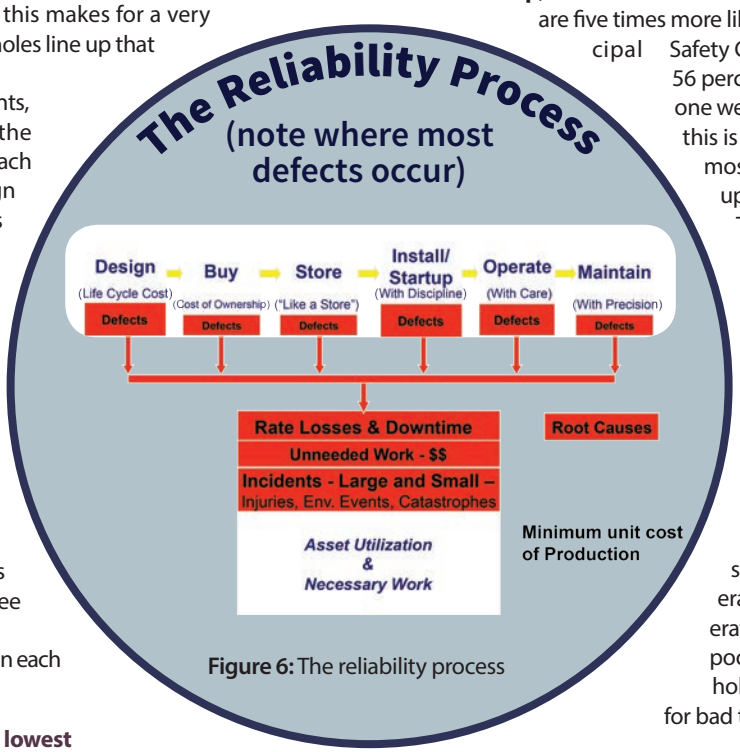

Figure 6: The reliability process

Designing for lowest installed cost vs. lowest lifecycle cost: This typically results in greater difficulty in operations and maintenance, and lower reliability and availability. Think of this approach as creating holes, or defects, in your design, increasing the risk of bad things happening in the system's operation. Ease of operation and maintenance, along with high reliability and availability, should be at the forefront of any design.

Buying primarily based on price vs. the total cost of ownership: Likewise, this increases the risk of poor reliability and availability, and the inherent risk in operations and maintenance. Think of these poorer practices in procurement as adding holes or defects into the system.

Stores operation: Having a stores' operation that is primarily focused on reducing inventory levels as opposed to balancing risk of loss, primarily production and maintenance efficiency, against working capital for a better system level effect also induces more holes in your system. This increases the probability of poorer performance and accidents. Likewise, having poor stores administrative and/or functional capability increases the risk of poor performance and accidents.

Installation/Start-up: One of the greatest risks to any operation is having poor installation and start-up practices. Huge holes occur in the system during this effort. For example, Rohm & Haas Company reported that you're seven to 17 times more likely to introduce defects **during start-up** than normal operation; BP reported that incidents are 10 times more likely **during start-up**; the chemical industry reported process safety incidents are five times more likely **during start-up**; Paul Lucas, Principal Safety Consultant for ABB Ltd., reported that 56 percent of forced outages occur less than one week after a maintenance shutdown. All this is indicative of huge holes or defects in most organization's installation and start-up procedures, standards and practices. These must be addressed to reduce this risk.

Poor operating practices: They induce large numbers of holes or defects into systems not only in start-up, but also in routine operation. Examples include not running the process or equipment per the standards, poor process conformance to standard operating conditions and procedures, having very loose standards that allow for excessive operational variation, inconsistency of operations across shifts, poor operator care, poor shift handover, etc. All these create holes or defects in the system, allowing for bad things to happen.

Poor maintenance practices: Examples include poor planning and scheduling, the inability to do proper planning and

scheduling because of conflicts with operations or production planning, poor condition monitoring, inadequate preventive maintenance (e.g., too much, too little, or inexact standards), and workmanship (e.g., imprecise installation, poor alignment and balancing of machinery, etc.). It is the responsibility of senior management to understand and address all these shortcomings or defects in the organization's practices. ***If you do all the little things right, the big bad things won't happen.***

No model is perfect in representing a given situation, particularly for complex systems, and these are just examples. Feel free to modify and adapt this to your circumstance.

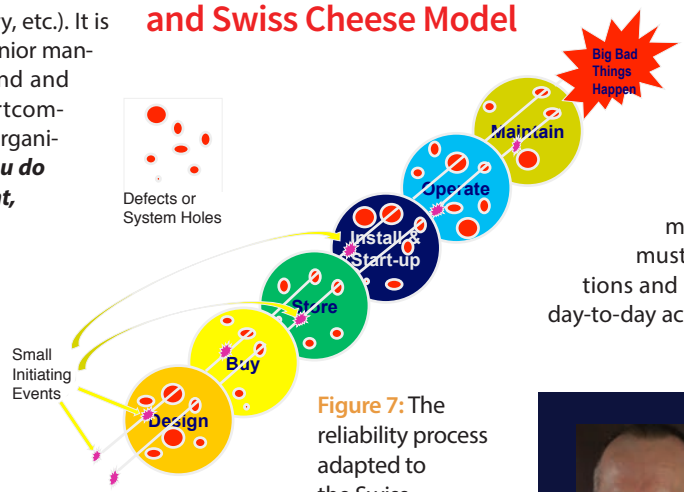

Figure 7: The reliability process adapted to the Swiss cheese model

As Deming suggested, underlying all these holes and defects in safety and reliability practices is primarily poor management and leadership that often lacks system-level thinking and creates a poor organizational culture. This results in poor operational discipline, leaving an abundance of holes in the layered Swiss cheese model and ample opportunity for bad things to happen, including poor operating results, high costs, poor quality, poor delivery performance and, of course, accidents, including catastrophic events.

All these defects in the practices must be addressed through senior management ***demanding and supporting*** operational excellence and discipline in all areas of the plant. They must put the systems and practices in place (e.g., policies, procedures, standards, checklists, etc.) to assure the defects covered in this article are addressed. They must also engage everyone, particularly the shop floor, in defect elimination. Performance measures, along with rewards (and even "punishment") must reinforce these principles. Leaders must set the expectations and standards, and then drive operational excellence in their day-to-day actions.

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

CASE STUDY OF SWISS CHEESE MODEL

To illustrate the model, a case study is being used from the work of Andrew Hopkins when he investigated a major explosion at a large operation that killed over 20 people and caused hundreds of millions in damage. With regards to the catastrophe, he identified a sequence of events, some of which are listed below, but all of which combined to create the explosion and disaster. Several of these are listed to illustrate the nature of the disaster, along with this author's speculation/comments on the possible causes of the small, initiating event.

1. The primary level indicator in a distillation column of volatile distillate was not designed to measure liquid beyond an approximate 12-foot level, leaving operators without knowledge of if or when the column had filled beyond its high level alarm. The high level alarm activated at the 10-foot level and, in fact, functioned properly. This appears to be primarily a design issue, one not recognizing the possibility of overfilling the column.
2. A second, redundant level alarm failed to operate. This could be a design, procurement, stores, operational, or maintenance issue, or more likely some combination.
3. A valve controlling flow out of the column closed. This appears to be an operational error.
4. The column was filling, but nothing was coming out. This appears to be an operational error.
5. The level indicator showed operators that the level was below 10 feet and falling, but the investigation showed it was actually at 138 feet and rising. The level indicator was apparently broken. This appears to be a maintenance error, or possibly a design error.
6. A high pressure alarm activated and burners turned off. This is normal for this design, but the investigation suggested a change in design may have prevented or mitigated the disaster.
7. The pressure relief valves did not work. This could be a design or maintenance error, or both.
8. A manual valve was opened to vent gases to an overflow drum. This appears to be normal operation, but is one that, in retrospect, is indicative of a system malfunction and additional caution and preventive action.
9. Excess fluid in the column was sent to storage, but passed through heat exchangers heating incoming liquid, thus increasing the risk of a volatile incident. Liquid entering the tower started boiling and expanding. The tower started overflowing liquid. This appears to be a design error.
10. Emergency relief valves opened due to increased pressure. These are the valves that did not open in Number 7 in this list. Their opening caused liquid to go to the overflow drum, with some liquid overflowing into the sewer. Again, a possible design or maintenance error.
11. The high level alarm on the overflow drum did not go off. This may be a maintenance or design error.
12. The overflow drum overfilled and liquid ejected from the top of the drum.
13. There was an ignition source in the form of a running truck near the overflow. This running truck was contrary to policy and rules in place at the time. This is clearly a management error in not enforcing the rules in place to minimize the risk of a disaster.

Further investigation revealed that this type of event had occurred some 10 times before it finally resulted in a massive explosion, killing over 20 people and doing millions of dollars in damage to the site, not to mention the company's reputation.

With this in mind, it is hard not to point the finger at senior executives for allowing such risks to be taken, poor site management and poor direct supervision, all of which combined to create a culture of complacency regarding risk and an environment where poor design, operations and maintenance, combined with poor procurement and stores, and poor training and development, to assure a disaster was only a matter of time.

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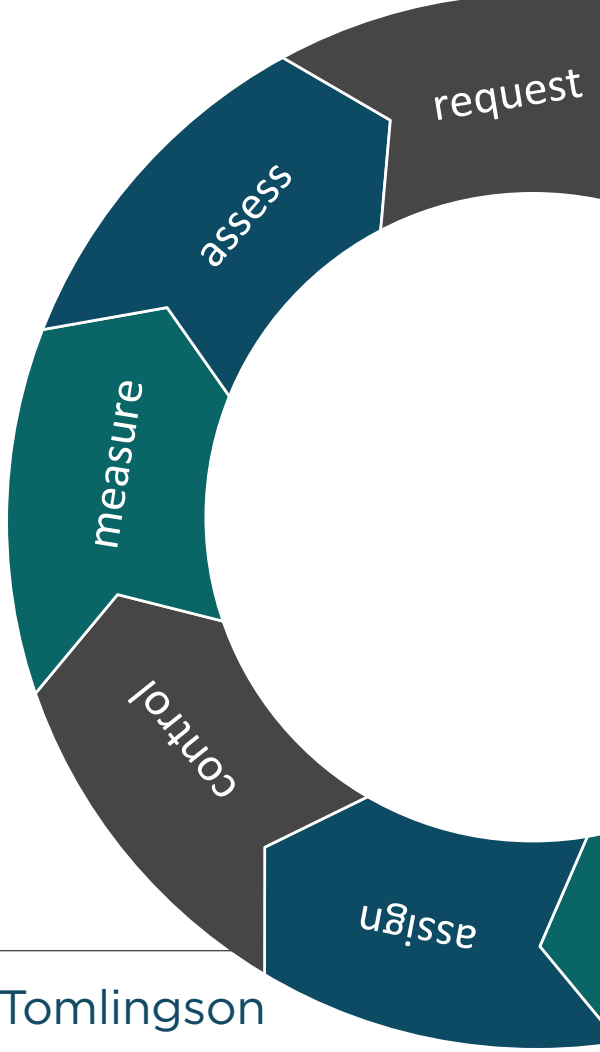
THE PLANT MAINTENANCE PROGRAM



It's a team effort

by Paul Tomlingson

What is the plant maintenance program? The plant maintenance program depicts the interaction of the total plant population as they ***request*** or ***identify*** work; ***classify*** it to determine the best reaction; ***plan, schedule, assign, control*** and ***measure*** the resulting work; and ***assess*** overall accomplishments against goals, such as performance standards and budgets.

The program explains and prescribes what personnel do and who does what, how, when and why? The personnel involved are more than those in maintenance. They also include all who support maintenance, such as warehousing, or depend on maintenance services, as with production.

The success of all maintenance functions is enhanced with a program commonly understood across the entire operation. But, the most important aspect of all is to ensure that those other departments that must support maintenance or utilize its services know how. If they don't know what maintenance wants and needs, they cannot deliver it. There is an axiom that suggests: If you want someone's help, you must first tell them how they can help. More simply: No tell; no help.

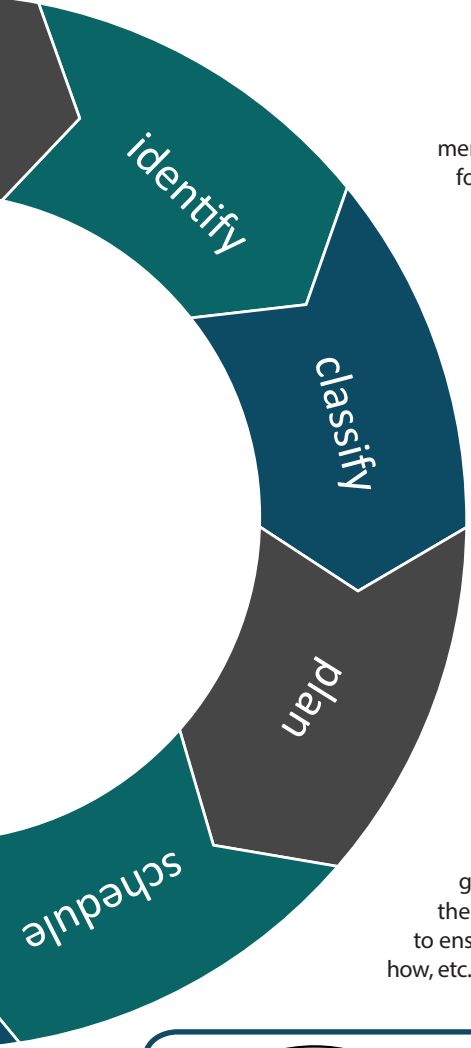
Maintenance is not a stand-alone effort. Any successful effort to improve maintenance performance, regardless of how, depends on the quality of the plant maintenance program. It's important to note that it is the ***plant*** maintenance program, not the maintenance department's maintenance program. Maintenance is a service provider, dependent for success on the cooperation and support of all other plant departments and the backing of a supportive plant manager. Maintenance is not to be carried out single-handedly by maintenance. Planning, for example, is a key maintenance function and the responsibility for successful planning rests solely with maintenance. But, the planning function requires the support of numerous plant departments, like warehousing, purchasing, shops, accounting, etc. Few maintenance functions are successful without help and cooperation from other departments.

> The program explains and prescribes what personnel do and who does what, how, when and why?

Getting Started

Only the plant manager controls all departments. Therefore, the ***existence*** of a quality plant maintenance program is the responsibility of the plant manager. However, the maintenance manager is responsible for the effective ***execution*** of the elements of the plant maintenance program. Yet, the maintenance manager depends on all other departments in order to execute the plant maintenance program. Thus, the plant manager becomes responsible for ensuring the support and cooperation of other departments, which, in turn, ensure the success of maintenance.

What must the plant manager do? Based on the corporate business strategy, the plant manager, as shown in Figure 1, develops a business plan (1), assigns depart-



mental objectives specifying responsibilities for primary operational or support activities to include interactions with maintenance (2) and specifies policies for the conduct of maintenance (3). In turn, departments acknowledge objectives and follow policies as they incorporate all experiences with merit (4) and follow principles (5) to develop internal and interdepartmental procedures (6). Procedures are then incorporated into departmental programs (7) and information systems utilized to control actions (8). Once tested, departments organize to support programs (9) and interact according to approved program details (10). Thereafter, information is used to control and manage the overall operation (11).

It follows that the best maintenance organization must be capable of executing the what, who, how, when and why of the plant maintenance program. And the best information system is the one that provides the right information to ensure efficient execution of the what, who, how, etc., specified in the program. It is reasonable to state that modern strategies, like reliability centered maintenance (RCM), cannot be successfully implemented unless there is a plant maintenance program, organization and information system to support them.

It logically follows that only when a plant and its maintenance department have solidly locked down what they do, how, etc., can they confidently choose the best organization and a competent information system to carry out and control plant maintenance activities.

Program Development

Program definition begins at the plant manager level. This individual states how the departments should work together efficiently and productively by assigning specific objectives. The plant manager provides policies so departments are guided as they develop internal and interdepartmental procedures that make the plant's maintenance program work efficiently.

Effective maintenance and actions that assure reliable equipment and workforce productivity don't simply happen! They happen only after clear, logical management guidance is provided and a quality program emerges.

Program definition is a composite interaction of all departments. As they work together, maintenance crews, equipment operators, supervisors and staff personnel, like planners, warehouse personnel, or purchasing agents, should confer as the procedures for each department are being developed and interdepartmental actions confirmed. This collaboration better assures the practicality and workability of the final program.

Program education is essential and must include everyone in the plant, from worker to manager. Plant managers should make a special effort to observe the discussion between departments as they commit to procedures necessary to carry out the plant's business plan. Questions should be answered promptly and correctly. Recommendations should be welcomed and encouraged.

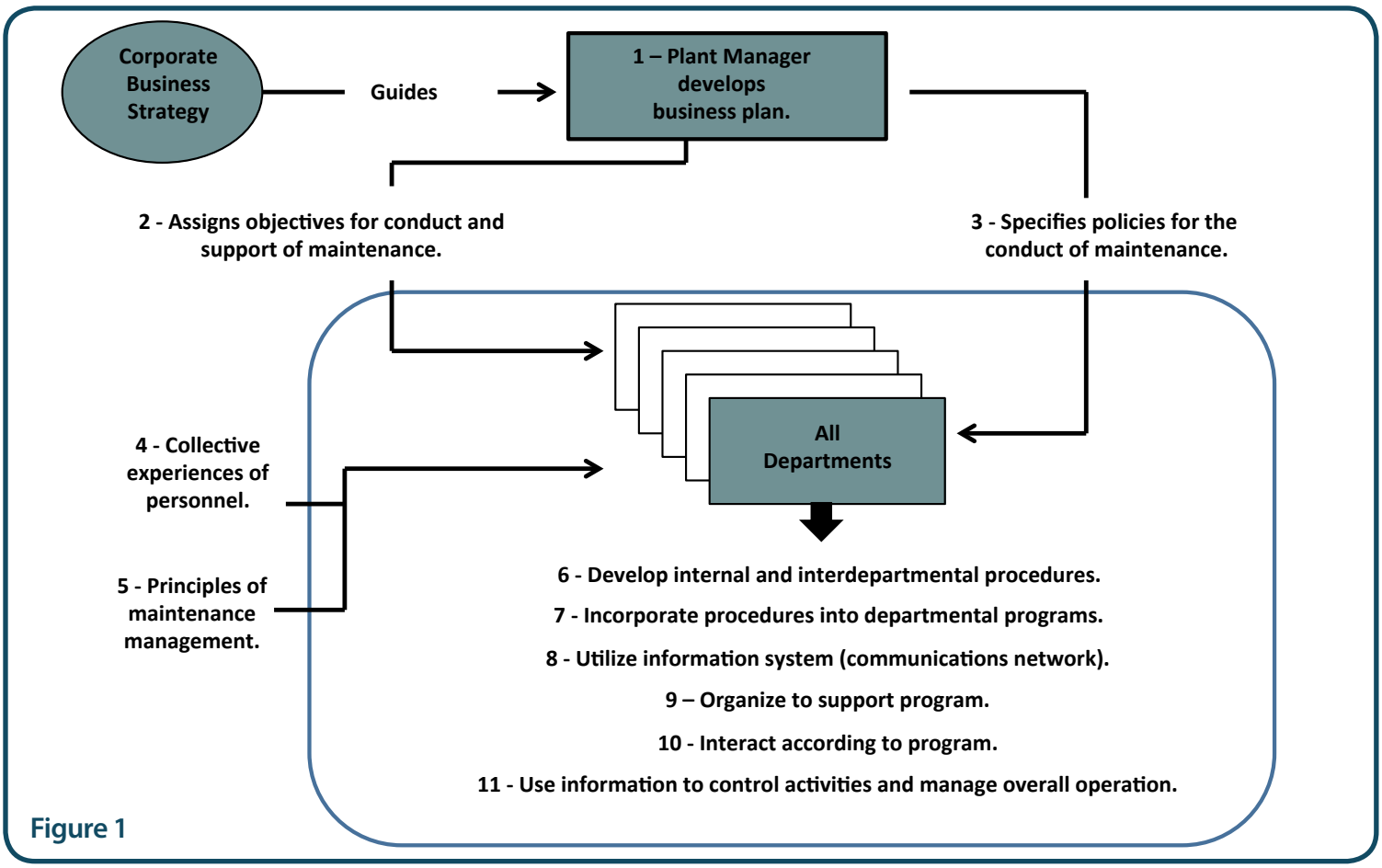
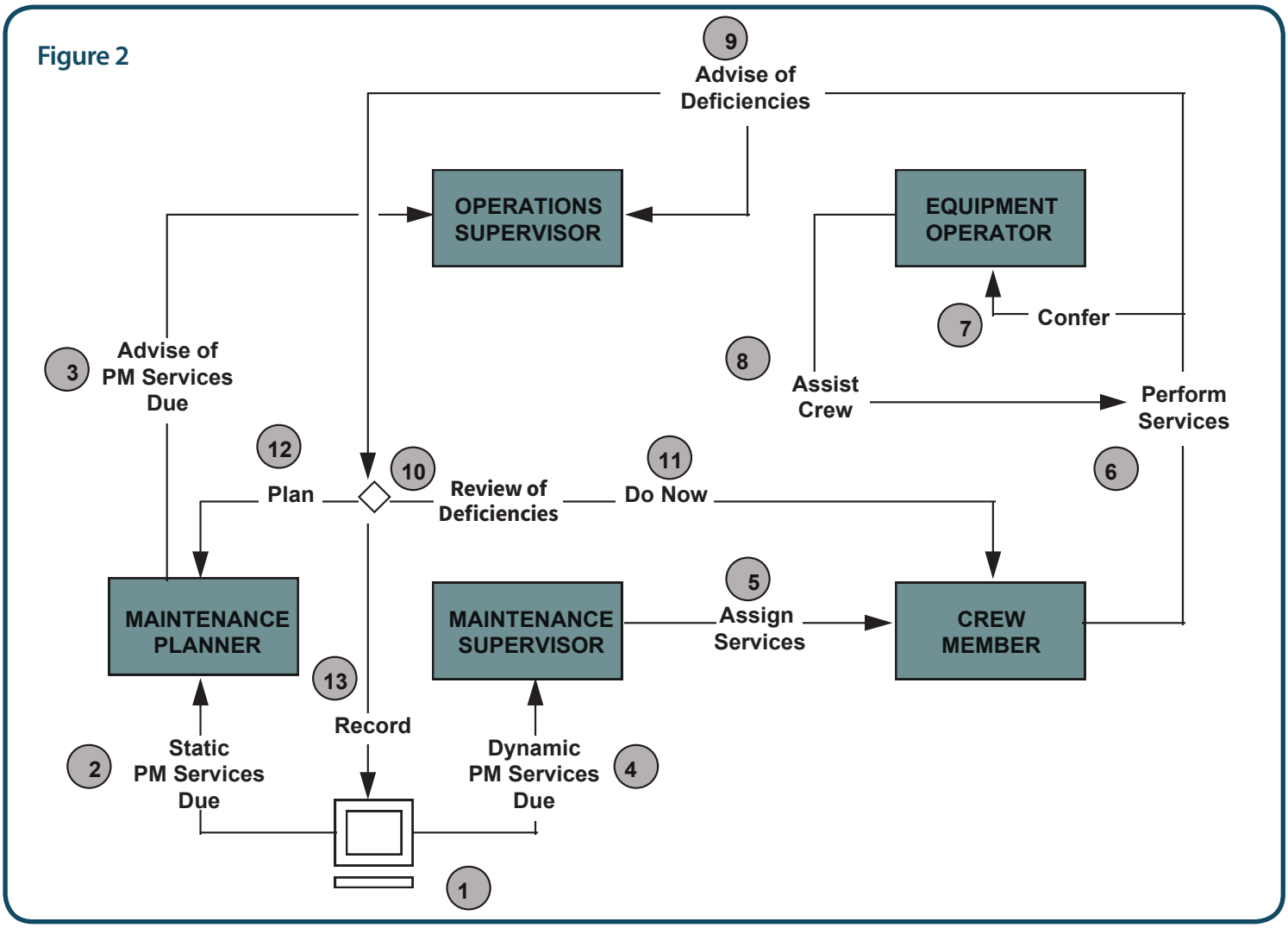


Figure 1



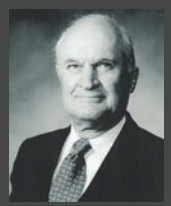
Program Definition Techniques

The most effective technique for documenting the program is a schematic diagram that depicts the interaction between individuals of participating departments. The schematic is accompanied by a legend to aid understanding of the step-by-step process. While other techniques, such as flow charts, decision trees, or narratives, with diagrams might be used, none are as effective as the schematic diagram in showing people's interactions. The schematic pinpoints 'you' and 'me.' It describes directly what ***'we'*** must do, how ***'we'*** will do it and the results ***'we'*** should achieve. It is this ***'personal'*** explanation that helps to bind people to the program.

As Figure 2 illustrates, preventive maintenance (PM) services due are shown by the information system (1). Services on equipment due (2) are either static (require shutdown) or dynamic (done while running). Static services are integrated into the weekly schedule and operations is advised of the approved, scheduled shutdown times (3). Dynamic PM services are done at the discretion of the maintenance supervisor (4). The maintenance supervisor assigns PM services to individual crew members (5). Services are performed by maintenance crew members (6) and crew members confer with operators to learn about actual equipment condition (7). Operators assist according to their instructions (8), while operations supervisors are advised of new deficiencies by the crew member (9). Deficiencies are then reviewed by the maintenance supervisor and the crew member (10) and converted into work as follows: Emergency repairs - Supervisor assigns at first opportunity (11); Work that meets planning criteria requiring planning - Supervisor forwards to planner (12); and Unscheduled repairs - Crew member enters them into the work order system as new work to be fitted in at first opportunity (13).

Conclusion

It is always prudent to ensure that everyone in an industrial organization understands their operational, support and cooperative roles and responsibilities. When this happens, the plant maintenance effort will be successful.



Paul D. Tomlingson, *retired, is a 44 year veteran maintenance management consultant focusing on heavy industry. Mr. Tomlingson is the author of eleven textbooks and over a hundred published trade journal articles. He is a graduate of West Point and received a BA in Government and a MBA from the University of New Hampshire.*

'All about the Data': An Interview with Redbird's Emmanuel de Maistre

Original publication DroneLife.com, March 2015. Interview conducted by SkyTech Conference and Events.

Q: The commercial UAV industry is rapidly evolving, with UAVs now being utilized for a wide range of industry applications. In the face of this expanding industry, SkyTech sat down with Emmanuel de Maistre, CEO and Co-founder of Redbird. Since its establishment in 2012, Redbird has become an industry leader and pioneer in the acquisition and analysis of aerial data collected by UAVs. Redbird is an information provider, developing innovative solutions to drive productivity and secure operations. It develops technology designed to fit specific industry requirements and offers services within three business units: Geospatial, Agribusiness and Network Supervision. Redbird's services include quarry monitoring, public works monitoring, oil & gas monitoring, agricultural research and agricultural disease diagnosis, amongst many others. Can you tell us a little more about Redbird?

A: Redbird is an information company capturing and analyzing data using small civilian drones. Founded in 2012, Redbird empowers large industrial companies and job sites to optimize their resources, improve their productivity, and ensure safety by offering comprehensive drone solutions and by processing massive amounts of accurate aerial information. Being one of the leading drone companies in France and in Europe, Redbird deploys advanced aerial & data analytics technologies for three major markets: mining and construction, infrastructure networks (transportation, oil & gas, electricity), and precision farming. Redbird is backed by Bergerat-Monnoyeur and GDF Suez New Ventures. Monnoyeur (5000 employees, 1.5 bn€ revenues) is the CATERPILLAR dealer in France, Belgium and Eastern Europe. GDF Suez (140.000 employees, 84 bn€ revenues) is the world's largest independent utility company, operating in the fields of electricity generation and distribution, natural gas and renewable energy.

Q: Redbird has experienced huge growth over the last two years, with many of your clients now considering the use of UAVs a normal part of their industrial processes. What is the vision behind Redbird?

A: We see high definition aerial data as a revolutionary tool to take the best business decisions in several big industries. This is a new world: robotics and new on-board technologies are now available to the industry, at low costs. Computers have an ever-increasing capacity to deal with massive amounts of information ("Big Data") and new regulations allow the commercial use of civilian UAVs. Our vision is to change the game in the industries by first collecting massive amounts of high-resolution aerial data using UAVs. Then we extract critical information and provide our client with new insights for a better decision-making process. Our objectives are to increase productivity and secure daily operations for our clients.

Q: Redbird has become an expert at using UAVs for a range of industries. Can you tell us more about the key services Redbird offers?

Press Release

April 1, 2015 -- French energy company GDF Suez said Wednesday it was investing in Redbird, a civilian drone company, to monitor natural gas infrastructures.

The French company's venture capital subsidiary said it invested $2.1 million in Redbird to facilitate drone monitoring of natural gas infrastructure, survey topography and monitor "security for public institutions."

GDF Suez said the investment builds on its portfolio of emerging technologies with high-resolution imagery needed for preventive maintenance.

Redbird President Emmanuel de Maistre said "exceptional support" from GDF Suez will help his company expand and develop more powerful drone technology.

"Since 2013, we are deeply convinced of the value of civilian drones for infrastructure networks, and this choice is relevant today," he said in a statement.

"Despite technical and regulatory complexities, it is one of the most promising sectors."

A: We deliver a large set of geospatial accurate data that are able to increase productivity and safety for our clients. Thanks to our partnership with Monnoyeur, we are now experts at delivering high added-value data for the construction industry. Because we have been betting on BLOS long distance flights, we are now well positioned in infrastructure networks (railways, roads, pipelines) where we deliver information for vegetation control, detection of dangers, etc.

Q: Redbird's ability to process a large quantity of data effectively is incredibly beneficial for a range of industries. Would you say it is the main benefit of using Redbird UAVs?

A: Our large processing capabilities are just a part of the whole system. The main benefit of using Redbird is our efficient industry-specific analytics. We have selected the best tools (vectors/sensors) from a large panel of manufacturers, and we use them as a tool. The UAV is just a tool. Since the beginning, for us, it is all about the data. Not to forget our dedicated team of professional pilots that are able to fly at the client's request in almost every flight scenario (VLOS & BLOS, with rotary or fixed-wing UAVs).

Q: Redbird provides clients with an online interface in order to visualize and to archive all data acquired by the UAV. Can you explain more about this?

A: After two years flying for clients almost every week, we came to the conclusion that our clients just want the good information, at the right time. Also, they do not want to handle, archive and store massive amounts of data (we are talking about thousands of Gigabytes per client). We therefore developed extranet solutions and mobile-based visualization systems to allow the clients' employees to easily access the data anywhere.

Q: UAVs are becoming increasingly beneficial for avoiding human intervention in dangerous industries such as quarrying. Do you see this to be a strong benefit of UAVs across the board?

A: Quarrying is an industry we know very well. Thanks to the relationships we have with Bergerat-Monnoyeur, we are probably the most experienced company using drones for quarries. Indeed, safety is a huge issue in this sector. Not only is using UAVs a safer process, but our data analytics are also dedicated to the identification of threats and safety breach on the site.

Q: Redbird also develops innovative solutions for precision farming, including water stress, nitrogen fertilization optimization and monitoring of experimental micro-parcels. What methods/technologies does Redbird deploy to detect pesticides and diseases?

A: We have been working on the *flavescence dorée*, a bacterial vine disease with the potential to threaten vineyards. There is no cure for the moment to this disease. We use drones and near-infrared images to detect the infected spots early, in order to treat them quickly through spreading, before the parcel is fully infected.

Q: Despite the speed at which the UAV industry is developing, UAVs do still face a number of technological challenges. How do you navigate limited flight times of UAVs, especially when it comes to surveying network infrastructures at length?

A: Limited flight time is a challenge indeed, but we already have high-performance UAVs that can fly up to 2 hours and map up to 100 km linear distance per flight. We can map 30-50 km per day at a very high resolution; which is already huge and quite unusual in the sector. In April 2013, Redbird became the very first UAV operator allowed to operate civilian UAV beyond line of sight (BLOS), in France.

Q: With UAV technology continually advancing, what direction do you see the industry taking over the coming years?

A: On the hardware side, I see the development of lighter UAVs (< 2kg) for the simplest missions. And for complex missions such as BLOS flights and network surveillance, I think heavier drones will be developed (> 10 kg), with a regulatory and certification challenge. But more important, I foresee a huge development of industry-specific, cloud-based data analytics processes. That is precisely the field we are investing in. For the last two years, we have been testing and developing our solutions with a large number of experimentations with early-adopter clients. Now we gain a real recognition of the quality of our products. We are now planning to scale-up our solution and emphasize our commercial development.

For more information, visit www.redbird.fr

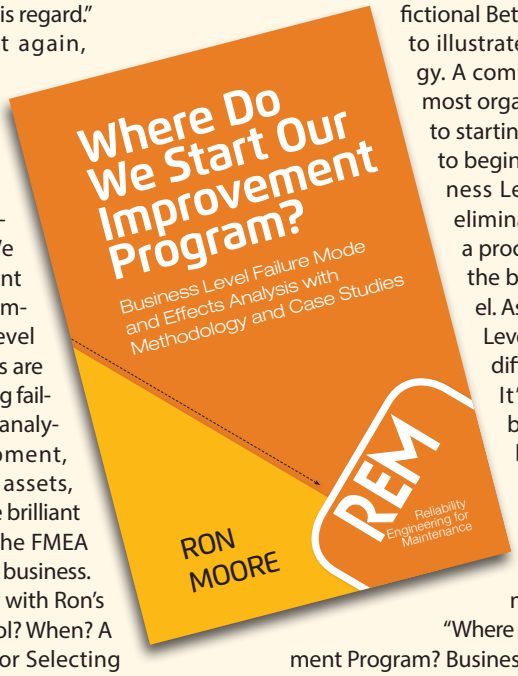
Where Do We Start Our Improvement Program?

Business Level Failure Mode and Effects Analysis with Methodology and Case Studies

Written by Ron Moore • Reviewed by Michael Eisenbise

"Most companies are looking for a relatively easy way to identify the biggest opportunities they have for improvement, ones that require the least amount of investment in either labor or capital for the greatest return. This book seeks to provide guidance in this regard."

Ron has done it again, writing a book that shares his vast expertise in helping manufacturing and industrial companies improve their performance. "Where Do We Start Our Improvement Program?" focuses completely on Business Level FMEA. While most of us are familiar with conducting failure mode and effects analysis (FMEA) on equipment, machines and other assets, Ron comes up with the brilliant concept of applying the FMEA principle to the overall business.



For those familiar with Ron's other books, "What Tool? When? A Management Guide for Selecting the Right Improvement Tools" and "Making Common Sense Common Practice – Models for Operational Excellence," this book expands upon the Business Level FMEA chapter found in those two books. You'll appreciate the more in-depth coverage on the topic presented in "Where Do We Start Our Improvement Program?" Personally, the additional details and case studies gave me the confidence to encourage the application of Business Level FMEA at my organization.

In this book, Ron outlines a proven methodology to start the process of bringing individuals from all levels and backgrounds together, as a team, to reach a consensus on the appropriate projects to select for immediate improvement. The book provides an objective way to select the appropriate projects and develop a business case for each of them.

A nice familiarity that provides continuity between Ron's books is the use of the fictional Beta International company to illustrate the FMEA methodology. A common stumbling block in most organizations when it comes to starting such an effort is where to begin, but the use of the Business Level FMEA analysis tool eliminates that by focusing on a process or production line at the business or operating level. As Ron points out, Business Level FMEA is simply taking a different view of a business. It's about looking at the business the same way we look at a machine, identifying functional requirements and failure modes and analyzing them to uncover major business opportunities.

"Where Do We Start Our Improvement Program? Business Level Failure Mode and Effects Analysis with Methodology and Case Studies" is a fast read, with the information succinctly presented in three parts: The Methodology, Case Studies, and References. The step-by-step methodology to eliminate defects are invaluable guidance, as are the illustrations of the Business Level FMEA model, Business Level FMEA Questions and Decision-Making Model. You could literally start implementing your own Business Level FMEA after reading just Part I of the book.

But be sure to continue on because the Case Studies section takes you through the process and encompasses different types of plants, including automotive, chemicals, pet food, steel and food, as well as a distribution and supply center. The role-playing dialogue that Ron chose to use to explain the analysis technique is right on the money. I'm sure you'll relate to some of the cast of characters. In reading the case studies, I felt like I was actually in the room and part of the discussion to identify issues, apply the analysis methodology to determine the best improvement tools, and decide when to deploy the tools.

After I finished reading "Where Do We Start Our Improvement Program? Business Level Failure Mode and Effects Analysis with Methodology and Case Studies," I realized that the most valuable thing about Business Level FMEA is that it is directly linked to the bottom line, so an organization can calculate the gross profit that will result from applying Business Level FMEA, whether it's to reduce costs or improve production processes.

In my opinion, this book is concise, to the point and most informative. It's a must-have for anyone that wants to jump-start a reliability/operational excellence effort. It is clear that Business Level FMEA is a powerful tool that all organizations should implement. After reading Ron's book, you will be able to do so with confidence and demonstrate exactly how it will benefit the bottom line.

I have conducted many system level FMEAs during my 40-year career. However, my system level FMEAs focused on different aspects. From "Where Do We Start Our Improvement Program? Business Level Failure Mode and Effects Analysis with Methodology and Case Studies," I have learned a great deal about how I can improve my system level FMEAs.

I highly recommend this and Ron's other books.

Available at mro-zone.com

Ron Moore

Michael Eisenbise
BP Senior Process Reliability Implementation Specialist Supporting Refining

Author's views and opinion are not a representation of those of BP.