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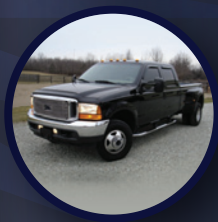

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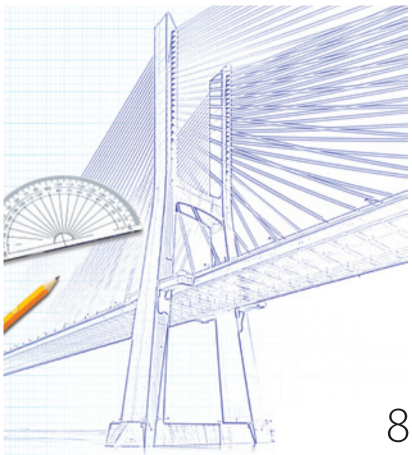
8


23


34

Features

Elements

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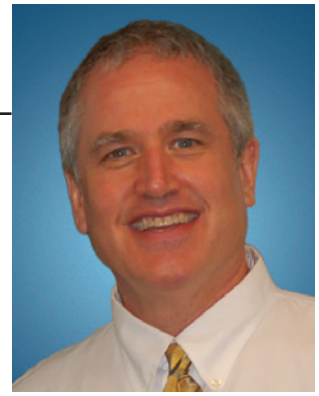
Editorial

An Exercise in Patience



Patience is a virtue, so they say. Those of you who know me also know that patience was **not** one of my original virtues, but recent events have changed all that.

Back in February, I got a nasty case of pneumonia. While recovering, I got Guillain-Barré syndrome, a rare nerve disorder where my own antibodies attacked the myelin sheath (insulation) of my peripheral nervous system. Luckily for me, I was diagnosed and treated early. Even so, some nerve damage was done and now, in addition to my work at *Uptime* magazine and Reliabilityweb.com, I am doing physical therapy, hydrotherapy, yoga, meditation and visualization, and using good nutrition to support and speed my healing and recovery.

I am also blessed to have a wide support network of family and friends who have shown up, prayed, laughed and cried with me – moving my recovery much further along than I would be without them.

As I mentioned, I am using every strategy, technique, tool and technology I can to make a "speedy" recovery, but the slow nature of nerves regrowing the sheath is more gradual than I prefer and is the primary limiting factor in my eventual 100% return to full health. Do not get me wrong, the physical therapy and other things I am doing certainly prepare my body and mind, however, doing an extra 30 minutes of exercise does nothing to speed the regrowth of the myelin sheath. In some instances, it is possible to regress by trying to overdo it! Hence, my current theme: patience.

I have come to appreciate the value of patience, not only for my own progress, but also as a virtue for those making the journey to improved maintenance reliability performance.

You can (and should) employ a great strategy, use effective techniques, and apply all the right tools and technologies, but one thing is for sure, your organizational culture and the people in it will need time to adapt to the new way of being and that requires patience.

Like health, you cannot simply write a check and get reliability. You cannot get reliability by placing motivational posters on the shop floor or by giving slogan T-shirts to the team. You have to work hard, do the right things and earn reliability over time.

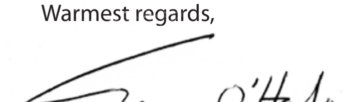
Other lessons I am being taught at the moment may apply to your reliability journey as well. I am currently learning things like persistence without evidence, how to ask for and receive help gracefully, how to find blessings in adversity/challenge and how to be personally accountable for everything in my life – no excuses. I am working hard to grab every bit of wisdom I can from this experience and I implore you to do the same with the things in your life.

One more lesson I have learned that I would like to share is that all we have in this world is the love of our family and friends, hopefully some meaningful work and, of course, our health. This may sound preachy, but please do not take this lesson for granted, even if your day seems too busy to stop and appreciate the people and things you have in your life. Just do it!

As for me, I have been knocked down before and I have learned that all I can do is get back up, dust myself off and continue with my journey. That is exactly what I am doing with great appreciation for the people in my life.

You can keep up with me at www.facebook.com/assetmanager if you want to know more about my experiences.

Warmest regards,



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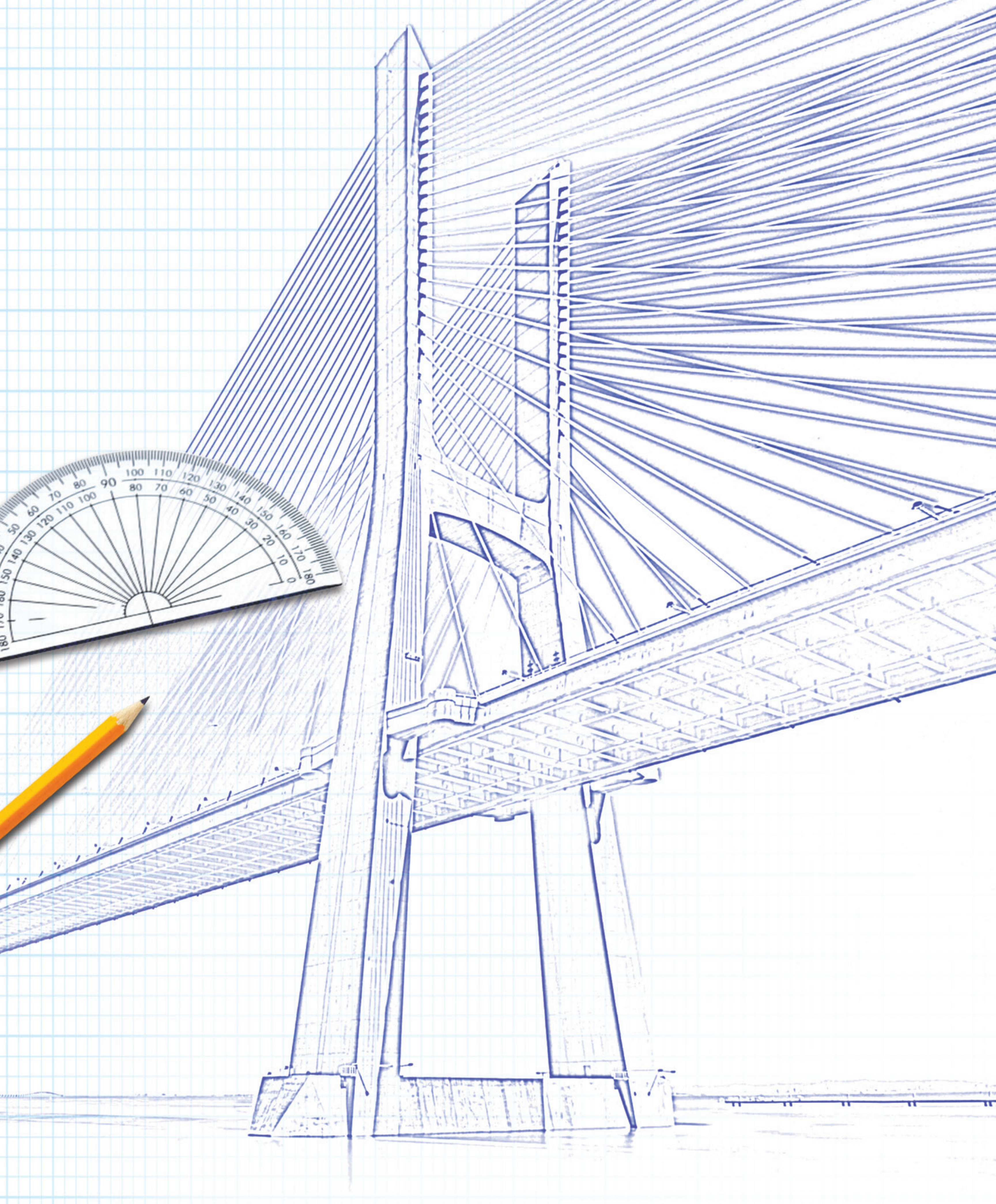

Operational Readiness: Bridging the Gap Between Construction and Operations for New Capital Assets

Bob DiStefano with Co-Authors Will Goetz and Bruno Storino

Introduction

Despite the global economic slowdown, several factors are conspiring to spark a spate of new capital construction. These factors include: demand for various commodities (e.g., oil, gas and other natural resources); new discoveries along with new extraction and processing technologies for these commodities (e.g., oil deposits in deep water ocean and shale gas deposits in the U.S.); high commodity prices enabling more costly production technologies (e.g., oil sands); and the current cheap cost of capital. Deloitte, in a recent whitepaper about the mining industry in Africa, suggests that countries and companies in Africa and worldwide “continue a push toward significant industrialization and infrastructure renewal.”[1] As industrial organizations today tackle the challenges of deciding when to build new capacity, they tend to be driven by carefully formulated business cases. Compelling business cases often lead to sizeable capital expansion projects justified by the anticipated growth in revenue and profits that eventually will be garnered. Do these anticipated benefits materialize? Unfortunately, the reality is they typically fall short of expectations for many reasons and risks span the gamut of variables, including political, economic, market, financial, organizational and operational. Arguably, operational risks are, at the same time, one of the largest and one of the most controllable risks and, ironically, one of the most mismanaged.

It traditionally has been the case that significant leakage of anticipated project value occurs during the turn-over/commissioning and ramp-up periods of the new asset lifecycle. Case studies have measured this leakage to be as much as 30% of the value that was anticipated during the *early* stages of the total lifecycle.[2] The early stages consume the first three to five years and include the engineering, design, construction, commissioning and ramp-up phases. The ramp-up phase is usually the first year after commissioning—often a painful period of unstable operations, with significant lost revenue and profit opportunities due to unexpected and extended downtime.

The early stages consume the first three to five years and include the engineering, design, construction, commissioning and ramp-up phases.

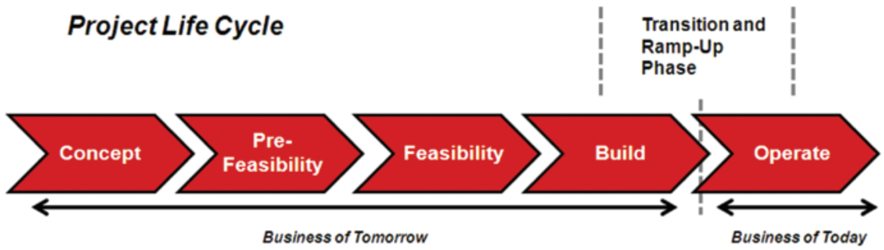

Figure 1: Ramp-up phase of new asset lifecycle (Source: Deloitte, 2012)

Of equal and often greater significance, the actual operations and maintenance costs (O&M) of the assets during the longest portion of the total asset lifecycle—the operate/maintain stage (often 30 years or more)—typically are 1% to 2% higher (conservatively speaking) than the expected total lifecycle costs assumed in the initial business case—and this does not include the operability value destroyed because of poor design choices, unprepared operators and maintainers, antiquated maintenance strategies and a lack of necessary documentation. Choices made during the early design and construction phases set in place the long-term operating performance, as well as the long-term operations and maintenance costs for the more than 30-year life of the asset. Poor choices can doom the organization into incurring unnecessary lifecycle costs, reaching into the hundreds of millions of dollars for some large projects.

This article will explore the factors that determine the level of lifecycle costs, as well as the emerging operational readiness best practices that can dramatically reduce risk and improve ramp-up, operational performance and long-term O&M costs with relatively modest investment up front.

Value Leakage

Let's first explore the value leakage in the early ramp-up stage of a typical capital project (up to 30% of anticipated early benefits). For clarity, the ramp-up stage of the new asset lifecycle is the period spanning the construction/commissioning phase and the first year of the operate/maintain phase, as illustrated in Figure 1.

In the cited Deloitte whitepaper, the authors try to quantify and categorize the typical value leakage occurring in the construction and ramp-up phases. See Figure 2 for Deloitte's graphical depiction of the value destruction in typical capital projects.

The chart in Figure 2 starts with a "best case" business case (considered theoretical and not often used in the project justification) and then whittles away at that business case with major categories of value destruction, including start-up delays, equipment failures (occurring both during construction as well as during the first year of operation), systems failures, skill deficiencies and external factors. Keep in mind this chart only deals with short-term value losses; it does not address the impact of early decisions on long-term operations and maintenance. We'll look at that in a moment.

This chart actually rings quite true for experienced professionals in the industrial community. In your experience, how familiar are the following conditions?

- The new plant has been "tossed over the fence" to the operations and maintenance organizations from the capital construction people.
- The operations and maintenance people were not given the opportunity to contribute to the design or equipment selections.
- The plant is being commissioned later than scheduled because of construction delays, and now the company is pressuring operations to make up the lost time.
- The project came in over budget and at the end of the construction phase, options to facilitate maintenance and reliability (e.g., instrument packages) were sacrificed in favor of saved time and cost.
- Voluminous operations and maintenance documentation is delivered coincident with commissioning in the disparate formats that the engineering and procurement contractor firm, construction contractors and equipment suppliers elected to use (usually inconsistent and not readily transferable into the enterprise asset management (EAM) system).
- Some of the equipment selections were based on the value of lowest initial cost and not on the basis of total lifecycle cost or reliability/maintainability.
- No consideration was given to make and model of already installed assets, resulting in no standardization, a need for overstocking of spare parts, and a requirement for operations and maintenance to become familiar with every brand and model under the sun.
- Abundant spare parts have been procured and delivered, usually at great capital cost, in anticipation of the frequent equipment failures that likely will occur given the operations and maintenance organizations' unfamiliarity and lack of experience with the new equipment.
- The EAM system has not been loaded with asset and spare parts master data or maintenance procedures representing the new assets.
- Original equipment manufacturer (OEM) maintenance recommendations are contained only in the OEM hardcopy manuals and are largely time-based preventive maintenance with heavy reliance on parts replace-

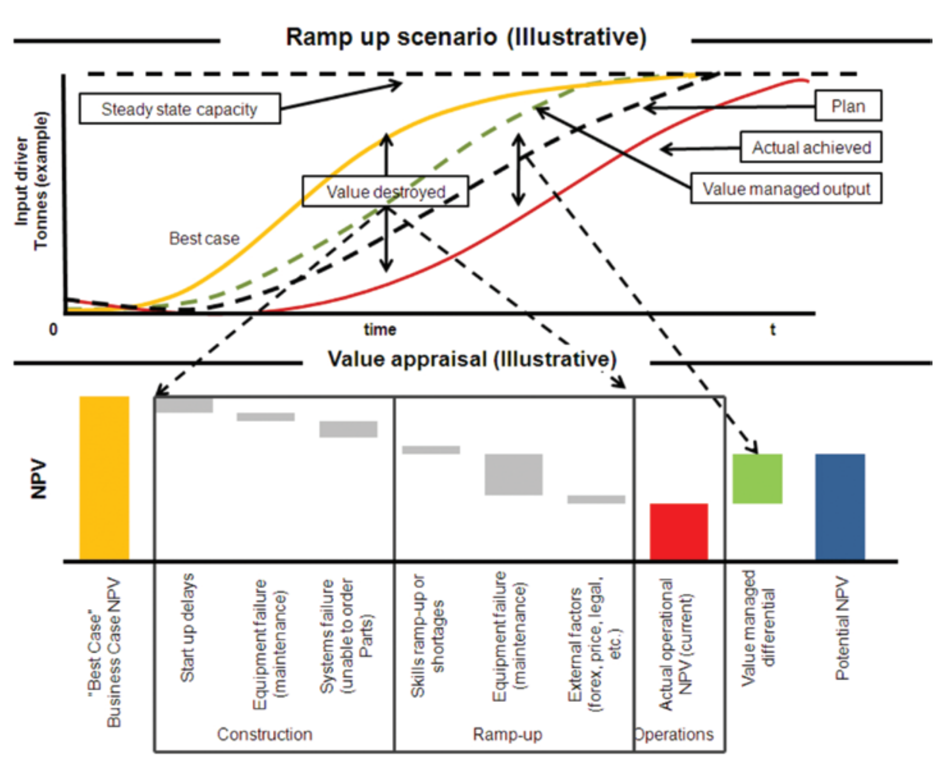

Figure 2: New capital project value destruction (Source: Deloitte, 2012)

ments and little use of predictive maintenance or condition-monitoring technologies.

- Little was done to perform acceptance testing (e.g., predictive maintenance baselines) and ensure proper installation and readiness for mission prior to releasing the contractor(s), leaving the operations and maintenance organizations to fix the mistakes of the contractor(s).
- The first year of operations is very stressful, with significant unexpected downtime due to the operators and maintainers trying to learn the new plant on the fly, not having had time to prepare, train and be ready for the operations phase.

This list can go on and on, but the point is hopefully made. Please remember, the chart in Figure 2 addresses only the ramp-up period opportunities. Potential avoidable *long-term* costs related to the total lifecycle cost over the majority of the lifecycle is additional.

As mentioned earlier, actual total operating costs during the longest portion of the total asset lifecycle—the operate/maintain stage—typically are 1% to 2% higher than the expected total lifecycle costs assumed in the initial business case, and remember, this does not include the operability value destroyed. In addition, on the basis of overall equipment effectiveness benchmarks reported by Aberdeen and others, top maintenance reliability performers can conservatively expect 10% more production throughout their assets' lifecycles than mid-tier performers.[3] The increase in production and reduced costs all add up to a lot of money.

Why Does This Status Quo Continue?

It is a fair question to ask. With hundreds of millions of dollars to be saved, why is this a common practice? The answer is largely cultural; this is not the way we do things. In industries where a change in practices could bring about the greatest benefits, there are strict divisions between construction and operating responsibilities that reach conflicting objectives. This is also reflected in the division between financial management of capital expenditures (CAPEX) and operating expenditures (OPEX). To put it mildly, there is a gap that new assets have to cross as they become operational from construction and CAPEX to operations and OPEX.

The gap reflects the earnest and best intentions of both the engineering and operations organizations. The typical goal of the engineering and design groups is to complete the project on time and on budget, and they work diligently to prevent the introduction of additional requirements. When operations takes possession of the assets, it, in turn, focuses on attaining production targets and hitting operational efficiency metrics. Typically, neither side includes budget for the development of asset data or maintenance strategies. For the engineering group to build the necessary information, it would need additional engineering services. The operations group often falls victim to the fallacy that the staff needed to maintain the assets will just have to build the plans as they go. There are no provisions for additional staff or contractor expense to build the needed information after the handover. As a consequence, information sets developed during the project's engineering, construction and commissioning phases are not properly translated into operational information, and critical aspects of the assets' histories are lost forever.

In recent years, very thin project margins (reportedly as low as single digit) for engineering and procurement contractors (EPCs) have further exacerbated the situation. Where one might reasonably expect EPCs to differentiate their offerings by including structured asset data and detailed maintenance strategies, such options, EPCs argue, only further erode margins.

The systems used by engineering and operations also add complexity to the exchange of information. Engineering design systems are largely document oriented. They produce and manage isometric drawings, piping and instrumentation diagrams (P&IDs), mechanical data sheets, and a host of other drawings and documents. In contrast, EAM systems are highly structured and largely dependent on data populated in database fields. Different in nature, engineering data needs thoughtful transfer into EAM systems to maintain consistency and ensure the integrity of data relationships. The challenge of moving data from unstructured, document-based systems that are built from contributions of many different EPCs to a single, structured, database-backed system is significant but not insurmountable.

Underlying these challenges is a failure on the part of the corporation that will own and run the assets to include the whole asset lifecycle in their management of data standards. In several cases, companies have built data standards into their EAM system. The reporting functionality of top tier EAMs—such as MAXIMO and SAP—benefit from data standards for asset hierarchies, classifications, characteristics and domain values. Indeed, companies that have put these standards in place are generally in the group that continues to show improvement in asset management performance. Nevertheless, in very few cases have these standards been trans-

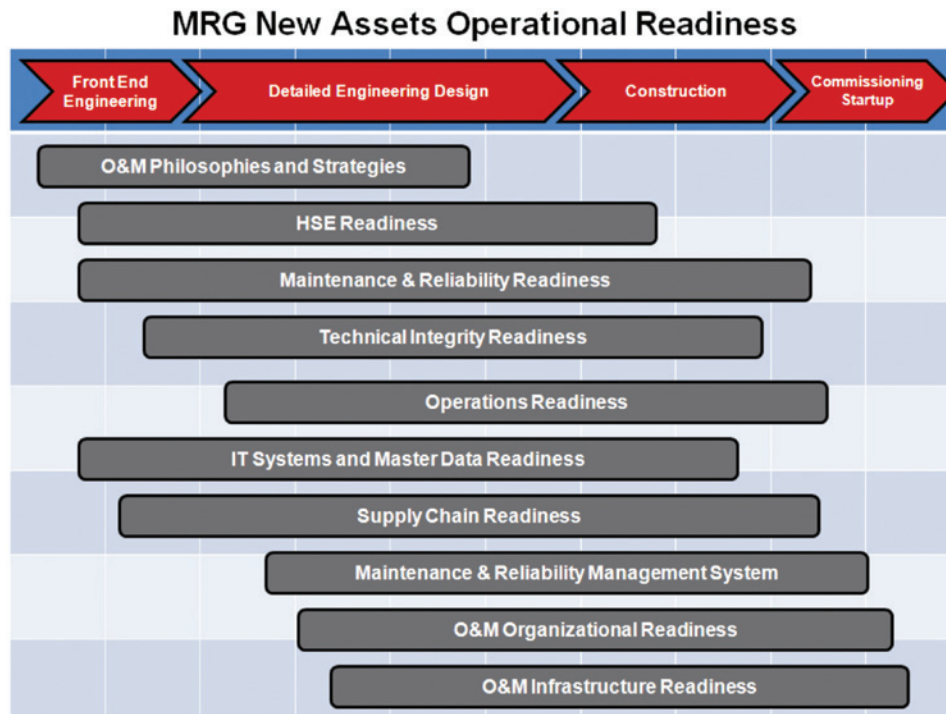

Figure 3: Comprehensive operational readiness plan (Source: Management Resources Group, Inc.; 2012)

Choices made during the early design and construction phases set in place the long-term operating performance, as well as the long-term operations and maintenance costs for the more than 30-year life of the asset.

lated into handover requirements that EPCs must include in their project bids. This generally reflects the lack of an entity with the authority to span from engineering into operations and maintenance. It follows that without a requirement for the foundational data, the maintenance strategies are also overlooked.

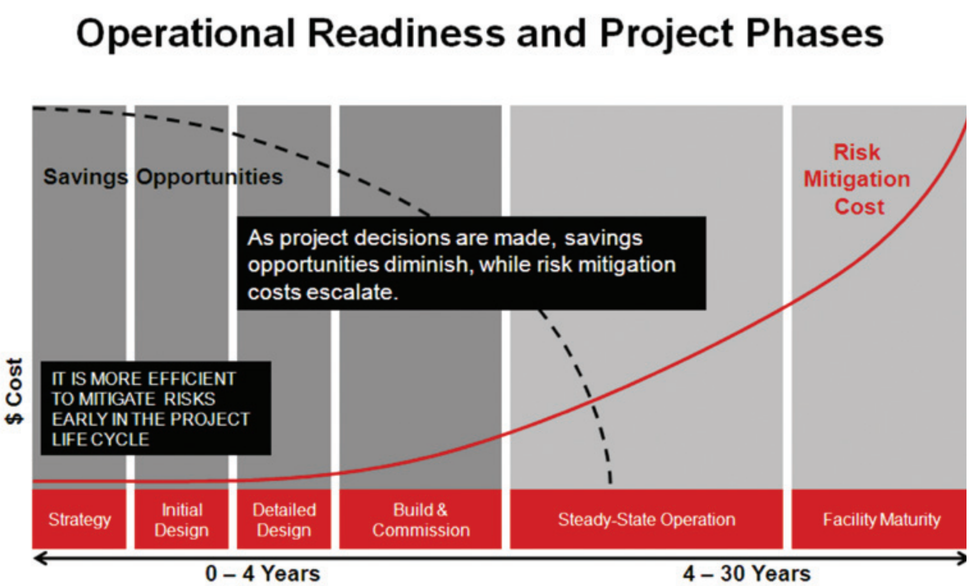

Figure 4: Theoretical risk mitigation costs vs. lifecycle phases

The typical status quo will continue without investment in and attention to operational readiness during the early design and construction phases of the project.

Mitigating Strategies

As mentioned earlier, there is ample published proof that a well-designed risk mitigation program will easily reduce total long-term lifecycle costs by 1% to 2% (conservatively speaking, and again, this does not include avoided operability risks and CAPEX benefits), streamline start-up and ramp-up activities, and enhance early operational performance. Robust programs address myriad risks by capturing asset data; developing failure-mode-based maintenance strategies; creating condition baselines; charging the work management system with all relevant asset, spare parts and maintenance strategy data; and finally training and preparing the operations and maintenance workforce—all during the engineering and construction phases of a project.

Figure 3 is an example of the business areas addressed by a comprehensive operational readiness program.

Each major category shown in Figure 3 represents a detailed and comprehensive set of activities, each almost a sub-project in itself. The threads of the operational readiness plan illustrated in Figure 3 are detailed in a separate paper by Bruno Storino[4]. While it is a lot of work to carefully develop and execute a comprehensive operational readiness program, remember the short- and long-term benefits far outweigh the costs.

In addition to a clear plan consisting of the categories outlined in Figure 3, the effectiveness and efficiency of the new asset program can be greatly enhanced by these supporting standards: guidelines, reference documentation and formal requirements. For example, master data standards provide the detail needed to develop handover requirements for the EPCs during the initial bid process. Later in the project, these standards support consistent implementation of maintenance strategies. Maintenance strategy standards, organized according to the equipment types defined in the master data standards, significantly reduce the engineering effort required to analyze and build the maintenance program. A comprehensive review of the standards needed and the supporting development process is detailed in a separate paper by Will Goetz[5].

"The Early Bird Catches the Worm"

There is ample proof and little argument today that organizations that deploy best reliability-based maintenance practices to *existing* operational assets produce significantly more asset availability at lower costs. Where making a profit is important, such organizations have a dramatic bottom-line impact and enhance their competitive footing. Numerous articles have been written detailing the mechanics of such programs and the successes of companies that have employed them. We argue (and empirical evidence supports) that developing such a program, that is bringing new assets into these reliability-based maintenance programs *early in an asset's lifecycle,* is more cost effective than developing a program at any other time, and, as we've presented, can drive significant value both in the short and long term.

Think of best reliability-based maintenance practices as a risk-mitigation program designed to anticipate and mitigate potential problems that are likely to negatively impact total project value once operation begins. Such programs prepare the organization that will be responsible for the operation and maintenance of the new assets *during design and construction*. With the right preparation, the organization will be more ready to assume the operations duty than has historically been the case. The term "operational readiness" is rooted in this principle.

Figure 4 illustrates the increasing cost of risk mitigation as a new capital project progresses through its lifecycle stages.

Note in Figure 4 the sharply increasing cost of risk mitigation as a project progresses. It is significantly cheaper to address risk mitigation at the earliest stages of the asset lifecycle.

Interestingly, as Figure 5 shows, the vast majority of the total lifecycle cost of new assets may already be irreversibly incurred *prior* to new plant commissioning. The ability to influence the total lifecycle cost of new assets by 1% to 2% (conservatively speaking) is lost once the assets are commissioned.

There is ample proof today that organizations that deploy best reliability-based maintenance practices to existing operational assets produce significantly more asset availability at lower costs.

Incorporating the reliability point of view as an equal partner at the earliest stages of the new asset lifecycle will add costs to the capital expenditure (estimated to be 2% to 3% of total project cost), but will drive benefits far in excess of those costs—both immediately upon commissioning and over the long haul.

As we have demonstrated, the business benefits of bridging the gap between construction and operations are substantial. They are realized from several areas and have the potential of reducing the overall project budget. Within the design and construction phase, the development of asset data and maintenance strategies can be both applied to the reduction of initial capital spare parts costs. Rather than accepting

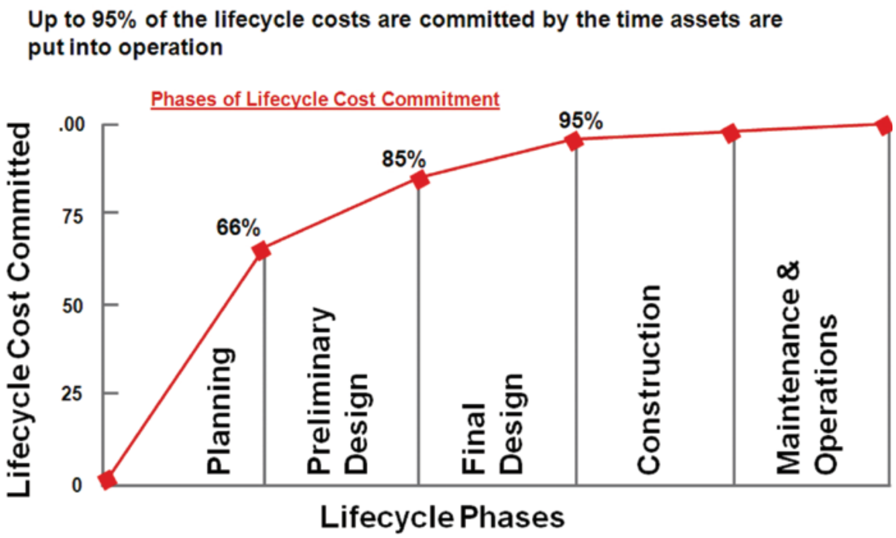

Figure 5: Phases of lifecycle cost commitment (Source: Ben Blanchard: Design and Manage to Lifecycle Cost; MA Press)

the equipment manufacturer's recommendations on spares stocking, optimal stock levels can be established that more than offset the data and strategy development costs. Furthermore, an organized approach can avoid spare parts duplications and foster interchangeability with benefits to the investment in capital spares and the inventory account. The application of predictive technology for the development of baselines prior to acceptance has the added benefit of identifying installation defects, which saves repair costs (and downtime) from affecting operating expenses. MRG, Inc. has proven these two benefits, offsetting the upfront operational readiness investments for several clients.

In addition to cost-savings benefits, development of asset data and maintenance strategies during the capital phase of the asset lifecycle also makes good financial sense. Since the asset data and maintenance strategies provide a benefit to the company throughout the lifecycle, they should be capitalized and amortized across the life of the asset. Incurring the expense to build the program prior to the operating phase of the asset lifecycle allows the operating budget to be built on an assumption of steady-state operation and based on budgeting benchmarks for similar assets. Paying for these efforts as operating expenses can impact margins, overstate operational costs and affect business performance. Remember, thinking that these foundational programs will be built over time is a flawed assumption. As countless examples across numerous companies show, the program is never really built and assets are allowed to degrade into less than top quartile status, a difficult condition from which to recover.

Conclusion

Reliability-based maintenance organizations create significant value, and the organizations that implement programs early in the lifecycle enjoy the greatest benefits. The costs of the program are typically in the range of 2% to 3% of overall project costs. Confirming Deloitte's findings, companies like Shell Oil have observed that these costs are typically recouped quickly in increased asset reliability, improved safety, lower modification costs, and especially, in reduced operating and capital expenses associated with turnarounds.6 Extending asset data and maintenance standards into the design phase and establishing strict reliability-based turnover and commissioning standards will undoubtedly encounter cultural and political challenges, but the business benefits are significant enough to warrant the level of executive sponsorship needed to overcome such barriers. Companies like Chevron are establishing executive sponsorship of this philosophy, where a higher authority bridges the gap between engineering/construction and operations—insisting that data standards and reliability-based maintenance strategies be part of the capital project deliverables, prohibiting projects from being declared complete without these programs, and disallowing engineering/construction decisions that will be detrimental to the long-term operating and maintenance phases of the asset lifecycle.

A successful operational readiness program—including a data and maintenance strategy program for new assets—depends on a set of detailed corporate standards and well organized workflows. Success with large capital projects further depends on software systems used for managing the vast number of documents and for validating data from documents against the standards. Fortunately, many organizations already have the software platforms and parts of the standards needed. As awareness of the business case, tabulated in Table 1, increases and early adopters establish further proof, more organizations will be seeking to put all these pieces together and take on the early incremental costs in favor of the long-term, game-changing benefits.

It is high time we relegate these antiquated practices to the ash heap of history, and for serious and well-informed companies, there are ample financial and practical reasons to do so.

Lifecycle Phase	Ramp Up	Operate
Cost Category	2% to 3% of Project Cost	NA
Benefit Category	30% Project NPV Improvement	1% to 2% reduction in lifecycle costs 10% greater production potential across the asset's lifespan

Table 1: Summary of business case elements

1. Deloitte. Effective Operational Readiness of Large Mining Capital Projects – Avoiding value leakage in the transition from project execution into operations. Article, 2012.
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Bruno Storino is a Senior Manager with Management Resources Group, Inc. He is a Mechanical Engineer with an International MBA and twenty years of experience in the process and manufacturing industries.

Pump Improvement Opportunities

Increase Uptime

Heinz P. Bloch, P.E.

When performing reliability audits decades ago, pump failure statistics were made available or could be recovered with relative ease. But even then, the sources were usually kept confidential because fire incidents are stressful, to say the least. (See Figure 1).

It was known (in 1974) that for every 1,000 refinery pump repairs, there was a pump-related fire incident. More recently, and in an oil refinery with approximately 2,000 installed pumps, the acknowledged mean time between repairs (MTBR) was six years. This would allow us to calculate that approximately 333 pumps underwent repair each year. Since that particular facility experienced five pump-related near-disasters in the span of 14 years, doing the simple math tells us that its rate of major pump issues tracked the 1,000-per-1 rule for presumably API-compliant pumps within 6% accuracy.

Figure 1 (above): Assets and human lives are at stake when there are pump fires in refineries or petrochemical plants.

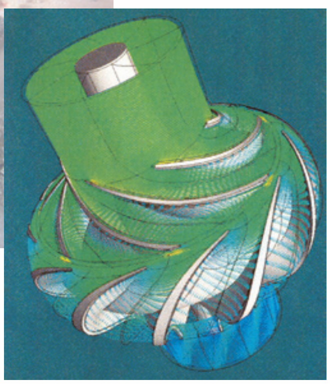

Figure 2 (right): Relative velocity plot of an optimized vertical pump stage (Source: Pump Design, Development & Diagnostics; gregcase@pdcubed.net)

Failure statistics tell the story

An airplane has about 4,000,000 parts, an automobile approximately 10,000 parts and a centrifugal process pump only about 200 parts. It's fair to say that if a machine is made up of a large number of parts, more parts could malfunction. However, this does not mean that more parts will, in fact, malfunction during an operational cycle. So, what's the point of this reminder?

As we think about the reasons why the average process pump requires a repair after approximately six years, we realize that not all of its components are designed, fabricated, assembled, maintained, operated, or perhaps installed with the same diligence as aircraft components.

It doesn't have to be that way. Alloys can be upgraded and better components are sold to owner-purchasers that insist on such upgrades. Advanced computer-based and reasonably priced design tools are available for the pump hydraulic assembly. It has been shown that computational fluid dynamics (CFD) can be used to define the improvement potential of impellers and stationary passages within pumps; Figure 2 certainly attests to that.

But the mechanical assembly (drive end) of some pumps also deserves attention, especially since this portion of the pump has been neglected in some brands or models. Fortunately, expert advice is available for the specification and selection of better drive end geometries for process pumps (see author's note below regarding availability of full-length text).

Thoughtful specification and selection used to be par for the course at best-of-class companies and there is really no reason why this thinking should have undergone change. What we see lacking today is an awareness of the precise steps that are needed for such specifying and selecting. Management has fallen prey to consultant-conceived generalities, including "lean and mean" and similar catchy utterances.

Opportunities in sealing and environmentally-friendly technology

Superior dual seals and environmentally-friendly sealing systems (Figures 3 and 4) are now available and routinely selected by reliability-

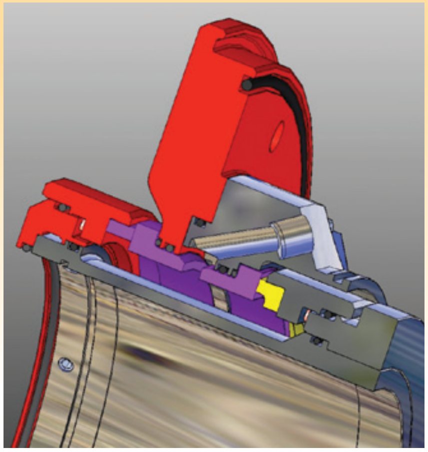

Figure 3: A dual mechanical seal. The space between the sleeve and the inside diameter of the two sets of seal faces is filled with a pressurized barrier fluid, usually clean water.
(Source: AESSEAL Inc., Rockford, TN and Rotherham, UK)

focused owner-purchasers. The primary use of cost-effective sealing is likely on ANSI and ISO-style pumps. Many slurry services in the mining, pulp and paper, and power generation industries also have benefited from adopting dual seals (Figure 3) with closed, water-containing seal support systems (Figure 4). At the pump, the sealing water is totally confined in the space between the bore diameter of the two pairs of seals and the outside diameter of the shaft sleeve. The amount of makeup water required can be as little as 40 liters per year and many systems pay for themselves in less than one month.

Taking advantage

We obviously believe that good managers must lead and ought to reinforce a failure avoidance culture. That said, the user industry should get away from the obviously flawed approach whereby people are instructed to run equipment to failure and to then try to resurrect it to a better life than ever before. It also makes no sense to wait for things to go wrong and then heap praise on super-human efforts to rebuild. The old adage of an ounce of prevention being worth a pound of cure is as valid as ever. So, consider this a call to do something about your repeat failures and start asking questions. Better yet, offer some of the solutions that have consistently kept best-of-class performers in the top rankings for safety and profitability. They have stayed at the top because they take advantage of best available technology.

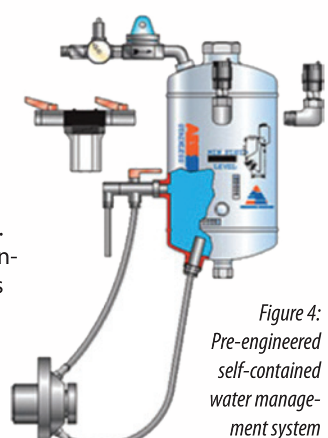

Figure 4: Pre-engineered self-contained water management system found highly effective for dual mechanical seals in slurry services
(Source: AESSEAL Inc., Rockford, TN and Rotherham, UK)

Author's note: This material was excerpted and condensed from Bloch, Heinz P., Pump Wisdom—Problem Solving for Operators and Specialists, New Jersey: John Wiley & Sons, 2011 (ISBN 978-1-118-04123-9). The hard-bound text is available from Amazon.com (List price: $49.95). It highlights highly effective techniques to prevent repeat failures of process pumps. Among other issues, it divulges and discusses superior bearing protection and sealing issues that not all pump manufactures share with their clients.

Heinz P. Bloch is a practicing consulting engineer with 50 years of applicable experience. He advises process plants worldwide on failure analysis, reliability improvement and maintenance cost avoidance topics. A frequent contributor to Uptime magazine, he has authored or co-authored 18 textbooks on machinery reliability improvement and over 500 papers or articles dealing with reliability-related subjects.

Maintenance Reduction

With the Help of a Computerized Maintenance Management System

Devesh Dubey

An asset intensive enterprise aims to keep assets always in a productive state. A Total Productive Maintenance (TPM) philosophy has been proven vitally useful in approaching this ideal state. Key points of TPM are:

1. Improvement in the overall equipment effectiveness(OEE);
2. Improvement in maintenance activity;
3. Maintenance skill development;
4. Focus on daily autonomous maintenance and operator skill enhancement;
5. **Reduction in the maintenance activity itself.**

TPM companies usually focus on the initial four points, therefore they increase OEE with a fixed average preventive maintenance cost over a period of time. But other companies invest in a computerized maintenance management system (CMMS) to help them efficiently manage maintenance activities.

When an asset is procured, a company does a long-term investment as a fixed cost of asset. There is also an expected cost of maintenance included in the asset's variable cost. Maintenance costs include money spent on both planned and unplanned maintenance work. Yes, accidental breakdowns abruptly increase it [see Figure 1]. As an asset undergoes different types of maintenance activities in its lifetime, its total cost of asset ownership, which includes AMC, also increases.

All assets have fixed designs when a CMMS system is implemented. A CMMS implementation project does not focus on modifying asset design to optimize its performance and reduce maintenance activities and cost. Rather, this system helps in better management of preventive maintenance activities. This significantly reduces the probability of accidental breakdown events. All breakdown associated costs, including productivity loss, is thus avoided. Here we can say that an asset with a CMMS system can now be operated with a fixed average maintenance cost (see Figure 1).

The real question is, Should we be satisfied with just this one-time reduction in maintenance cost? If a company wants to achieve the next level of maintenance cost reduction, it should reduce maintenance activity itself (see Figure 1). Consequently, maintenance reduction planning can be the way forward and CMMS can be leveraged in this pursuit since companies don't have reliable data that can help them in reducing maintenance activity and associated costs.

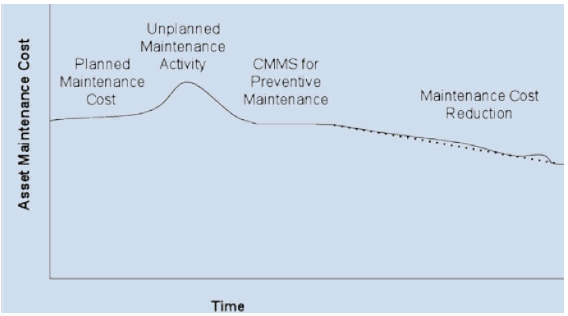

Figure 1: Maintenance cost reduction over a period of time

Maintenance reduction is a continuous process that focuses on working assets, their spare parts and maintenance costs. CMMS systems can collect maintenance time and cost data at asset or spare parts levels. There are several metrics that can help in maintenance reduction planning.

Average maintenance time (AMT)

A CMMS should be able to record actual maintenance time when a specific planned preventive maintenance activity (PMA) is performed on an asset. Over a period, there will be many times when the same PMA is carried out, but actual time required for this activity may vary. These time data points can be used to calculate simple average maintenance time for an asset's PMA.

Now planning should consider different ways to reduce it. For example, during procurement decision making, only those spare parts that help in reducing AMT should be bought. Collaboration with suppliers is also possible to develop better spare parts.

Average time in between two same unplanned maintenance activities (ATBUM)

With preventive maintenance planning in place, we have constant elapsed time in between two same planned maintenance activities. But there will be accidental breakdowns or unplanned maintenance activities. A CMMS should be able to record the elapsed time in between two similar accidental breakdowns or unplanned maintenances based on which average time can be calculated. Planning should try to increase this by modifying asset design, procuring better spare parts, improving job plans, and implementing better training and skill development.

Daily autonomous maintenance time (DAMT)

For each asset, a CMMS should be able to record DAMT. This data will help in maintenance reduction planning. For example, while procuring the same spare parts, we can compare spare parts from two or more different suppliers and select the one that helps in reducing DAMT. This metric will also help in collaborative research and development of spare parts, which can result in lesser maintenance time.

Average skill cost of maintenance activity

Maintenance activity is carried out either by operators or specialized skilled labor. There is always cost associated with each hour spent by them on maintenance activity. The more skilled labor hours spent, the more the cost associated with maintenance activity. The CMMS should be able to record the asset-wise total skill costs required over a period of time. This cost reduction also should be an aim of maintenance reduction planning.

Skill cost reduction can be possible by the following means:

1. Operator's skill sets can be improved so more maintenance activities can be carried out by the operator only.
2. Incremental modification in asset or procuring better spare parts so a person with a lesser skill set or a sole operator can maintain it. The lesser skill set person will obviously cost less.
3. Improvement in asset or better spare part use so skilled labor requirements can be reduced. This may also help in reducing the time (hr) spent by a skilled person on maintenance activity.

Maintenance common and special cause recording

There are both common (historical and quantifiable variations) and special (unusual, not previously observed, non-quantifiable variation) causes behind maintenance requirements. Maintenance reduction should focus on eliminating common causes, like inappropriate procedures, poor design, ambient temperature and humidity, substandard raw material, etc., and special causes, like power surges, operator absent, broken part, operator falls asleep, etc.

During maintenance activity, if common or special cause is identified, it should be recorded in the CMMS. Root cause and statistical analysis will help in the elimination of common causes, while better job plans (having instructions for avoiding special causes) and training will help eliminate special causes.

Conclusion

Computerized maintenance management systems are helping with end-to-end enterprise asset management. They have been helpful in efficiently and effectively managing preventive maintenance activities, but they should also help in reducing maintenance activities and costs. Gone are the days when information systems were just used to manage information and processes. Now their role is extended to smartly manage the information and help in analytical decision making. A CMMS with maintenance reduction features/metrics will surely reduce costs associated with maintenance activities. This, in turn, will finally reduce an asset's total cost of ownership.

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Devesh Dubey is currently working as a senior associate consultant for Infosys Ltd. His expertise lies in the area of enterprise asset management. He has also played a key role in service request management system design and development.

reliability

eR electrical reliability

Implementing ESA

as Part of Your Predictive Maintenance Program to Improve Electrical Reliability

PART 2

William Kruger

This is a follow-up to the article that was published in the Dec/Jan 2012 issue of Uptime.

Premier on ESA

Abtract

This is the second part of a series of articles discussing using electrical signature analysis (ESA) to improve a plant's electrical reliability. This article was written to give those not familiar with spectrum analysis the basics to read and interpret the graphs and displays used in spectrum analysis. It also introduces some basic analysis techniques to begin using ESA to identify developing problems in the motor system that could lead to either a loss of production or an increase in maintenance costs.

Electrical Signature Analysis

ESA is a predictive maintenance (PdM) technology that uses the motor's supply voltage and operating current to identify existing and developing faults in the entire motor system. These measurements act as transducers and any disruptions in the motor system cause the motor supply current to vary (or modulate). By analyzing these modulations, it is possible to identify the source of these motor system disruptions.

Machinery Analysis

Historically, vibration analysis has been the basis for rotating machinery analysis to assess the condition of rotating equipment and has been used very effectively for over 70 years. Modern electronics and microprocessors have matured this process, from simple vibration amplitude measurements using a coil, magnet and a meter to measure overall vibration amplitudes to quickly assessing the mechanical condition of rotating machinery. It soon became apparent that machines with high levels of vibration generally were in poor mechanical condition and led to the development of various vibration severity charts, all of which are based solely on users' experience.

Spectrum Analysis

Spectrum analysis in signal processing is the process that defines the frequency content of a time domain signal. Once the frequency content of the measured signals are known, they are correlated to the operational and design characteristics of the machine or machines to help identify the force that creates the oscillating motion.

Spectrum analysis in signal processing is the process that defines the frequency content of a time domain signal.

Machinery vibration spectrum analysis begins with the sensor (transducer) placed on or near the oscillating component; this is usually at the bearing or the bearing housing to convert the component's mechanical motion to an electrical signal. The output electrical signal follows the component's motion exactly, which varies with time and is referred to as time domain signals. The strength or amplitude of the signal varies depending on the amount of movement.

Early spectrum analysis used tunable filter analyzers to sweep an analog bandpass filter across a predetermined frequency range. These analyzers worked similar to tuning a radio. As the bandpass filter scans through the frequency range, any signals present in that range would create an output. The output of the bandpass filter would be traced on a frequency graph to identify the frequencies that were present in the output of the transducer.

The modern multi-channel, high resolution, digital analyzers create the frequency spectra using fast Fourier transform (FFT). Additionally, they allow various signal processing techniques, such as sideband analysis, synchronous time averaging, negative averaging, envelope processing and many other advanced techniques that accurately interrupt the spectra.

Regardless of the advances in signal processing, vibration analysis is still limited by the laws of physics and the limits of the transducers. Since the vibration is a measure of a machine's mechanical oscillations, either random or periodic, sufficient force is necessary from the machinery condition or component fault to overcome the mass and stiffness of the machine and structure, as well as any damping supplied by the bearing or support system.

Additional limitations are created by the measurement transducer itself. These are the types of measurement, relative or absolute, frequency response of the transducer and the inherent frequency limitations of the measurements themselves, displacement, velocity, or acceleration.

The frequency range determines the frequencies that will be included in the fast Fourier transform (FFT) calculation. If the selected frequency range is too low, faults at higher frequencies will be missed.

Frequency Analysis

Time Waveforms

A time waveform is simply a display of a variable function in relation to time. If the variations occur at the same time intervals, the waveform is periodic. A periodic waveform is one which repeats the exact same shape or pattern for the waveform's whole duration.

The simplest form of a waveform is a sine wave and consists of a single frequency. Waveforms that are made up of multiple frequencies are called complex waveforms. The graphical display of waveforms is called the time domain. The display simply shows the instantaneous value of the variable in relation to time. In the time domain, the horizontal axis indicates time, whereas the vertical axis indicates the magnitude of the variable.

Fourier Transform

Jean Baptiste Joseph Fourier, an 18th century French mathematician and physicist, was one of the first to recognize that complex waveforms are a combination of multiple sine waveforms and initiated research into this field. The mathematical solution used to determine the series of frequencies that make up any complex waveform is named in honor of him and is called Fourier transform. The original Fourier transform assumes an unbounded or infinite sample. Since then, it has been determined that Fourier transform can be applied to a finite waveform and has been called discrete Fourier transform (DFT). Algorithms have been developed for the efficient and high speed calculation of DFTs; these algorithms are referred to as fast Fourier transform (FFT).

In simple terms, FFT takes a finite sample of a time waveform, then calculates the amplitude and frequencies of the sine waves that are combined together to create the complex waveform.

The graphical displays of FFTs are presented in the frequency domain and are referred to as a frequency spectrum. The frequency spectrum displays the frequencies present in the complex waveform on the horizontal axis and the amplitude of the signal on the vertical axis. If sufficient motion is present at any frequency, a vertical line will be displayed on the horizontal axis to indicate the presence of that frequency. This height of the vertical line or spectral line indicates the strength or amplitude of the waveform at that frequency. If one of the sine waves present in the complex waveform is at 30 Hz with amplitude of 3 amps, a spectral peak would be placed at 30 Hz and the height would represent three units.

There are many programs available to perform FFT and the analyst is not required to perform these, but the analyst does require a basic understanding of this graphical display itself. The minimum understandings of the FFT display are the frequency range, resolution and bandwidth. More advanced analysis can be performed with an understanding of sidebands, harmonics, logarithmic scaling and demodulation. The following information attempts to provide a sufficient understanding of these basic FFT principles to allow the reader to accurately analyze the data gathered using ESA.

Understanding the FFT

Understanding the limits of any display is invaluable in the accurate analysis of that display. FFT is a mathematical computation and these limits are established before the mathematical computation is performed. These boundaries are frequency range and lines of resolution.

Frequency Range

The frequency range determines the frequencies that will be included in the FFT calculation. If the selected frequency range is too low, faults at higher frequencies will be missed. If the selected frequency range is too high, frequencies' series that are close together might be combined. Additionally, the frequency range determines the data acquisition time. The frequency of a periodic signal is the inverse of time; the lower the selected frequency range, the longer it takes to perform the data collection. In PdM, most FFTs start at DC (0 Hz) and continue to some maximum value. The maximum frequency range is referred to as Fmax. For more in-depth analysis, it is possible to set the lower limit of the frequency range at a value greater than 0 Hz and some higher limit. This is referred to as a zoomed spectrum.

Resolution

The second pre-determined boundary is the lines of resolution. Each frequency spectrum is divided into a finite number of spectral lines. Spectral line is actually a misnomer since in reality it is not a line, but a spectral bin. Each spectral bin will have a high and low frequency limit. These limits are determined by the frequency range of FFT and the number of lines. The width of the spectral bin is called the bandwidth (BW). To determine the width of each spectral bin, simply divide the number of spectral lines into the frequency range (FR). If the frequency range is 100 Hz and there are 100 spectral lines, the width of each line is 1 Hz.

BW = # lines/FR

The bandwidth of each spectral bin also can be calculated by subtracting the low frequency limit (f_l) from the upper frequency limit (f_u) of each spectral bin.

BW = $f_u - f_l$

Each spectral bin is aligned next to the previous bin and the lower frequency limit of each bin is the upper frequency limit of the previous bin. The upper frequency limit will be the lower limit of the bin plus the bandwidth.

For example: In the first spectral bin in a 100 line spectrum with FR from DC to 100 Hz, the lower frequency limit is 0 and the upper frequency limit is 1 Hz. The BW of the spectral bin is 1 Hz. Then the second bin would go from 1 Hz to 2 Hz, the third bin from 2 Hz to 3 Hz and so on, with the last spectral bin 99 Hz to 100 Hz.

If the bandwidth of a spectral bin is too wide, multiple frequencies may reside in the same spectral bin. Additionally, when evaluating a frequency spectrum, the displayed frequency of the spectral bin is the center frequency (cf) of that spectral bin. To determine the cf of the spectral bin, simply calculate the average of the upper frequency limit and the lower frequency limit.

$$cf = (f_u + f_l)/2$$

What this means is that the indicated frequency may not be the frequency of the actual signal. The frequency value displayed is the center frequency of the spectral bin, whereas the actual frequencies of the waveform(s) could be any frequency within the bandwidth of the spectral bin. Each spectral bin may include more than one frequency. The wider the bandwidth, the less accurate the frequency of the displayed value of the spectral bin, and this increases the probability of analysis error.

To reduce this analysis error, simply increase the resolution of a FFT spectrum. Reducing the frequency range of FFT increases the resolution, but also increases both the time intervals between data sampling time and the data acquisition time. Another method is to increase the number of spectral bins into which FFT is divided. Increasing the number of spectral bins requires taking more samples of the measured signal. To double the number of lines of resolution, twice as much data must be acquired.

Determining Resolution

The number of lines of resolution (# lines) of a FFT spectrum can be determined by simply multiplying the period (P) of the time waveform by the frequency range (FR) in cycles per second (cps).

(# lines=P x FR)

Since ESA digitizes the time waveform, FFT is performed in the computer, where it is possible to change the FFT resolution after data collection. This allows the analyst to examine very small portions of the captured waveform. However, it is important to remember that by reducing the period of the time capture, the number of lines of resolution will be reduced proportionally and the probability of analysis error increases.

Amplitude Displays

Linear Scaling

The most commonly used graphical display of FFT is the linear scale. On the linear scale, the spacing between the markers is always the same and equally spaced. This allows all of the data to be conveniently displayed on a single graph. Linear graph displays work well with data sets when meaningful changes are important and very small changes are insignificant. The units displayed on the linear scale are the engineering units of the measured variable. In ESA, these units are either voltage (volts) or current (amps).

Logarithmic Scaling

The logarithmic scale displays the amplitude in order of magnitude or a logarithm of the variable instead of the variable itself. One advantage of the log scale is the ability to display a very large range of amplitudes on a single graph. When very small changes in the measured variable are significant, displaying the variable in the linear format may not adequately identify the change. In these instances a logarithmic (log) display is used.

In ESA, the log scale is commonly used since the measured variables are line voltage or current. Very small changes in either of these measurements are used to identify faults in the motor system. The carrier frequency of these variables is at the frequency of the applied voltage, usually 50 Hz or 60 Hz.

Since the logarithmic display is essentially a ratio, it is also a very convenient method for comparing unlike variables. This has proven extremely useful in ESA since one of its important aspects is the ability to differenti-

Field Quantity Ratios		
Engineering Unit Amplitude	**Decibel (db)**	**Ratio**
1000	0	1:1
700	-3	1.414:1
330	-10	3:1
100	-20	10:1
33	-30	30:1
10	-40	100:1
3.3	-50	300:1
1	-60	1000:1
0.33	-70	3000:1
0.1	-80	10000:1
0.03	-90	30000:1
0.01	-100	100000:1

Table 1

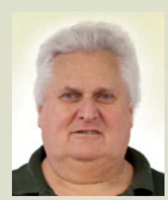
ate between faults in the incoming power and faults added by either the motor or the driven machine.

The units used in the log scale are decibels (db), which are a logarithm with a base ten. The db is a unit used to describe a ratio. The measurements of voltage and current are field quantities and the db ratios used in ESA are also field quantities. Table 1 provides a guide to the relationship of the measured variable and the peak value of the current and voltage waveforms compared to the highest peak in the spectrum.

Summary

Effective use of ESA as a PdM technology requires the ability to manipulate, interpret and understand the graphs, charts and displays developed by the ESA software. These graphs, charts and displays are then used to identify faults in the motor system. Engineers and PdM technicians familiar with vibration analysis will find that ESA FFT is similar to the vibration spectrum and many of the analysis techniques are the same.

However, even in MVA, it is important that the analyst has a thorough understanding of not only what FFT is indicting, but more importantly, what it isn't.



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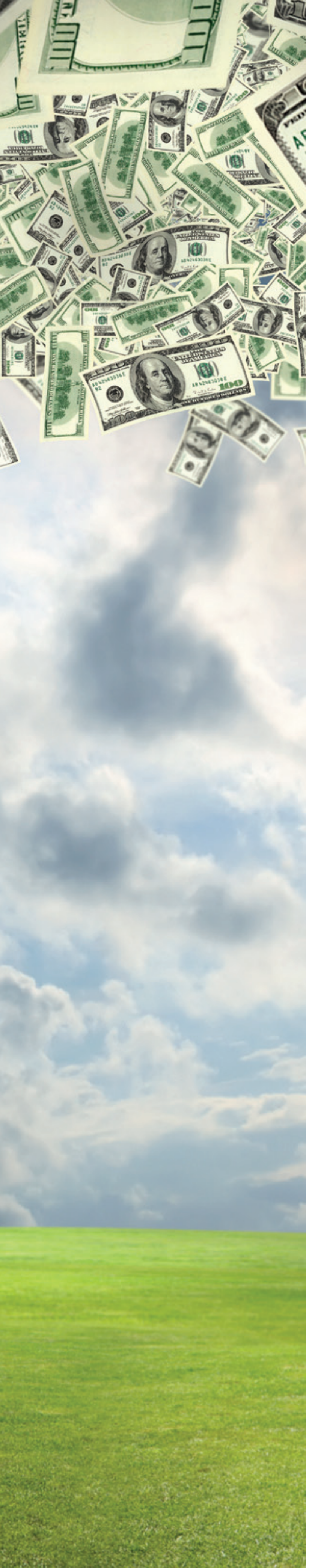


condition monitoring

Mt motor testing

Motor Performance Management

The art of saving money by extending motor life and optimizing motor performance

Derek Norfield

Electric motors are the prime movers in the industrial environment. Although motors are efficient and reliable, they do eventually fail - and those failures often disrupt production, causing lost revenue that can be many times the cost of the motor. Managing motors saves both direct costs and the disruption of lost production.

In general, today's electric motors are so well designed and built that they are very efficient and continue to operate even when receiving a lot of abuse and neglect. This is fortunate since they generally are both neglected and abused.

Motor performance management (MPM) takes a systematic approach to extend the life and reliability of motors and to better predict their end of life so they can be removed from service at a scheduled outage without disrupting production.

An MPM program starts by looking at the recent history of failures and repair costs to uncover the most expensive and disruptive events and then works to minimize the chances of recurrence. Since each facility is different, there is no "cookie-cutter" solution, but normally two or three areas show up as above average in failures and become the "low-hanging fruit" in the improvement process. On the other side of the coin, we look for some things being done right that we can build on in a positive way.

Figure 2: Bearing total failure. Cage destroyed, ball spacing lost and rotor rubs on the stator.

Figure 4: The invisible motor. Between the shaft coupling and the electrical connections is unknown.

As we look at the failures, we start to see patterns. Maybe a lot of the failures have been in service for a similar period, for example. It could be that a lot of bearings die due to grease being washed out. Frequently, a motor shows distress but no one thinks it important to report, or maybe the pressure for production causes it to be ignored. Without playing "The Blame Game," we work on educating people about the true cost of failures that take down production compared with pulling the motor at scheduled shutdown.

A motor will fail at some point and usually shows signs of distress for a while before that. Vibration measurements, IR scans and ultrasound readings can detect the impending failure with enough time to prepare a replacement. Sometimes, a voltage spike or low voltage (causing contactor to partially drop out and cause single phase operation) will cause an almost instantaneous failure and then it is a matter of whether a spare is available – part of the planning phase of motor management.

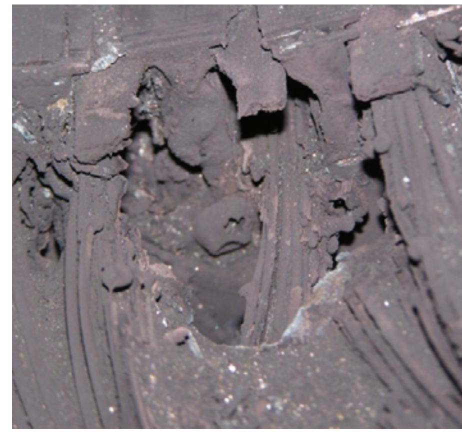


Figure 1: Electrical failure and resulting arc damage

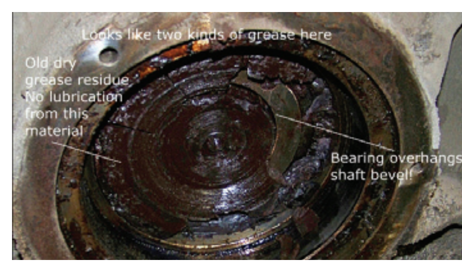


Figure 3: Bearing functional failure - noise, vibration, rapid wear. Old grease can no longer provide lubrication.

Here is a typical electrical failure (Figure 1): Gradual deterioration of the insulation leads to an occasional arc across the surface and maybe low insulation resistance at startup (cold and damp). Overload or a spike will trigger the final failure sequence, which might take a second or two. Once the arc starts, it generates intense heat, melts – or rather vaporizes – copper and the high current causes the starter to trip out.

Root cause analysis would normally indicate insulation damage by factors like grease on the windings degrading the insulation, over temperature due to blocked cooling, thermal cycling causing abrasion, or mechanical damage such as a balance weight coming off the rotor. One other cause is overheating due to a rotor rub after bearing failure.

As we look at the failures, we start to see patterns. Maybe a lot of the failures have been in service for a similar period, for example. It could be that a lot of bearings die due to grease being washed out.

Bearing failure is the leading cause of electric motor failure. In many cases, the dying bearing generates a high noise level to alert users of trouble. The real problem is when the bearing goes quiet again. That means the balls are no longer supporting the shaft! In a very short time, the noise level goes high due to rotor rub, followed by silence after the winding fails as in Figure 1.

Bearings gradually fail. There are early life failures due to installation damage and contamination, but generally bearings are designed for 100,000 hours of operation. After ignoring a bearing for a few years, adding fresh grease is as likely to move contaminated material into the load zone as it is to improve operation. Over greasing, even with clean, fresh grease of the right grade, will cause over temperature due to the churning effect as the balls continually squish the excess grease out of the track. In turn, the temperature will rapidly degrade the grease so it ceases being a lubricant and now metal to metal contact causes wear. Wear generates particles, noise level increases and the bearing is on the fast track to failure. (Figure 2)

If we are able to pull the motor before complete failure, we may see some of the following conditions. (Figure 3)

The motor had not reached catastrophic failure and was still running when removed. In other words, a success story for the MPM program. We see old dry grease where the oil has leached out, leaving the binder behind. From two colors, it also looks like someone used the wrong grease when relubrication took place. Incompatible greases may harden or liquefy – in either case the lubrication process stops. Careful observation may show other problems, for instance there may be dirt or a metal chip behind the bearing that prevents it from seating properly and maybe even causing it to be out of square (another cause of rapid wear).

Bearing failure is the leading cause of electric motor failure. In many cases, the dying bearing generates a high noise level to alert users of trouble. The real problem is when the bearing goes quiet again. That means the balls are no longer supporting the shaft!

A motor performance management package is a system in which appropriate tools are used to improve motor reliability, reduce cost of repair and replacement, manage spares inventory and ensure appropriate preventative and predictive maintenances are carried out. Program and supply chain management are part of the package as well.

In other words, MPM is a total focus on motors.

An electric motor is a conversion device that converts electrical energy into mechanical work, thus putting it between two separate work groups.

- To mechanics, electric motors finish at the drive coupling.
- To electricians, motors finish at the junction box.
- In between is the invisible motor. (Figure 4)

The MPM program makes the motors visible. The preventative and predictive tasks are monitored to detect developing problems. In many facilities, the vibration data is collected and never analyzed because of staff reductions, loss of knowledge and its low priority until something fails. The MPM program must look at the data and find the motors that are in distress. The problems must be documented to establish credibility so operations is given a real reason to get a planned replacement into service with minimal production disruption.

Figure 5 shows a motor in which simple visual inspection will tell there is a contamination problem.

Figure 6 depicts a motor which an infrared scan will reveal as overheated. It is likely that the bearing will soon be like Figure 2.

Figure 7 shows what a dirty winding will cause due to blocked airflow. Over time, excess heat degraded the insulation, but after 10 years

Figure 5

without any problems, the motor fails overnight and with no warning. WRONG! The warning signs were ignored, preventative maintenance was not done because motors are invisible until they fail.

What goes into an MPM program?

A number of standard procedures conducted regularly cause a steady improvement in performance and overall equipment efficiency:

- Improving repair specifications to give high quality with minimum cost;
- Precision aligning motors upon installation;
- Reducing wear and tear through preventive maintenance;
- Using predictive measurement data to replace critical motors on planned schedule before they cause downtime;
- Doing root cause analysis on critical motors that fail and feedback the results to reduce future failures.

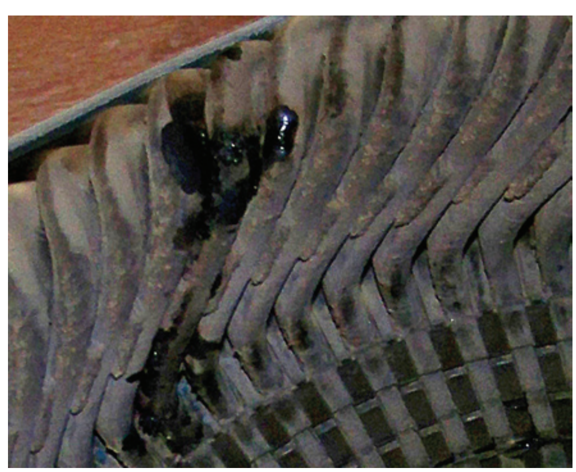


Figure 7

The first step is research to get an understanding of the current condition and the areas with the highest potential for improvement. Some of the factors we look at are:

- Number of motors;
- Average age of motors;
- Sizes of motors;
- Number and condition of spare motors;
- Preventative maintenance and predictive maintenance practices;
- A review of the information to obtain a snapshot of the current situation.

To maximize return on investment, the MPM program needs to have highly effective:

- Planning - with concepts for effective material management and ensuring the workflow is effective.
- Information management – data available when you need it, where you need it and at your fingertips.
- Implementation of preventive maintenance/predictive maintenance programs.
- Work schedule - based on production needs and doing preventive maintenance work at scheduled downtime.

The key word in MPM is "management," but an equally important word is "focus." The MPM team is concerned just with the motors and checks everything on a regular basis without distractions.

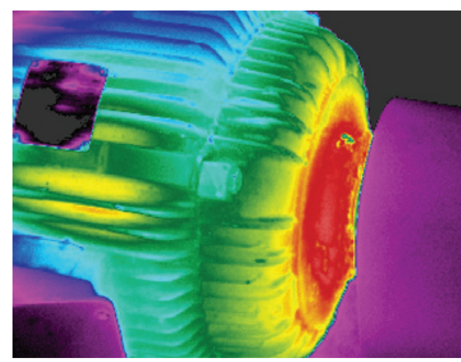


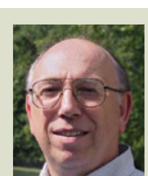
Figure 6

An MPM program uses a small, dedicated team of expert engineers and technicians focused only on motors to achieve the following goals:

- Extend motor life (environment, lubrication, loading);
- Predict failure in time to schedule required actions (vibration, infrared and ultrasonic emission testing, data management, etc.);
- Replace motors with ones that are correctly sized, suitable for the operating conditions and correctly installed (alignment, grounding and safety, etc.);
- Reduce the costs of repairs by actively working with repair shops to ensure quality, specifications, scope of work and pricing are optimized.

A solid set of tools to cover oil analysis, machine alignment, vibration analysis, thermography, electrical signature analysis and ultrasonic emissions is crucial, as is the experience to use them.

An asset maintenance database is an integral part of MPM to track the motors, build a history of each location and to ensure maintenance is kept current. It also helps to ensure all the small things get done right so they don't grow into major problems. Planning and execution are the twin brothers of successful maintenance.



In 2009, Derek Norfield joined ABB as a Motor Performance Management Specialist building programs to improve plant reliability and reduce costs using predictive and preventative maintenance with a focus on electric motors. Born and raised in England, Derek graduated from Croydon College, London in 1969 with a BS degree in Mechanical and Electrical Engineering. Since then, he has been a specialist in vibration, balancing and reliability. www.abb.com

management Ps planning and scheduling

Using Metrics

to Influence Planning and Scheduling Behaviors

Jeff Shiver

While many organizations have maintenance planning and scheduling individuals or groups, few measure the effectiveness of the function. Why is it that we want to measure anyway?

Improvement is one reason. For improvement, we need to know where we have been and hopefully, where we want to go. Another is that people like to get a score or feedback on how the organization sees their work. That said, while metrics reflect individual performance, the focus of metrics should be to identify issues with the business processes associated with the work and not the individual themselves. From the metrics, we can identify trends and patterns. Adding to that, consider: "What gets measured gets done. What gets celebrated, gets done well."

Recognize that there are two types of metrics, leading and lagging. Both are useful. To better understand the difference, ask yourself if you are operating within the organization as doctors or coroners? Are you taking a pulse of the organization or performing a postmortem on last month's performance? In most organizations, the reality is that everyone is focused on the postmortems. Often, the reason for the postmortem focus is those numbers are the

Time in Status or Phases

Metric	Target	Objective
% of work requests remaining in "request" or "new" status for more than five days, over a specified time period (e.g., last 30 days)	80% or more of incoming work requests should be reviewed and validated within a maximum of five days. (See the following metric and target)	Eliminating partnership issues regarding "responsiveness" of maintenance and the entry of additional requests with inappropriate priorities to get a response
Activity times of other statuses could be measured, such as: "Awaiting approval" "Awaiting planning" "In planning" "Awaiting materials"	80% of all work orders should be processed in five days or less; Attention must be paid to "late finish" or "required by date"	Provides an understanding of on average processing times to identify opportunities for improvement Are there obstacles preventing timely processing?

Planner Thoroughness

Metric	Target	Objective
Planning Work Order Completion – % of work orders with all planning fields completed (e.g., task duration, required by date) over a specified time period	95% or more of all planned jobs	Measure of planner accuracy and thoroughness

For Organizations New to the Planning Function - measure the level of job plan preparation

Metric	Target	Objective
# of detailed job plans written per week	Varies by site, but if new with no or few job plans, target a minimum of two to three detailed job plans to be developed per week	Not every job requires a detailed job plan, but when applicable, job plans help transfer knowledge, and drive precision maintenance activities and wrench time

most readily available from current reports. They are easy to identify and it is the quickest way to satisfy the demand for metrics. Lagging metrics are like looking in the car's rearview mirror; they only tell you where you have been and not where you are headed.

Ideally as a rule of thumb, you should have two leading metrics for every lagging metric. Leading metrics are performance drivers. Utilizing them allows you the opportunity to make preemptive actions to improve your chances of meeting the desired outcomes or lagging metrics. Leading metrics often measure activities or even processes.

Understand that the selected metrics (much like processes, too) the organization chooses to employ will drive employee behavior as well. As an example, one organization chose to measure the number of work orders requiring re-approval if the labor or materials cost exceeded 10% of the original estimate. This measure is a lagging metric because it was after the work had been completed. The re-approval process was designed as a heads-up information sharing activity to show more dollars spent than anticipated. What behaviors did it drive? Planners would significantly overestimate labor hours and contractor/materials costs to avoid the re-approval process. Look at how the domino effect takes hold from there. Those labor hour estimates were used to create the following week's schedule. Now we aren't assigning enough work to the technicians as the hours were padded. Wrench time suffered. As the CMMS was also used as a time clock for payroll purposes, work orders on completed work that were left open became easy targets for technicians or contractors to charge time to when working on other jobs or idle. Materials for other jobs were charged to those work orders as well.

How can we use metrics to drive behaviors? Introducing or revising the organizational metrics requires training for all stakeholders, not just maintenance personnel. Don't assume that the standard metrics that you might take for granted, such as "schedule compliance," are understood by all. Using this metric alone, questions like, "What counts toward the metric?," "When is the cutoff point that items can be added to the schedule and count?" and "What is a scheduled job?" should be addressed from an educational perspective.

Before reviewing specific metrics, it should be noted that variations to the following metrics could be defined or utilized based on your requirements. The listing is not intended to be comprehensive, but to provide insight on specific behaviors related to maintenance planning and scheduling. Let's begin with those metrics directly influenced by the maintenance planning and scheduling function. (See Tables shown on these two pages.)

For New and/or Mature Planning Organizations

Metric	Target	Objective
% of planned work for the week with job plans supplied	Varies by work requirements and site as not all jobs require detailed job plans; Think precision maintenance, standardized work	To have consistency in your work execution from a standardized work approach; Upwards of 70% of equipment failure is self-induced, with ~40% of that due to human error

More Planner Metrics

Metric	Target	Objective
Job Planning Accuracy – % of work orders with man-hour estimates within 10% of actual over the specified time period	Accuracy of greater than 90%	Man-hour estimates are utilized to determine schedule loading and assignment of enough work to the technicians
% work orders with materials and parts used identical to planned over the last 30 days	Accuracy of greater than 90%	Missing materials and parts can create significant delays and missed schedules
If the planner creates job kits – % of planned work orders with the materials staged and kitted over a specified time period	Varies by organization, planning maturity and procurement/storeroom partnerships (could also be a storeroom metric)	Elimination of an avoidable delay to wrench time; Ideally, someone other than the planner should do this to allow the planner to focus on future work
Replan – % of work orders assigned "replan" status due to a need for additional planning over 30 days	Should not exceed 2%	Missing materials and parts can create significant delays and missed schedules
# of job plans updated over a specified period (e.g., 30 days)	Varies – looking for updates to parts or materials, job duration, special tools, etc.	Continuous improvement loop following the execution of work to improve the job plan based on technician feedback

General Scheduling Metrics

Metric	Target	Objective
Schedule Compliance – # of scheduled jobs completed divided by # of jobs scheduled as a % once the schedule is "locked" for that period	Accuracy of greater than 85% to 90% Can be measured by week, by day, or by hour	Man-hour estimates are utilized to determine schedule loading and assignment of enough work to the technicians
PM Compliance – % of PM work orders completed as scheduled using the 10% rule	Greater than 95%	Timely execution of PM and CBM activities drives equipment reliability and helps to break the reactive cycle
% of work orders over the specified time period that have a scheduled date earlier or equal to the "late finish" or "required by date"	Greater than 95%	With appropriate "required by dates," is maintenance providing the appropriate partner response from a timing perspective?
Delay or Reschedule – % of work orders assigned "delay" or "reschedule" status due to the unavailability of labor, equipment, or parts over the specified time period	Less than 3%	Highlights opportunities with respect to partnerships or the scheduling process
Schedule Effectiveness – % of scheduled available man-hours to total available man-hours over the specified time period	Ideally 100%, but often not achievable due to the reactive nature of the organization; Some organizations opt for 80%, while others target 120%	Are we scheduling enough proactive work for the maintenance crews?

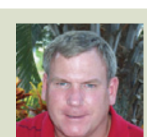
General Maintenance Metrics		
Metric	**Target**	**Objective**
Schedule Compliance – # of scheduled jobs completed divided by # of jobs scheduled as a % once the schedule is "locked" for that period	Accuracy of greater than 85% to 90% Can be measured by week, by day, or by hour	Man-hour estimates are utilized to determine schedule loading and assignment of enough work to the technicians
Productive work time or wrench time	Greater than 55% to 65% of the available crew hours Typically determined by work sampling studies	Elimination of the avoidable delays, such as waiting on parts, information, or the equipment to be available; these three items are primary reasons for planning and scheduling activities
% Uninterrupted Work	Varies	Interruptions create delays and possibly inhibit the completion of scheduled work
Rework – # of jobs requiring rework within the specified time period of original work completion	Less than 1%	Rework is corrective work done on previously maintained equipment that has prematurely failed due to problems in maintenance or operation
Work order closure rates trended on 30/60/90 day intervals	Review and closure within three days or less	Timely closure to ensure items like budgets accurately reflect maintenance cost, for example
Backlog – Trend "ready to schedule" and total # estimated work order hours for each category divided by # of available labor hours in the week (man-week) Also consider Backlog Aging - 30/60/90 day	For a typical manufacturer: Total: four to six man-weeks Schedule Ready: two to four man-weeks, however it can vary based on the organization and business objectives. Some organizations, such as Tier 4 data center, may choose to overstaff and have no backlog as a business decision.	The metrics is a tool to evaluate staffing levels and response times. Backlog is simply the amount of unfulfilled demands at a given point of time within the CMMS. Backlog can also be used to measure function compared to monetary (capital) commitments.

The metrics shown on this page are more general in nature to the maintenance organization. However, the planning or scheduling role can and often does influence these metrics. Consider the simple metric of "schedule compliance" as an example. If the planner has not correctly identified the materials and parts, or incorrectly estimated the hours required for the job, it may be very difficult to complete the number of jobs that are scheduled. If the scheduler has not coordinated the various crafts and the work cannot be completed in the scheduled window, schedule compliance may be impacted.

Are your metrics headed down south or stagnating, not improving? Wondering how to identify the problems or root causes? Do you know the behaviors the metrics are driving? There is a saying from the Six Sigma training world that the "product always follows the process." W. Edwards Deming said, "If your system is not working, don't blame the people, blame the system." To that end, where is your audit program to evaluate if the processes are working? Ideally, you should be pulling three completed work orders off the pile randomly every 30 days as a minimum. Gather the planner scheduler, supervisor, technician(s), storeroom person, and maybe even the plant manager, as examples and walk the jobs. When you get to where the work occurred, you should be stepping through metric type items to determine the process effectiveness. Did the planner scheduler estimate the job duration correctly? Did he or she have the right parts? Were the parts staged and kitted? What about multi-craft coordination? Did operations have the equipment ready based on the schedule? Did the job get completed before the due date? Was any follow-up work required? Was the work order completed and closed in a timely fashion? The primary goal is to determine if the business processes worked, but inherently, you can also determine performance issues or the need for training, as examples.

W. Edwards Deming said, "If your system is not working, don't blame the people, blame the system."

At this point, you may be reflecting on all that you have read and are considering adding to your suite of metrics to bring better focus to your planning and scheduling activities. When selecting metrics, focus on the behaviors you are trying to drive. Keep the number manageable so you are not looped into a state of paralysis by analysis. Strike a balance, as the decision-making process should be driven by leading measures, ideally two to one over lagging metrics. Remember, leading metrics are the ones you can manage, while the lagging metrics tell you the result of how well you managed.



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Multi-Level Perspective

This article provides a different perspective on the difficulties experienced by companies that try to achieve business excellence.

Daniël A. Lachman and Roy Tjoen A Choy

Companies are seen as socio-technical entities that have ruling regimes that are path dependent (in their routines, beliefs, infrastructures, strategies, etc.) and thus hamper the adoption of practices that propagate efficiency, reliability, productivity, etc. A "heuristic device," such as the multi-level perspective originating from science and technology studies, is presented as a tool for managers, consultants and other analysts to decipher socio-technical entities in order to identify landscape factors, regimes and niches (the locus for innovation). This will enable them to discover bottlenecks and opportunities for transitions of companies towards viable alternatives.

1. Insanity

Currently, it can be read all over the news: a new financial crisis. Some argue that it is already here, while others are reluctant to believe these notions and state that we haven't fallen off the edge into the abyss yet. Nevertheless, with the 2008 financial crisis still lingering in our minds, most people play it safe and carefully evaluate (new) purchases, loans and other expenses.

The same goes for our industries. Capital investments are postponed, expenses are cut, plants are closed and – worst of all – jobs are axed. Though on one hand this seems like a logical move – in particular cost-cutting and letting employees go – during an economic downturn, one might wonder, on the other hand, if this is the only ointment against sour times. Especially since the moves named above turn out to be more harmful in the long run than originally envisioned. Like Albert Einstein said, *The definition of "insanity" is doing the same thing every time while expecting different results*.

2. Path Dependency

One part of the equation that is often overlooked is the opportunity to reduce cost by producing in a more efficient manner; this was indeed noticed by Ron Moore in one of his best works, "Selecting the Right Manufacturing Tools." Yes, regardless of how unfortunate it may sound, rather than grabbing the opportunity to reduce cost in combination with an increased overall equipment effectiveness, upper management usually makes the choice to slash costs and cut jobs since it is relatively the easiest thing to do, even though it thereby implicitly jeopardizes longer-term performance. Several studies have shown iteratively that DuPont's Vince Flynn was (and still is) right: *you just can't cost cut your way to prosperity*.

Reducing cost by increasing efficiencies, eliminating failures and failure modes, increasing productivity, reducing energy and material consumption, improving safety, health and environmental records, and practicing overall continuous improvement can be achieved by transitioning the organization towards a proactive culture with a focus on predictive and precision maintenance, thorough failure root cause analysis and follow-up, effective audits, reliability engineering, visual management, detailed planning and scheduling, smart performance metrics, etc.

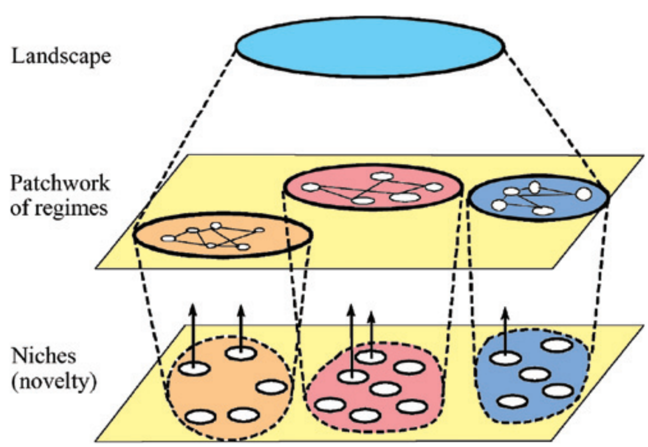

Figure 1: The multi-level perspective (Geels 2002)

Many companies in diverse industries are engaged in programs to transition the organization towards business excellence and benchmark performance by incorporating abovementioned conceptual tools and maintenance and engineering philosophies into their way of doing business. Unfortunately, a lot of companies have not been able to achieve this transition towards excellence, which usually means adopting new procedures, routines, rule sets and even paradigms. And very often, those who do manage to reach the top of the mountain don't stay there very long, but rather slip back to their old habits. They are apparently *path dependent* (often times also referred to as "lock-in").

3. Socio-Technical Entities

This brings us to the rejection of the notion of "technical" or "technological" industries or companies; factories, industries and manufacturing firms are rather *socio-technical* entities (a term first coined by Thomas P. Hughes in the 1980s). Apart from their technical artifacts that compose their production systems, companies also inhabit immaterial or epistemic elements, such as maintenance and engineering logic, operator procedures and routines, problem solving tools, search heuristics, reliance on dominant management and engineering designs (which are not by definition the *best* ones, consider the battle between VHS and BetaMax videotape), etc. The social and technical parts of a socio-technical system *co-*

evolve in the sense that they influence, shape and adapt to each other. For instance, there is not only one way in which an alarm clock can be used; it can be used to wake someone up or to trigger a bomb.

Due to their socio-technical nature, industries experience a so-called "path dependency" regarding their development (which can be good or bad) in the sense that they are not only confined to their physical artifacts (for example, once you have built a refinery, the physical infrastructure will guide operator routines), but also by their immaterial/epistemic elements, such as the procedures to build a new pipeline, failure investigation methodologies, problem solving tools, search (e.g. problem solving, opportunity identification) that sticks to existing routines, etc. To give an example where this can turn out to be detrimental, in his earlier mentioned book, Ron Moore adequately describes how certain conceptual tools can lead to inefficient problem solving (e.g. the Fishbone diagram) or poor outcomes (e.g. the 5-Why method). This actually builds upon Paul Feyerabend's seminal work, "Against Method" (1975), where he states that people and organizations should not be trained in one particular tool, but rather in the ability to properly assess when to use which tool.

If industries, given their socio-technical tenet, have the tendency to be path dependent in their development, then this might explain how it can be that numerous companies can't achieve and maintain business excellence (which after all implies a new set of philosophies, strategies, values, routines and methodologies). This coincides with earlier notions by Hammer and Stanton in "The Reengineering Revolution: A Handbook," where they state that change is the result of rethinking processes that guide and shape our work, and Jim Collins in "Good to Great," who notes that it sometimes takes only one new person with a fresh look on things to achieve business excellence.

4. The Multi-Level Perspective

One way this can be visualized is with the multi-level perspective (MLP) as depicted in Figure 1. It is a middle-range theory that was conceived in the Netherlands where it originated in the realm of science and technology studies (STS) in order to conceptually display mechanisms of variation, selection and retention (key notions in evolutionary economics) regarding innovations on the transition towards sustainable development.

The MLP consists of three levels, of which the one in the middle is arguably the most important one: the level of regimes. First coined in the beginning of the 1980s, but elaborated upon around the turn of the millennium, regimes are defined as "rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant

The MLP consists of three levels, of which the one in the middle is arguably the most important one: the level of regimes. Niches (the lowest level in the MLP) can be defined as the locus where innovative activity takes place and where time-limited protection is offered against dominant selection rules. The landscape level is defined as an exogenous environment that influences both niches and regimes.

artifacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures" (Geels 2004). In this definition, a distinction can be made between formal, cognitive and normative rules. Formal rules refer to standards, regulations, policies, etc. Cognitive rules cover rules of thumb, search heuristics, guiding principles, etc. Normative rules convey behavioral norms, sense of identity, role expectations, and so on. Niches (the lowest level in the MLP) can be defined (as it is done in literature on sustainability transitions) as the locus where innovative activity takes place and where time-limited protection is offered against dominant selection rules. The landscape level is defined as an exogenous environment that influences both niches and regimes.

Change in the regimes is fundamental to structural change in socio-technical systems. The logic goes that regime instability (e.g., when actors diverge and disagree on basic rules) and/or landscape pressure can create a "window of opportunity" for niches that can break through and get a firm hold on the regime level; thus transitions come about when processes at multiple levels link up and reinforce each other, resulting ultimately in a transition of the socio-technical entity.

5. Projecting the MLP on Business

Translating this into the daily practice of modern day business (though the definitions of the MLP levels aren't taken too strictly), one could say that in our contemporary age:

- the "landscape" level is characterized by the global economy;
- the "regime" level by the established artifacts, procedures, conceptual tools, search heuristics, values, beliefs, and so on;
- the "niche" level by the innovative, new and non-traditional insights, paradigms, beliefs, strategies, procedures etc.

Even more specific, referencing back to the beginning of this article, the current situation for a lot of companies is that existing regimes (i.e., the existing way of doing business) are threatened by the landscape level (i.e., the current/looming global economic crisis). Often enough, these regimes have not included efficiency/productivity harboring activities (such as precision maintenance, reliability engineering and root cause analysis) into their daily practice, and therefore, these activities belong to the niche realm. Even more, due to their path dependency, regimes will even actively oppose niches from breaking through to the regime level (training or communication equals deployment: "this is how we have always done it," "this won't work here," "we don't have the funds for that"). As explained earlier, if these niches can't break through to the regime level and become dominant routines and paradigms, it might spell disaster for the socio-technical entities, i.e., the companies under current global economic circumstances.

The question, therefore, is to what extent are existing regimes - which are not fit to lead the company through economic tough times - path dependent in the sense that they are not easily shook up by economic turmoil or promising niches? Examples of strongly path dependent, socio-technical systems where niches have the toughest times putting a dent in existing regimes are the energy and infrastructure networks. Though far from being fully explored (both theoretically and empirically), the advantage of the MLP is the relative ease with which complex, large-scale socio-technical entities can be structured. Furthermore, another advantage lies in the fact that the MLP has the ability to guide an analyst's attention to those issues that are relevant for transitions of socio-technical entities.

6. Conclusion

The MLP can thus be interesting for upper management, consultants, change managers, etc., who want to identify key bottlenecks (e.g., resisting regimes) and opportunities for the transition of socio-technical entities towards a more viable design, and want to answer the question why certain organizations can't seem to make the transition towards business excellence. As a matter of fact, the MLP can be used as part of the plan-do-check-act cycle on the road to benchmark performance. The heuristic device has proven its merit in science and technology studies where it has been used to analyze past transitions, and it is even used as the foundation for the policy approach, "Transition Management," in the Netherlands on the road towards sustainable futures.

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Eliminating Lubricant Cross-Contamination With Manufacturing Improvement Principles

Trigg Minnick

With the growth in base oil types and additive combinations that we have seen in the past couple of decades, the possible combinations of final blended lubricants has grown exponentially. While this can allow lubrication programs to hone in on the most suitable lubricant for an application, it also means we can have 15 to 20 different lubricants to manage in one facility. It's no wonder that issues of cross-contamination of lubricants are prevalent in many plants today.

Obviously, using or adding a fluid that does not meet the performance properties specific to an application is an issue. However, even lubricants that begin with similar performance characteristics may not coexist well. Different base oils can react chemically with each other, mixing base oils can lead to additives not holding in solution and various additives can even combat each other. All these issues lead to significantly lower performance of the lubricants. While the significance of incompatibility can vary widely, we can see certain indications, such as increased foaming, hastened oxidation rates, altered viscosity and film strength, water demulsibility issues and additive floc.

When determining how to minimize cross-contamination issues in a lubrication program, we don't need to reinvent the wheel (or the process to make it). Instead, we can learn from concepts that have been proven over several decades and adopt and amend them to overcome typical challenges in our lubrication programs.

Manufacturing Process Improvements

In the manufacturing processes of the 21st century, the methods of the Toyota Production System (TPS) are well renowned for eliminating waste while also improving quality. The success this system has generated for Toyota over the last half century has led to as many as 43% of U.S. manufacturers following some form of lean manufacturing.

From the days of Henry Ford all the way to current Toyota suppliers that are adopting the TPS methods, there is strong evidence that when executed properly, lean principles can and do help companies achieve sustainable improvements.

One of the many fundamental tenets of TPS is the concept of poka-yoke [poka joke]. In simple terms, poka-yoke is a method or mechanism that either prevents, corrects, or quickly draws attention to human mistakes. In fact, the translation for the Japanese term is "avoid mistakes." One good example is the use of left-handed threads on flammable gas cylinders to prevent accidental use of oxygen or other oxidizing gases.

Cross-Contamination Issues and Resolutions

Before we delve into applying poka-yoke to help us avoid cross-contamination, let's cover the issues cross-contamination can wreak on our lubricants and the equipment we are trying to protect.

As Table 1 indicates, some of the key properties of a lubricant can be expected to be altered when mixing incompatible lubricants. These alterations to the lubricant properties may come from incompatibility from base stock to base stock, or from issues with the compatibility of the many different additives found in today's lubricants. The severity of the conditions can

Contaminant Type	Damage to Lubricant	Damage to machinery
Cross-Contamination of Lubricants	• Oxidation • Additive loss • Viscosity changes • Loss of demulsibility of water • Increase in air entrainment	• Varnish/Deposits • Potentially exacerbates all wear mechanisms due to loss of film strength and changes in additive concentration • Premature filter plugging

Table 1: Cross-contamination effects on lubricant and machinery

range widely, from a slight reduction of oil service life all the way to sudden catastrophic failure. It's also important to note that a decline in the performance of any one property of the lubricant tends to directly affect the performance of other properties. For example, an increase in air entrainment can cause the viscosity to rise, which can cause the temperature to rise, which tends to increase the rate of oxidation.

The most common cause of gross cross-contamination is the inadvertent application of opposing fluids.

When working with mineral oils, compatibility issues are more common with the additives in solution. The interactions of the different lubricants often cause additive floc. As additives fall out of solution, we not only lose the performance properties these lubricants are designed to provide, but the floc tends to plug filters and even plug fluid passage ways in more severe cases.

The additive loss issues are certainly present in synthetic lubricants as well, plus it is more likely that the base oils will react negatively with each other. Special attention should be paid specifically to polyalkylene glycols (PAGs) and silicone base oils as they are incompatible with any other base oil stock.

With cross-contamination of lubricants, any and all of the main functions of a lubricant can be negatively affected. Friction and wear control are largely a function of the correct viscosity and/or anti-scuff additives. Mixing two incompatible lubricants of the same viscosity can still cause the anti-wear (AW) or extreme pressure (EP) additives to be reduced to floc. If we increase oxidation rates, the sludge and varnish byproduct build-up will reduce the ability to transfer heat. Dropping anti-corrosion or anti-foam additives from solution has obvious affects as well.

All these issues are true for both lubricating oils and greases. However, with greases, the compatibility concerns are greater because the thickener type is another component that adds to the complexity. When grease thickeners are incompatible, the likely result is a significant change in consistency. This change in consistency often causes the base oil to drop or bleed out at abnormal rates.

With all these negative effects that can all exacerbate each other, why does cross-contamination of lubricants happen frequently? The same reason most mistakes happen - we are human and therefore subject to many limitations. The cross-contamination causes can be categorized into two broad groups: intentionally selecting a different lubricant and inadvertently applying an opposing lubricant.

We may intentionally decide to change lubricants for consolidation purposes, to change vendors, or to attempt to improve the lubricant's performance properties. Changing lubricants can be challenging, largely because of how difficult most systems are to properly flush out the previous lubricant. Depending on how severe the compatibility issues between the new and old fluid, even small amounts of the old fluid may cause serious issues. Consulting the lubricant supplier in advance is key every time we decide to change lubricants in a system. Lubricant manufacturers go to great extents to properly blend and test their fluids, and have also performed a significant amount of compatibility tests. Rely on their expert knowledge and don't attempt to test for compatibility yourself.

At least when we have made a decision to change lubricants, we are on the alert for cross-contamination issues. But the more common cause of gross cross-contamination is the inadvertent application of opposing fluids. Operators may inadvertently top-up with the wrong oil because they don't recognize the significance of various lubricant types, there are limitations in the labeling methods, or it's a case of apathy. In any of these cases, the poka-yoke philosophy guides us to make it easier to perform the job correctly rather than do it incorrectly.

Error Proofing Lubricant Applications

Now let's talk about modifications that will help dramatically reduce the possibility of lu-

One piece of information that should be included in all lubricant tagging is the viscosity.

bricant cross-contamination. Once the lubricant has been selected, the next step for ensuring we get the right lubricant to the right place is to know (consistently and without question) which lubricant is the correct one. In lubricant application terms, we refer to this as tagging. But where do lubricant tags belong? The most obvious choice is on the equipment, specifically at the fill port. That will tell us what belongs in the equipment. We also need to consider the sources from which we draw on to get the oil (or grease) into its destination. After all, what good is it to know your blood is Type A, if the nurse can't tell whether the blood in the bag is Type A, Type B, or Type O? The solution is to tag all critical control points (CCPs). By this, we mean the fill port, transfer containers, off-line filtration systems, and of course, the storage reservoirs. This should include ALL containers that will hold any lubricant, including 'waste' containers that should specifically be marked with 'DO NOT USE.'

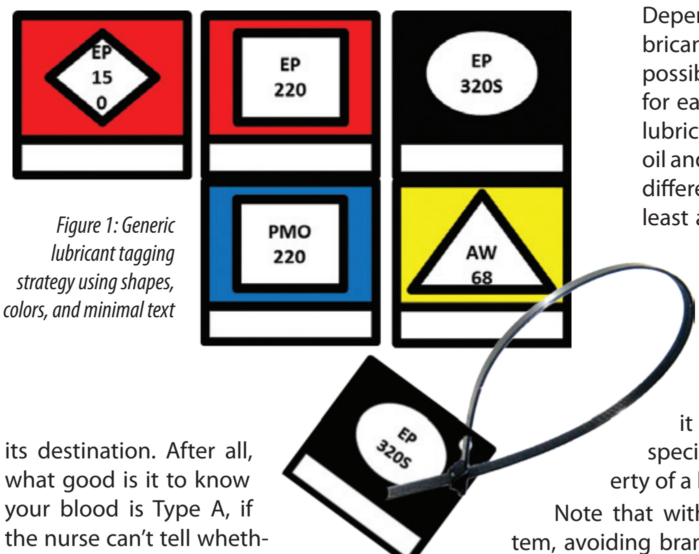

Figure 1: Generic lubricant tagging strategy using shapes, colors, and minimal text

Now that we understand where to place lubricant identification tags (everywhere the lubricant can be), what should these tags look like and what information should they include? The objective is to make it obvious which lubricant a particular component holds without making the tag difficult to read with small font size or overly-complicated information. We can include some obvious differentiators by using shapes and/or colors on the tags. This also helps to minimize the verbiage needed. We can then color-coordinate our transfer containers, off-line filtration systems and possibly our storage systems with our lubricant identification scheme.

Both colors and shapes (see Figure 1) can be used as indicators of major categories. For example, we may use orange for any PAO base oil, blue for a mineral oil and green to indicate a food grade lubricant. We might use a triangle to indicate an AW oil, or a diamond to indicate R&O turbine oil. Once we decide how to assign the colors and shapes, we will likely need just a little more information to hone in on the exact lubricant. For this, the tag should allow some space for any additional details, such as PMO oil, fire-resistant fluid only, etc. Depending on the quantity of lubricants you utilize, it may not be possible to have a different color for each. Using the same color for lubricants that have the same base oil and additive blend but a slightly different viscosity is one way to at least avoid the chemical reactions caused by more significant differences in lubricants.

One piece of information that should be included in all lubricant tagging is the viscosity. After all, it would make no sense to not specify the most important property of a lubricant.

Note that with the lubricant tagging system, avoiding brand specifics is preferable. After all, a complete system can encompass many points and labels, so why set yourself up to relabel all these points if you change your lubricant vendor again?

Once we have all CCPs outfitted with proper labeling, we can take the error-proofing strategy to the next level. In the first level, we have clear identification of which lubricant should be used and where each lubricant resides. Now we go from making the right choice obvious to also making the right choice the easiest. We do this through some simple equipment modifications. As proper contamination control practices dictate, we should be using quick connect fittings to both top-off systems and for periodic decontamination. Not only are these quick connect fittings best practices for particle and moisture control, they allow us an additional method to avoid cross-contamination. Take advantage of the various sizes and types of fittings by outfitting your storage tanks, transfer carts and equipment fill ports with a scheme that minimizes cross-contamination. For example, we can use an ISO B 1-inch connection on our drum of hydraulic oil, the same ISO B 1-inch on the filter cart dedicated to transferring clean oil to the reservoir and then the hydraulic fill port uses a multi-port adapter (as seen in Figure 2) that has a 1-inch ISO B connection. Then for our gear oil, we may use a 1-inch ISO A connection, for the turbine oil, a 1/2-inch flush face connection, and so on. The same philosophy applies to grease points; we can use regular zerks for grease with a lithium thickener and then button head fittings to indicate an incompatible polyurea grease. Figure 3 provides grease zerk examples.

Figure 2: Adapter kits like these allow the use of quick connects with various sizes and styles; always matching fill port tagging with lubricant tagging scheme

Figure 3: Utilizing a variety of grease zerks will allow us to reduce errors in our re-greasing tasks

Summary

In outfitting the CCPs with connections that only join similar fluids, we have made it much easier to dispense the correct fluid than to dispense the incorrect fluid. By proper labeling and by applying the labels to all relevant CCPs, we make the right choice obvious. When we make the best path the easiest and most obvious, we dramatically reduce the probability of mistakes. This may not earn you the Shingo Prize for operational excellence, but you can feel confident that the issues caused by cross-contamination of lubricants will be dramatically diminished under your watch.

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Why Can't We

Do It Ourselves?

Have you been asked this question by management?

George Krauter and James Rogers

To release value from our MRO operations, do we need to outsource our MRO storeroom to a 3PMRO provider? Why can't we obtain the lower price, the asset recovery dollars and the critical storeroom reliability ourselves?

The purpose of this article is to outline the answers to the question so we are all prepared when we are asked: Why Can't We Do It Ourselves?

- The industrial MRO consumer is not positioned in the MRO supply chain to realize functional discounts.
  - ◊ Manufacturers who sell products via distribution will not, except for rare occasions, sell around their distributors to the users.
  - ◊ Selling directly (manufacturer to user) does not eliminate the existing cost of distribution. Either the user or the manufacturer shoulders the cost; the costs do not go away.
  - ◊ Manufacturers have distributors because it is not economical for them to process orders and ship to all potential clients, let alone exercise sales and marketing programs.
  - ◊ The nature of MRO orders carries a wide diversity of products spread out over many categories. The average MRO order is $150; the number of transactions for the manufacturer would increase prohibitively as would the transactions for the user if all supplies were purchased directly.
- The concept of bringing the distributor on-site so the user is out of the internal distribution business is designed to reduce costs for the user.
  - ◊ Optimum cost reduction comes from eliminating an existing step in the MRO supply chain. If the user "did it ourselves," there is no step elimination and optimum cost reductions are not realized.
  - ◊ The "integrators" are an offshoot of traditional distributors. These distributors maintain warehouses, local stocks and all the costs associated with MRO distribution. When the "integrator" obtains a client, there is cost reduction for the user, however, there is no elimination of a "cost step" in the chain. The integrated supply program will eventually fail because it cannot deliver year-after-year savings.
  - ◊ Traditional distributors who operate/incorporate programs called "integrated supply" do so from a defensive position. Traditional distributors make more profit with traditional purchase orders than they do with "integrated supply" scenarios.
  - ◊ Profitability considerations of the distributor dictate that the integrated function utilizes the inventories and assumes a proportionate share of corporate overhead. These considerations are manifest in the financial proposals to the industrial consumer. The effect is an improvement, but the optimum cost position is not achieved. In addition, the distributor/integrator will supply authorized brands only; this denies the cost saving opportunities available from alternate sourcing.
- By definition, users will continue to own inventory if they "do it ourselves." If they utilize "vendor stocking," there would be multiple suppliers to audit with multiple invoicing variations creating higher administrative costs (add more people). In addition, users do not have the computer capabilities to control multiple inventory ownership, inventory controls, reporting and visibility of usage.

The concept of bringing the distributor on-site so the user is out of the internal distribution business is designed to reduce costs for the user.

  - ◊ If suppliers would agree to own inventory on site when the user is "doing it ourselves," the suppliers would charge higher prices because they have duplicated inventory costs. Distributors make money on price markups and multiple inventory turns on markups. Inventories that exist for one customer alone cannot be used for others, which effects lower inventory turns (*revenue*) for the supplier, ergo higher prices for the user. In addition, the unpredictable nature of MRO usage causes stock units to vacillate between repetitive and "just in case" usage. Inventory control and burden for the supplier would be unacceptable.
  - ◊ One time, non-stock buys constitute 25% to 30% of the MRO buy. If the user elects to "do it ourselves," the burden of the one-timers remains with little control of prices and little recognition of repetitiveness.

- Companies are not willing to invest the dollars necessary to convert existing stores into world-class operations or they would have done so. Dollars are invested in capital and production projects; the 6% to 10% MRO spend has little consideration.
- In most companies, the MRO buyer passes transactions and does little sourcing because there is little time available. The inefficiencies of stores create rushes and out-of-stock situations that consume purchasing time. It becomes a "catch-22" and there is no time to stop and correct the situation. The function of searching, sourcing and (frequently) pricing is accomplished by the requisitioners, taking time from more productive duties.
- Consider companies that have decided to do "IT" themselves; they exist in three categories:
  1. Those that have tried third parties and/or "integrated supply" and failed.
  2. Those that have a strong corporate indirect materials (MRO) purchasing department and have invested heavily in SAP-type computer systems.
  3. Those where a new senior manager comes on board and wants to show change.

<u>In number one</u>, the user has been burned and is reluctant to try again. This is a result of "integrators" who think coming on-site is a simple task and do not understand the commitment necessary for success. They do not understand the additional costs they incur until they realize that returns are inadequate. The opportunity costs become excessive.

<u>In number two</u>, it is us (corporate purchasing) versus them (the plant) or vice versa. Corporate price agreements are reached with national suppliers who exist as a result of the flawed market basket procedure. Pricing from the suppliers is based upon estimated (mostly overestimated) dollar consumption for the corporation. Plant personnel invariably can beat the corporate price (especially on any given day) to the detriment of the corporate agreement. Compliance is always a question, the level of which is directly proportionate to the strength of corporate purchasing. If a given site within the corporation recognizes the financial and non-financial benefits of hiring 3PMRO to operate its MRO stores, it is conceived by some in corporate purchasing as a threat to their department and a sapping of usage volume from the commitment to the selected suppliers. Corporate fights 3PMRO, stating that if one plant goes with 3PMRO and does not/cannot use the corporate supplier, the prices will go up to the other non-3PMRO sites. Nothing could be farther from the truth; the corporate suppliers will recognize competition and either offer 3PMRO a discount or reduce their corporate price. At the very least, they will not raise prices; what purchasing person would let them? Remember, corporate and the supply base cannot obtain compliance if the local plants decide to use their preferred supply base. If

Corporate fights 3PMRO, stating that if one plant goes with 3PMRO and does not/cannot use the corporate supplier, the prices will go up to the other non-3PMRO sites. Nothing could be farther from the truth; the corporate suppliers will recognize competition and either offer 3PMRO a discount or reduce their corporate price.

forced, the locals can slow down, show lower production, prove out-of-stock situations ***and*** beat the price.

In number three, the new manager looks at the existing financial program of the integrator and assumes the company can buy as well as the current supplier. There is little consideration that the company cannot buy properly, that it will add many suppliers and that it will increase transactions substantially. The manager does not realize the company will increase its costs by adding personnel, additional computer systems, increased inventory and a huge increase in their supplier base. Any price advantage would be temporary and would not be measured. The additional costs would obscure any perceived price reduction that may or may not be recognized. In addition, one-time spot buys would increase in price without control because they can.

With a strong corporate dictate, companies can deny the site the benefits of 3PMRO by saying to the site manager, "We have given you direction to the best suppliers and invested millions of dollars in SAP, et al; use the tools we have given you to 'do IT yourselves'." In these cases, site managers say phooey on it and turn to other site activities. The effect is the site continues with negative inventory turns, high levels of transactions, out-of-stock situations and little ability to reduce price – let alone measure it!

The graphs on the right show existing situations by comparing MRO (hammer) to production (steel). Note Figures 1 and 2. The administrative cost to process purchase orders is equal, re: steel versus hammers, however, look at the upside-down discrepancies considering the number of purchase orders, suppliers, emergencies, controls, history, dollar value and expertise.

Figure 3 shows the savings potential of MRO representing the largest percentage of opportunity for cost reduction. Figure 4 shows the liability of an insignificant spend (MRO) at 8% while generating 80% of all transactions; this is another case for 3PMRO.

The conclusion is that no manufacturer should operate its own MRO stores. Management will not spend the dollars necessary to establish a state-of-the-art storeroom because MRO is generally considered an unrecoverable expense. As the saying goes, "It is what it is … live with it."

If "doing it ourselves" is the best situation, why do companies continue the same process and incur the same avoidable costs year after year?

How Does Pure 3PMRO Differ?

- The cost of reengineering, installing, loading and implementing 3PMRO is paid by the user out of the savings the provider achieves as a result of the provider's position in the supply chain.
- The expertise and computer system indigenous to MRO must be already in place with the 3PMRO. The user simply replaces the current scenario with the 3PMRO model and reaps the benefits.
- Since a pure 3PMRO provider has no "traditional distributor" business, all assets and expertise is directed to goal achievement.
- This 3PMRO provider's financial model is not burdened with duplicated supply chain costs; therefore, the economic effects for the client provide optimum total cost of ownership benefits.


As the originator of the concept that became known as integrated supply, George Krauter currently serves as Vice President for Storeroom Solutions, Inc. Mr. Krauter's career began in Philadelphia and carried him through management capacities in all disciplines of the indirect materials supply chain, making him an authority on innovative methods in distribution and MRO outsourcing. www.storeroomsolutions.com.


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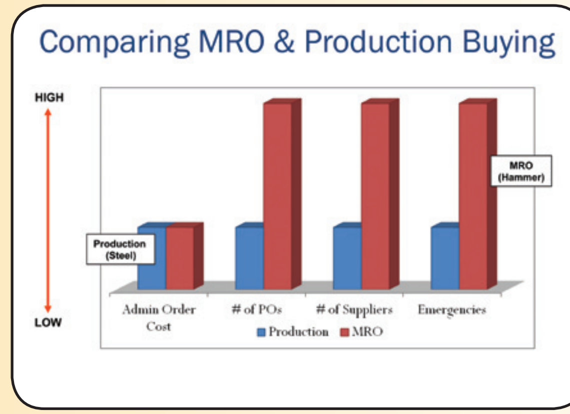


Figure1

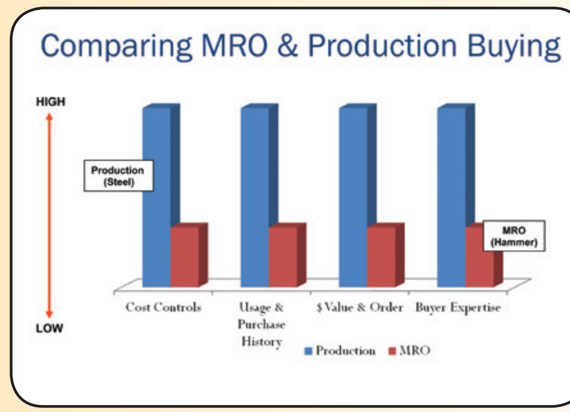


Figure 2

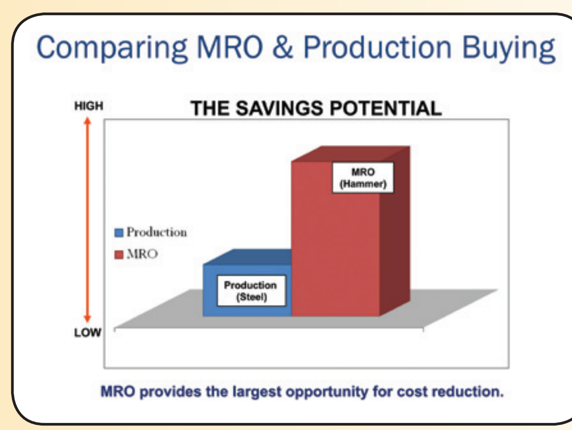


Figure 3

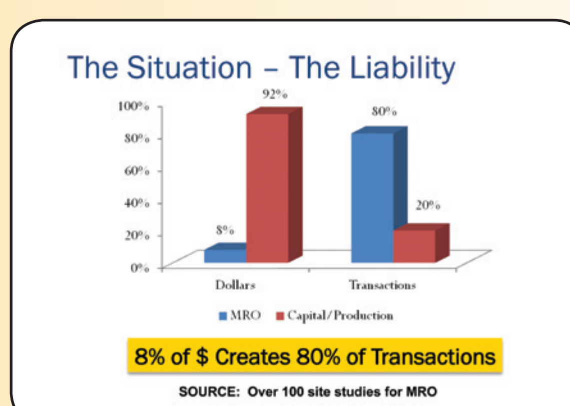


Figure 4

Our Journey to Discovery

Richard Woolley

To introduce or revamp an oil analysis program is nothing new to the mining industry. Many companies have successful programs that work within their reliability and maintenance engineering groups. Many other companies have found that through the ups and downs of the economy, they constantly have to improve the oil analysis program because of employee layoffs during the down periods.

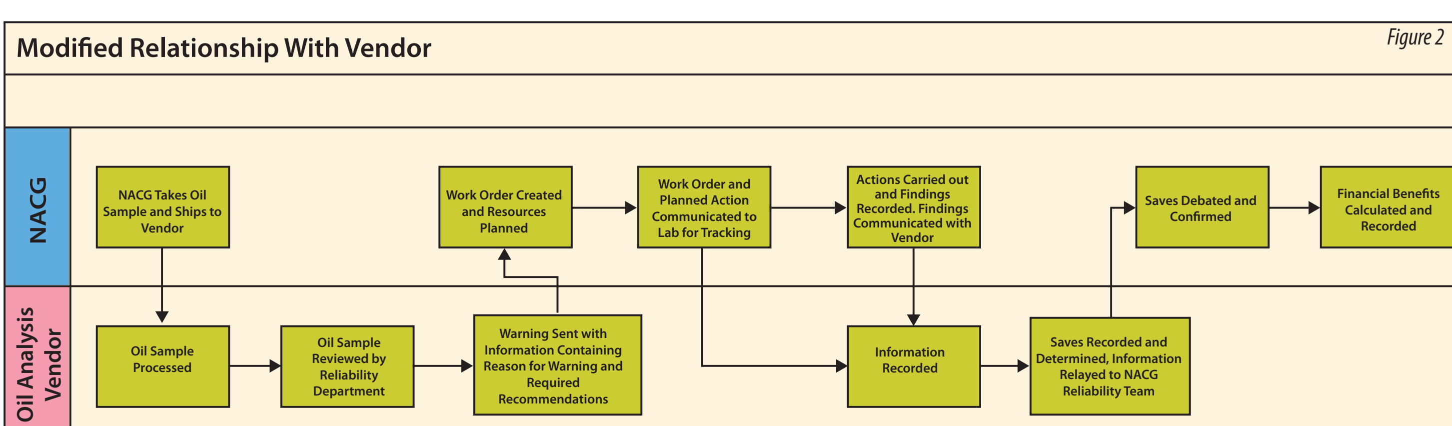
Many contract companies have difficulty grasping and achieving a cost saving oil analysis program because they fail to use their oil analysis program to the full potential possible. It was one such company that had plenty of opportunities where Harold Gudmundsen, General Manager of Asset Management for North American Construction Group, found himself in a senior position with many capable staff like myself.

There were plenty of opportunities that could have been used to reduce the maintenance yearly spend, however it was the oil analysis program that Harold knew could instantly start showing results. It was with determination that Harold wanted to show the executive team that oil analysis was a worthwhile opportunity. As Harold and I would find out, the largest roadblock to improving this system would be the actual people responsible for its success. Originally, I would own, implement and manage the program and be responsible for calculating its successes and losses, but later shared these responsibilities with other team members.

Figure 1

To begin with, we found that the industry in Alberta, Canada, had become accustomed to oil analysis, where the responsibilities of the sampling labs were simply to do the scientific testing of the oils, perform a quick view of the results and give a simple reply to the results as seen in Figure 1. The in-depth analysis of the results was left to the companies themselves. Second, I found there was little emphasis internally on oil analysis unless there was a failure, at which time it was too late.

As I began implementing new processes, I was met with utter restraint, sometimes even coming from the site maintenance superintendents. I eventually found out that the flagged samples were not even being sent to the proper on-site individuals. When that was corrected, often times there were not enough individuals in the planning department to handle the volume of flags being received. Sometimes, the oil analysis results were not even looked at before the delete button was pressed on the computer, eliminating the email in which they were contained. Of course I shuttered at the thought whenever I heard or saw this occurring. With the assistance of our oil analysis account representative, I implemented a new and simple process that has saved enormous time for the service personnel. But the introduction of elec-



tronic sample setup with labels preprinted for the samples was actually met with disgust and restraint. It was at this time that Harold, as the general manager, decided his intervention was mandatory, which I gladly appreciated.

The solution was simple, though the success of it was greatly slowed due to resistance within. We requested that the sampling lab take on greater responsibility for the overall interpretation of the oil analysis results, which increased the level of service they could now offer. They would then send the information to the site specific personnel and hold them accountable for any actions taken or not taken, as seen in Figure 2. It was to be a partnership more than the vendor type relationship the two companies had previous to the project, paving the way for a higher level of expectations. A timeline was given and it was reiterated that if financial benefits were not achieved during that time, the services of the oil analysis lab would no longer be required.

People are the greatest asset, if they are not properly trained, held accountable and managed properly, they also can be the largest roadblock to success.

Now Harold could have easily directed the method in which to accomplish the task, however in doing so, he would have taken away from his employees the greatest opportunity for them, which is the opportunity to grow. The only way there was going to be success was for the employees to rise to a higher level of both understanding and competency. The oil analysis lab also needed to rise up to a higher level of expectations and service offerings.

When the mandate was given, I truly didn't know what was going to happen. I was given the authority to enact the changes that had long been sought, but with great resistance the program was greatly scaled back so as not to further inconvenience the already overburdened maintenance planning group. Only a distinct number of warnings would be issued despite the number of flags that actually existed. This made the planning group a little less hostile, however it still was not able to produce great results. Having already trained them in oil analysis, their little experience caused them to make the wrong decisions and actions to the flagged samples. Components failed because the decision to resample was the decision carried out instead of inspecting for the contaminants or wear metals.

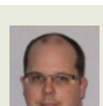
With the deadline looming, Harold again reiterated to me that if no financial benefits were recorded, the services of the analysis lab would be cancelled. I no longer had the option to guard the maintenance planning group. I informed the vendor to start analyzing all severe flags and sending warnings for these items regardless of whether the maintenance planners were able to deal with all of the added work load. Despite the mountains we would have to climb, we would be victorious.

All of these actions upset the internal balance within the maintenance division and I found I was not a very popular person at times. Some employees were often uncertain as to why such drastic measures were being taken, but they didn't fully understand what really was at stake.

Initially, the oil analysis lab also didn't understand why they had to provide the higher service offerings since the expectations were outside the usual services provided by an oil analysis lab. How could it be? Is the only responsibility of an oil analysis lab to analyze oil and provide the data back to the customer? For oil analysis, what service is actually being provided, data or information? Again, the previous expectations were that they would analyze the oil samples, deliver the data and provide some training; that was the end of the expected service offerings. A higher level of expectation was given to everyone, both for our company and for the oil analysis vendor. Risk was expected to be shared equally and not solely on one party, as both parties equally had something to lose.

The goal was achieved, higher standards have been set and more progress is being made every day. The process that was developed allowed for internal review of other processes, which allowed for further improvement. The vendor was also able to further improve its service offerings. Since the beginning of the process, I have been able to calculate cost avoidances over $2.7 million with missed opportunities equal to the same amount. These cost savings were calculated over and above the cost of the program, as well as the cost of the extra services being provided by the oil analysis lab.

While many lessons were learned, I would have to say that the two biggest were: 1) Even though people are your greatest asset, if they are not properly trained, held accountable and managed properly, they also can be your largest roadblock to success; and 2) As you set higher expectations for your maintenance divisions and vendors, only with these higher expectations can you begin on the path for continuous improvement.



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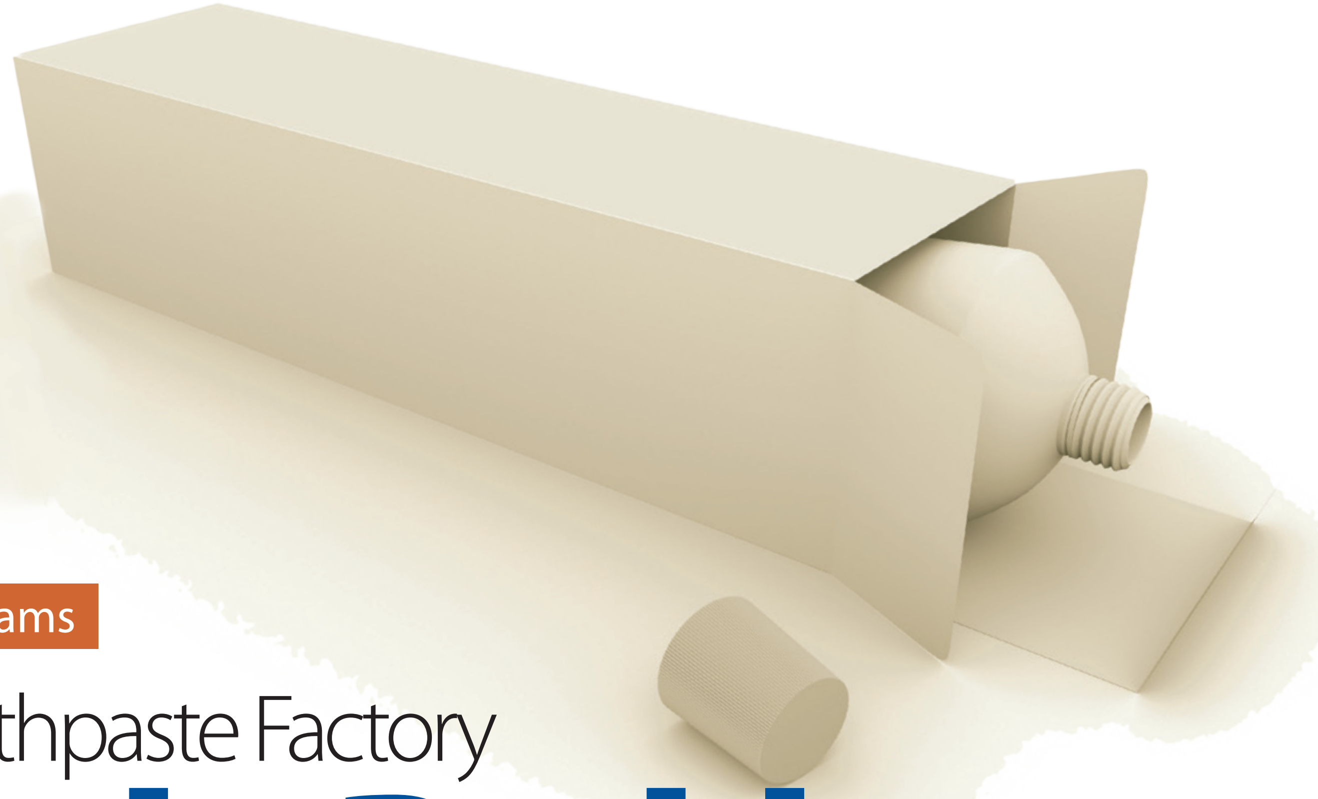


Cliff Williams

A Toothpaste Factory Had a Problem

Many of you may have read a post by Terrence O'Hanlon on the LinkedIn site (www.linkedin.com) **of the Association of Maintenance Professionals**

For those of you who haven't, here is Terrence's post:

A toothpaste factory had a problem. They sometimes shipped empty boxes without the tube inside. This was caused by the way the production line was set up, and people with experience in designing production lines will tell you how difficult it is to have everything happen with timings so precise that every single unit coming out of it is perfect 100% of the time. Small variations in the environment (which can't be controlled in a cost-effective fashion) mean you must have quality assurance checks smartly distributed across the line so customers all the way down to the supermarket don't get angry and buy another product instead.

Understanding how important that was, the CEO of the toothpaste factory got the top people in the company together and they decided to start a new project in which they would hire an external engineering company to solve their empty boxes problem since their engineering department was already too stretched to take on any extra effort.

The project followed the usual process: budget and project sponsor allocated, RFP and third-parties selected. Six months (and $8 million) later, they had a fantastic solution - on time, on budget, high quality and everyone in the project had a great time. They solved the problem by using high-tech precision scales that would sound a bell and flash lights whenever a toothpaste box would weigh less than it should. The line would stop and someone would have to walk over and yank the defective box out of it, pressing another button when done to restart the line.

> ***The project followed the usual process: budget and project sponsor allocated, RFP and third-parties selected.***

A while later, the CEO decides to have a look at the ROI of the project and sees amazing results! No empty boxes ever shipped out of the factory after the scales were put in place. There were very few customer complaints and they were gaining market share. "That's some money well spent!," he says, before looking closely at the other statistics in the report.

It turns out the number of defects picked up by the scales was zero after three weeks of production use. It should have been picking up at least a dozen a day, so maybe there was something wrong with the report. He filed a bug against it and after some investigation, the engineers came back saying the report was actually correct. The scales really weren't picking up any defects because all boxes that got to that point in the conveyor belt were good.

Puzzled, the CEO travels down to the factory and walks up to the part of the line where the precision scales are installed.

A few feet before the scale was an inexpensive desk fan blowing the empty boxes out of the belt and into a bin.

"Oh, that," says one of the workers, "one of the guys put it there 'cause he was tired of walking over every time the bell rang."

What followed was a number of posts, mine included, that made comments such as, "That's what's wrong with industry" and "Those closest to the problem," or "Keep it simple."

The general consensus was that the CEO was in the wrong and there was no doubt the worker had done the right thing and we need more of those types of solutions. On the face of it, this appears to be true, but what happens if we take a deeper look at this story.

First of all, the worker just ignored a system that the company had paid a lot of money for – that was set up to capture information that would help measure the extent of the problem and maybe, just maybe, prompt further investigation. Or at least it might have, but the worker didn't know or care to know.

The project took six months – this must have meant people were in and around the area – ample opportunity for the worker to give input. Why didn't he give it? Why wasn't he asked for it? (Isn't that what some consultants do – come into your plant, ask the operator what the problem is and then write a report stating that?)

I've worked for Ma and Pa shops and Coca-Cola and I can state categorically that there was never a problem such as this - in consumer packaged goods, the biggest crime is for a faulty product getting to the marketplace as the empty boxes did – when the CEO was the only person who knew about the problem. This type of problem is the biggest stick that CEOs will use to beat those below them. So what happened to the plant manager, quality group, etc.? Did they show up and the worker ignored them too?

Next, an inexpensive fan was installed. Whenever I've seen such solutions, they are plain unsafe! The cord runs across the floor, or even worse, is draped about head high onto the machine. Did anyone check if the fan could fall into the conveyor? Did maintenance know they now had another strategic piece of equipment to take care of?

The engineers visited the site to ensure the scales were working correctly. Didn't they see the fan?

So what at first seemed to be a case of a stupid CEO and a much maligned worker turns into a comedy of errors. Would you want any of those people – CEO, plant manager, quality, engineers, or even line worker – working for your company?

Before you answer that question, did you see the biggest mistake of all? The one most prevalent in North American industry? The one that most often gets missed?

They were all dealing with SYMPTOMS; the actual problem they all needed to address was WHY WERE THE BOXES EMPTY?

No one was upset that what the worker had done was just maintain waste – empty boxes that had been printed, cut and formed ending up in a bin.

There was no mention of the missing toothpaste tubes – waste also?

So many times in accident reports, downtime analysis, etc., we look at the story at the level that Terrence posted it – and never dig deeper – never get to root cause – never eliminate the defect.

So maybe when we next see a story or read an incident report, we won't take it at face value and instead probe a little deeper.

A toothpaste factory had a problem, they sometimes shipped empty boxes without the tube inside. This was caused by the way the production line was set up.

Later on I posted a "Happy Ending" for this fairy tale – and it goes like this:

So the CEO returned to his desk very happy that at least the empty packages weren't getting to the customers. He continued to monitor the results, and for a couple of weeks there were still no empty packages causing line stops. However, on the third week, there were 15 instances of alarms, but the CEO believed this might just be a blip.

When the next week revealed another 15 alarms, he decided to visit the shop floor again. When he got to the scales, he noticed the fan was no longer there.

"Hey Bill, what happened to your fan?"

"Don't talk to me about that fan. Your new safety officer came down here and decided that the fan was unsafe. The cable was on the floor and the fan was held in place with electrical ties. He said until we had a conduit run and a proper mounting for the fan, we couldn't use it. Knowing how long projects take in this place, that will be a couple of months!"

"Well, you know that safety is #1 Bill, keep up the good work."

"Oh, one other thing before you go back to your office."

"What's that Bill?"

"My name is Bob!"

So the next week, the CEO saw the alarms at a rate of 15 again and took solace in the fact that it wasn't increasing.

When he saw the following week's report with no alarms, he was intrigued. Even he knew that the electrical group never did anything that quickly and he was afraid that they had ignored the advice of the safety officer, so he headed back down to the scales.

"Hi Bill, er Bob, I see the fan's not ready yet, but you didn't seem to have any empty packages last week, how come?"

"Come with me," and Bob started off up the line. "I got so fed up with that bloody alarm that I called Joe the mechanic to see if he could do anything. Well he asked me a stupid question, 'Why are they empty?' When I told him I didn't know, he said, 'Let's go find out,' so we did and that's where we're headed now."

Bob and the CEO finally reached the area where the toothpaste tubes were fed into the boxes and the CEO could see two pieces of plastic tie wrapped around the feeding chute.

"When we got here, Joe noticed that every now and then a tube wouldn't enter the package and so he started to take stuff apart. He seemed happy when he told me the problem was really a simple one yet at the same time one that wouldn't go away. He said the feeding chain for the boxes stretches as it gets used and that's normal. The problem is when it stretches to the point of not quite lining up with the chute. The chain still has plenty of life though, so he put those pieces of plastic there so the tube wouldn't fall over and would find its way into the box!"

The CEO just laughed and shook his head. "I guess that's what you call getting to the root cause of the problem. Bob, can you talk with Joe and figure out when would be a good evening for me to take you both out to dinner - this is great work. Oh, and don't forget to cancel the fan project!"

Cliff Williams is a 30-year veteran in the maintenance world. Cliff is a sought after speaker at maintenance conferences around the world. He is currently the Corporate Maintenance Manager for ERCO Worldwide, a Canadian-based specialty chemical producer.

Determining an OEE Goal Based Upon Customer Takt Time

Rich Jansen

What is the basis for your current overall equipment effectiveness (OEE) goal? Is it clear to you and is it one in which employees in the organization have a motivation to achieve?

Regardless of how you get there, it all starts with building an awareness of the need for the targeted performance level. It is from this awareness that the desire/motivation can be developed. There are a variety of approaches for establishing your OEE goal, each with their share of questions that can limit the level of motivation.

- Is it based upon an industry benchmark? "*But we are unique and no one else does what we do.*"
- Is it based on a senior management directive? "*They just always want more and are never satisfied!*"
- Is it based on a popular, well-rounded number, for example 85%? "*But why not 86% or 87%? What is so magical about 85%?*"

Because these approaches do not provide a clear answer to the question "Why?," they are often not effective. So how about a goal that focuses on customer satisfaction, like takt time?

You might be wondering, "What is takt time?" First you have to understand the word "takt," which is a German word meaning *pace* or *rhythm*. Takt time means the pace or rhythm of customer demand. The ability to match your production with your takt time requires mastering the art of making the *right part* at the *right time* in the *right quantity*. This concept is a key aspect of lean manufacturing, and building a connection to the customer is one way for rationalizing a goal that the general population can understand.

But first we need to comprehend takt time value more clearly by understanding its formula shown below:

$$\text{Takt Time} = \frac{\text{Total Planned Production Time during Period (hours or seconds)}}{\text{Total Customer Demand during Period (units)}}$$

An actual example could be as follows:

Four Week Demand = 150,000 units
Production Day = 3, 8-hour shifts, each with 50 min for breaks and lunch
= 3 x (8hr x 3600 sec/hr – 50 min x 60 sec/min) = 77,400 seconds
Weekly PM Time = 6 hours or 21,600 seconds

If you used all 28 days over the four-week period, then the takt time (TT) would be:

$$TT = \frac{\left[\left(28\text{days} \times \frac{77{,}400\text{sec}}{\text{day}}\right) - \left(4\text{weeks} \times \frac{21{,}600\text{sec}}{\text{week}}\right)\right]}{150{,}000\text{units}} = 13.9\text{sec/unit}$$

So we now know that the customer needs the production of one unit every 13.9 seconds. This is a goal that is easy to understand, but how does it relate to OEE?

OEE is a representation of operations performance that is composed of three key performance indicators (KPIs):

- Availability rate (breakdowns + changeovers)
- Production rate (minor stoppages + cycle time losses)
- Quality rate (rework + scrap)

These OEE KPIs, represented as loss factor percentages, can be applied to the target process cycle time to determine the actual production pace (PP), which is demonstrated in the following example.

Target Process Cycle Time = 10 sec/unit
OEE = 72% (or a 28% loss)
Availability loss = 12% breakdown + 8% changeover
Production loss = 3%
Quality loss = 5%
PP *= Target Cycle Time x (1+OEE loss %) = 10 sec/unit x 128% =* **12.8 sec/unit**

Now we understand that despite the 10-second cycle time, product is actually produced at a rate of only one unit every 12.8 seconds based upon the current OEE performance. At least this is faster than customer demand of one every 13.9 seconds. By using these same basic formulas and matching takt time with production pace (Table 1), one can see that customer demand requires 26 production days to produce under the current OEE performance.

Production Days	Takt Time sec/unit
28	13.9
27	13.4
26	12.8
25	12.3
24	11.8

Table 1

Twenty-six production days over four weeks means the operation is required to run six days per week, plus two Sundays. This is the starting point for establishing a goal. For example, what about the goal to produce the required demand without the Sunday overtime? In other words, in 24 days. Using the data from Table 1, this would mean a takt time of 11.8 sec/unit. By knowing that the production pace needs to satisfy the takt time, an OEE goal can be established.

PP = Target Cycle Time x (1+OEE Loss %)

$$\text{OEE Loss \%} = \frac{\text{PP - Target Cycle Time}}{\text{Target Cycle Time}} \times 100\%$$

$$\text{OEE Loss \%} = \frac{\text{11.8sec/unit - 10sec/unit}}{\text{10sec/unit}} \times 100\% = 18\%$$

The OEE loss of 18% means an OEE goal of 82% is required to achieve customer demand in 24 days – a goal focused upon satisfying the customer.

By understanding OEE losses, a strategy can be established to achieve the business goal.

Based upon loss factors for the example provided (visualized in Figure 1), the following strategy could be rationalized:

- Eliminate cycle time losses
- Reduce rework loss by 50%
- Reduce change-over loss by 33%
- Reduce breakdown loss by 25%.

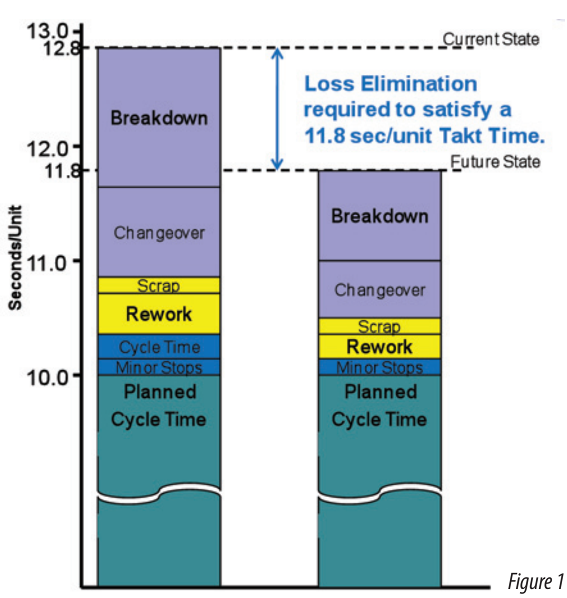


Figure 1

With this approach, employees of the organization, working in teams to address these specific goals, can understand the basis for the individual goals that are being deployed. Respecting employees by providing this understanding during the process of goal deployment can go a long way in determining if the goal is achieved.

The value of the OEE metric is to identify sources of losses that affect the ability to achieve business goals, which then leads to improvement strategies. Connecting the OEE metric with business goals keeps it aligned with a continuously improving organization so there is no static number for a goal. Using the concept of takt time is one way to maintain alignment with the business goals (goals that are aligned with satisfying the customer).

Rich Jansen is a Reliability Engineering Subject Matter Expert with Life Cycle Engineering (LCE). Rich has over 20 years of experience in the automotive industry in the areas of Quality Engineering, Manufacturing Engineering and Maintenance. Rich is a graduate of the University of Cincinnati, with a Bachelor of Science degree in Mechanical Engineering. www.LCE.com

Way of Life at Luminant

2011 Winner

Keith B. Lawson

The success of Luminant's non-destructive testing (NDT) program over the past 35 years is the result of our extremely talented employees and their trailblazing initiative to make it a successful program. Through new technologies in NDT, we've been able to prevent major equipment failures and future damages, while producing documented cost savings for the company.

At the heart of our success is our team, consisting of five full-time predictive maintenance (PdM) specialists, each a champion in his field, highly-skilled, motivated and taking tremendous pride in his work. Each specialist holds several certifications, including ultrasonic flaw detection, flaw sizing, vibration-ISO, thermography, ultrasound, magnetic particle and liquid penetrant, just to name a few.

Our PdM specialists are assigned dedicated routes and equipment inspections. The group currently inspects nearly 100,000 points yearly across Luminant's nine mine sites, meaning the team's work area spans 325 miles from northeast to central Texas. Needless to say, scheduling is critical to the team's success, ensuring that PdM specialists are as productive as possible and the appropriate equipment is available when they are on-site.

The group currently inspects nearly 100,000 points yearly across Luminant's nine mine sites, meaning the team's work area spans 325 miles from northeast to central Texas. Needless to say, scheduling is critical.

The team is responsible for 15 draglines, 10 loading stations with 45 conveyors (one is 12-miles long and another is 5-miles long) and 600 pieces of mining rolling stock and railroad components. We also use our expertise to perform quality assurance inspections on components before installation and to evaluate both new and repaired components. Ultrasonic (pulse echo) techniques in large component testing take unique individuals who can think outside the box, evaluate many variables on the component at one time, and have the necessary knowledge base of each component's geometry and design. Team members Robbie Cross, Jackie Merket, Tony Jumper and Michael Brinkman were chosen to work on the team because of these unique abilities in NDT and ultrasonic evaluation. Their field experiences, training and certifications are invaluable for the success of the program.

Our current maintenance philosophy includes components of reliability-centered maintenance (RCM), predictive maintenance, condition-based maintenance and root cause analysis (RCA) – each has been part of Luminant's culture for a long time. Implementation of a reliability strategy development methodology, like RCM, across our fleet has made a difference moving forward by utilizing a condition monitoring system on our 12-mile and 5-mile conveyors. RCM has helped our teams focus their efforts on the right proactive tasks while continuing to trend positively month by month.

Our predictive maintenance includes standardized inspections and inspection routes performed by trained maintenance employees and certified PdM specialists. This approach has kept our equipment safe for our employees, while at the same time, reduces costs to maintain the equipment. We deploy new technologies whenever possible to expand our evaluation and inspection abilities. For example, we are considering the purchase of alternating current field measurement equipment for detecting and sizing surface breaking flaws or cracks in gearing and other components that standard ultrasonic testing (UT) cannot inspect. Cracks in tooth valleys can be found with magnetic particle or liquid/dye penetrant, but the specialist needs to know how deep these cracks run into the band rim. Our goal is to deploy sustainable processes and procedures in proven technologies to ensure mining company success.

Over the past 30 years, the group has developed and improved its component testing procedures by building a library with thousands of inspection procedures, processes and scan charts. There are also hundreds of test components used for calibration and training. Failures are never acceptable, but when failures happen, the group uses the situation as a learning opportunity. PdM specialists focus on what could be done differently to identify the flaw and how it can be incorporated into the inspection and evaluation program going forward. Through our best practices, we improved safety and built up our asset reliability while ensuring the equipment is available.

We have had our successes and, perhaps more importantly, our failures along the journey to a world-class program. It has been through these experiences that we have obtained a significant amount of data to help build and/or modify procedures and processes in NDT. We approach our work with a focus on being proactive instead of reactive. This helps us prevent major failures from occurring within our organization. We also share our experiences with others in the industry to help them prevent similar failures. By sharing knowledge, we have also gained knowledge.

Catastrophic failures on draglines can make or break a mining company. This is why we select motivated individuals who have a passion for NDT and PdM work. We continually measure results from our NDT program to ensure we are getting the desired results. Every component removed from service is evaluated by our specialists or sent to a lab to determine and document its general overall condition and to formulate a metallurgical test protocol. Occasionally, an immediate evaluation is necessary due to the component's exposure to contaminants or the environment. For this reason, a field microscope can be operated from the specialist's laptop, enabling him to take pictures and size the failed area for later evaluation.

After the completion of a RCA of each failure or near failure, we establish a maintenance strategy and inspection procedures for identified failure modes. An example of this process can be seen in Figure 1 with a failure on a Marion 8750 series dragline main suspension line socket.

This failure was evaluated in the field with a DinoScope.

One week later, another socket ear crack was discovered in a different location, but changes in the inspection process led to a better UT evaluation of the entire socket (see Figure 2). Maintenance and operations personnel had the opportunity to be proactive in their planning instead of reactive. Collateral damages were avoided by finding this near-failure early. Each dragline had to lower their booms to make these repairs.

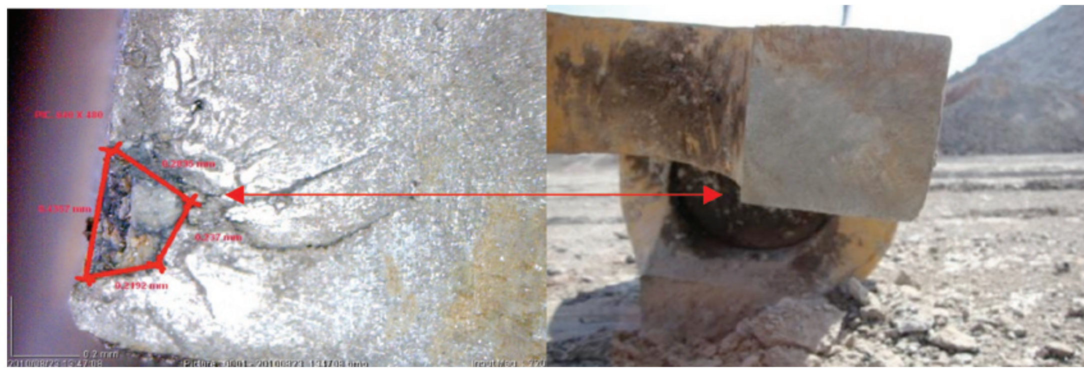


Figure 1: Beginning of the failure location verified with a field microscope.

Figure 2: Upper main suspension socket found crack using UT and magnetic particle testing (MT)

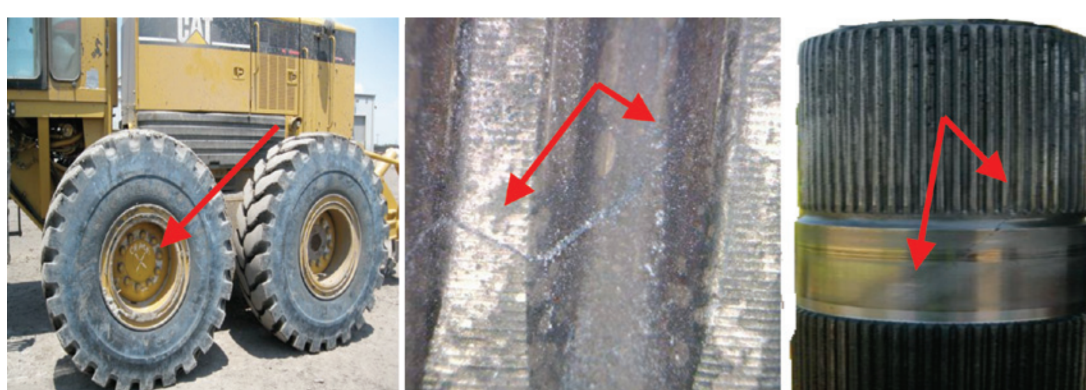


Figure 3: Cracked motor grader axles found with UT and verified with MT after removal

The NDT program for our mobile equipment fleet has also been invaluable. From our rebuilds and preventive maintenance programs, we have developed inspection processes and procedures. One of these is bore scoping the loader fleet differentials components, changing them from a time-based maintenance program to a condition-based maintenance program. Collateral damage was done to a tandem box after failure of a 14G or 16H/M final drive spindle. The challenge in this situation was to prevent a failure by inspecting the spindle with ultrasonics. The RCA data and the spindle evaluation revealed that the failure started at the bottom of the machine bolt hole and propagated outward in a torsional stress crack (see Figure 3). It was also noted that the differential lock was on when turning. Working with OEM on component design and mine operation departments on operator training practices was the first step in isolating this failure. A scan chart was designed based on a new and broken spindle so a

Figure 4: Acoustics routes on conveyor pillow block

process for UT inspection could be implemented. The inspection was a success – in the first year, five cracked spindles were found and changed out before failure. Currently, 98 spindles are under UT inspection. When cracked spindles with the old design are found, they are being replaced with the new design spindles.

NDT is a large part of our overall reliability program, but condition monitoring is another tool we use with heavy and mobile equipment. Even though this technology has been a great help in preventing failures, it still requires a specialist to evaluate the data and recommend the best reliable course of action.

Over the past five years, we have expanded our ultrasound program. The program started with airborne processes on our pressurized booms and A-legs, but quickly moved into vibration and sound inspection routes. Before a condition-based monitoring system could be implemented on our longest beltline system, acoustic routes were started on all pillow block bearings. We are trending vibration, heat and the sound of the bearing while running (see Figure 4). This inspection process is currently covering 1,400 pillow block bearings. A sound library trains craft and technicians on how certain bearings sound when failing, including dry bearings, broken bearing cages, flat or damaged rollers, and damaged racing. Our experience with slow speed pillow block bearings using acoustics over standard vibration has actually been a huge success.

We are also using acoustics with our infrared inspection routes for electrical components. Spot check acoustic routes on power line connections and substations can be done during the day with a more extensive infrared route at night if a problem is found (see Figure 5). Acoustics has enhanced our vibration and infrared programs, but each has its own place in reliability.

By mixing different NDT and reliability technologies together, we have developed many different recipes for success. One recipe that has proven itself time and again is the bringing together of a committed team and innovative tools and practices. We will continue to deploy sustainable technologies while measuring our results as well as our wins. We believe the best is yet to come on our journey towards world-class NDT and reliability.

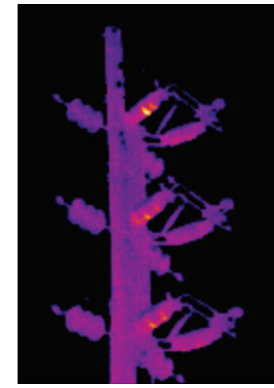
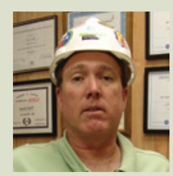


Figure 5: Cracked and leaking insulator - acoustics spot check audibly picked up the leakage in the day, infrared identified the heat at night and pinpointed the location



Keith Lawson is a PdM specialist supervisor for Luminant. Luminant has nine mines located from Central Texas to Northeast Texas. Keith has 32 years of mining experience in maintenance, operations and railroad. He became a PdM specialist in 2006, and in 2007 became the PdM specialist supervisor.

New Twist on Interpreting Vibration Analysis Faults

Daniel T. Ambre

The Original Concept

Walk into most high school science labs and you are bound to see glossy, oversized displays of the periodic table of elements. Invented in 1869 by Dmitri Mendeleev, the original table design reflects the groupings of chemical properties, atomic weights and element forms (solids, gases, liquids). The design is elegant and orderly (even if you have forgotten all aspects of your high school chemistry class). This is where we begin.

The New Concept

Not unlike chemical elements, the world of vibration analysis is also built on patterns. There are unifying commonalities in mechanical systems, such as rotating shafts, bearings, blades, gears, etc. Sources of vibration create measurable response **amplitudes**, repeating rates of occurrence (or **frequency** response) and sometimes induce overall structural motions (**phase** response), each providing clues to the underlying machinery fault.

The amplitude component tells the analyst that a measurement may be "out-of-family" with groups of similar machine "types" or "classes." Frequencies are generated in the FFT spectrum, providing patterns that can be related to the design or function of the machine (e.g., rolling element bearings, gear teeth, turbine blades, etc.). Sets of frequencies can indicate normal operation or the onset of mechanical faults or defects. Phase analysis is a diagnostic tool that allows the analyst to sift through faults that have similar appearance in the spectrum and cannot be distinguished individually.

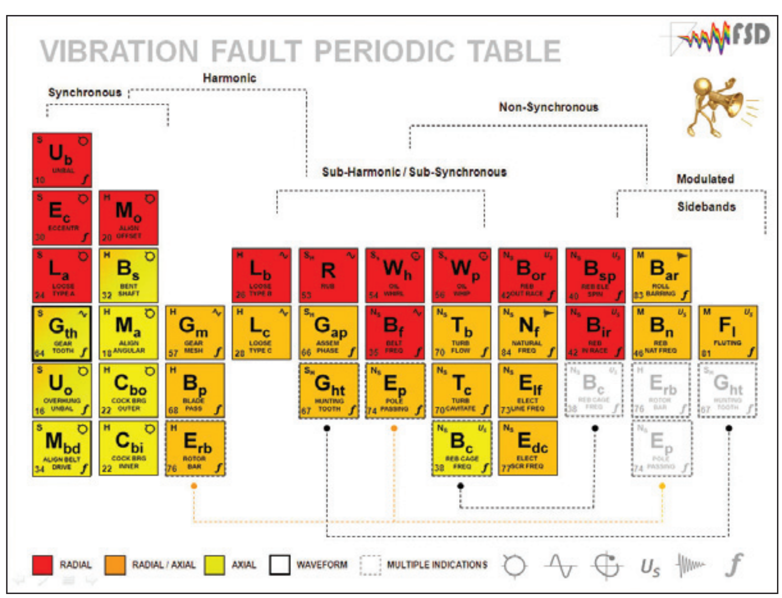
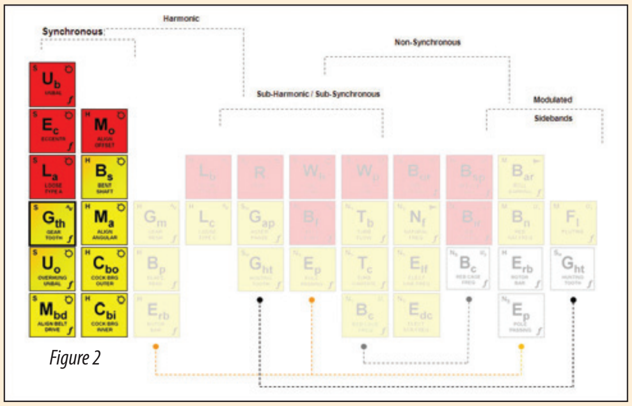


Figure 1

Thus far, this information should be secondhand to the seasoned vibration analyst. However, when the faults are grouped directionally and according to frequency content, a significant amount of information unfolds in our one-page table format. Instead of searching for sample spectra in a book or on a wall chart for something that looks similar to the measurement spectrum from your machine, we can now logically define the fault from a different direction. The result is a useful tool designed to help the analyst narrow down the numerous possibilities when faced with a difficult machinery vibration signature.

Terminology & Groupings

A review of terms is required as we walk through the structure of the ***Vibration Analysis Periodic Table***. The groupings by column contain the dominant vibration faults by frequency content. The column headers are shown on the full table in Figure 1.

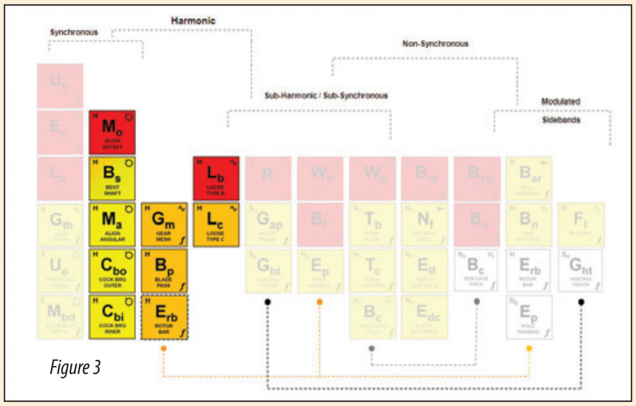


The Synchronous Group

The *synchronous grouping* in Figure 2 includes faults that generate a predominant 1x rpm response in the spectrum. There are many faults that fall into this category, including some faults that may start as a synchronous fault and, if left unchecked, may deteriorate into another group.

For our purposes, the synchronous faults start with an elevated 1x rpm response and hold this pattern (save increasing amplitudes). The *synchronous group* is a small select group that is narrowly defined in the first column on the table. This group includes unbalance, eccentricity, mechanical looseness type A, gear tooth faults and belt drive misalignment problems.

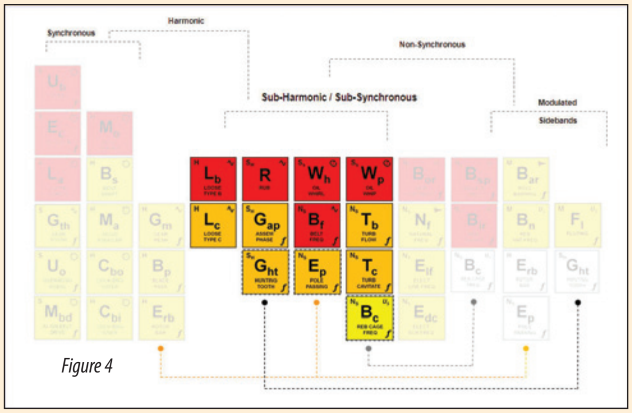
The second column is also representative of synchronous response, but often may include an additional harmonic as well as the 1x rpm peak. This effect can be related to the severity of the fault and may change with overall fatigue in the machine. However, we will see that some of the other categories will also, on occasion, overlap into adjacent groupings.



The Harmonic Group

Frequency content that is considered harmonic will include (you guessed it) harmonic or integer multiples of the 1x rpm rotating speed (see Figure 3). As noted previously, there can be a bit of overlap with the synchronous group, however, the harmonic group can include a single harmonic or dozens of harmonics of the fundamental frequency.

The second column on the table includes faults that have typically elevated 1x rpm and a single second harmonic. This group includes coupling misalignment (offset and angular), bent or bowed rotors, and cocked rolling element bearings. The expanded group of faults is found in columns three and four of the table. These faults include gear meshing harmonics, blade passing, rotor bar passing and mechanical looseness (types B and C) signatures.



Sub-Harmonic/Sub-Synchronous

The *sub-harmonic* or *sub-synchronous* table grouping (see Figure 4) generates frequency content below the 1x rpm synchronous rotor speed or the fundamental order of the fault. The fault can be an integer fraction of rotating speed or non-synchronous with respect to this speed. The group includes mechanical looseness types B and C, rotor/stator rub events, belt drive frequencies, gear tooth repeat problems (assembly phase and hunting tooth), oil whirl and oil whip instabilities, flow turbulence/cavitation problems, electrical pole passing frequency and rolling element bearing cage (train) frequency.

This grouping includes overlap from harmonic and non-synchronous groups and can include additional frequency content. However, the analyst should remember the unique "sub-synchronous" aspect of these faults that can eliminate other potential sources.

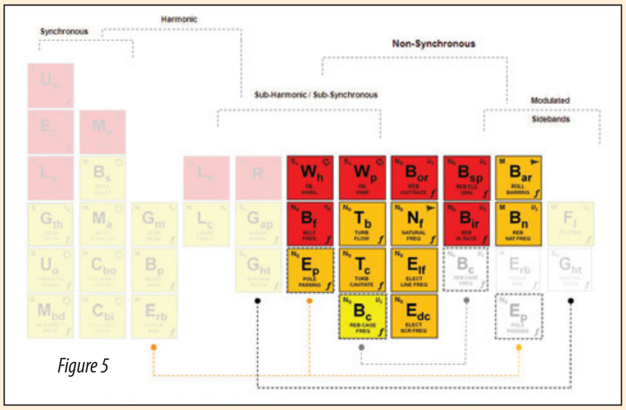


Figure 5

The Non-Synchronous Group

The *non-synchronous* group shown in Figure 5, somewhat overlaps the sub-synchronous group. This grouping of faults requires that the fault frequency is NOT a multiple or whole fraction of the fundamental rotor speed or even a function of that speed. All of the sub-synchronous faults in this category are also non-synchronous faults. These fault frequencies are created from geometric quantities in bearing design, belt diameters, piping design, or created from electromagnetic field theory.

All rolling element bearing faults (including the cage, element spin and raceway frequencies) are always defined as non-synchronous. The geometry in the design of journal-type bearings creates clearances and eccentricities that ensure the instability point (whirl) is non-synchronous.

Flow-related problems create random energy and broad-band frequency responses that are not related to the rotor speed.

The AC and DC motor electrical faults are added to this group, as well as the natural frequency fault series. Specialty faults, such as "barring" or "corrugation" problems in paper rolls and film production, are related to roll diameters, alignment, or structural natural frequencies. The "fluting" or "electro-erosion" fault is related to the already noted non-synchronous rolling element bearing signature.

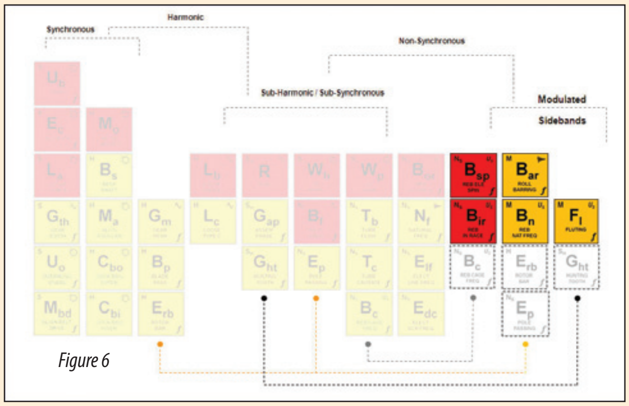


Figure 6

The Modulation/Sidebands Group

The *modulation* group (see Figure 6) includes faults that are more commonly distinguished by their "sideband" sets. Many rolling element bearing faults tend to generate sidebands in later failure stages. Electro-erosion in rolling element bearings will generate "haystacks" of peaks related to the defect frequencies in the bearing. Barring faults tend to create sidebands surrounding a paper roll natural frequency. The center frequency can be related to the diameters of the rolls in nip, their alignment, or eccentricity ratios.

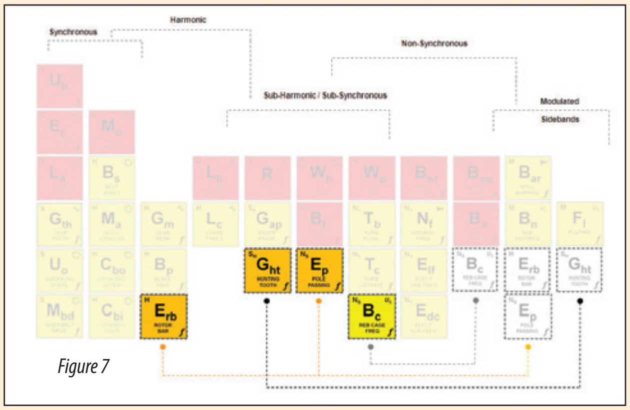


Figure 7

The Multiple Indication Group

Several faults are highlighted with dotted lines and linked to other areas of the table. These are faults that can be described by another category and/or by modulation signatures alone. This is the *multiple indication group* (see Figure 7).

Whenever modulation is involved in the vibration signature, the severity of the problem is typically related to the number of sideband sets found in the frequency spectrum, or the amount of amplitude pulsation noted in the time waveform. Either indicator will allow trending of the deterioration included in the fault over time.

The Directional Response Pattern

A secondary useful pattern in the ***Vibration Analysis Periodic Table*** can be found in the directional groupings inherent in the fault. Vibration amplitude response can present itself in various directions, but there are preferred directional responses in many fault signatures. A side note here will remind the analyst that measurements in multiple directions require making a directionality assessment.

The table is color-coded for the dominant direction of the vibratory response. It may not be casually apparent, but this concept of directional screening is very useful in reducing the likelihood of potential fault sources.

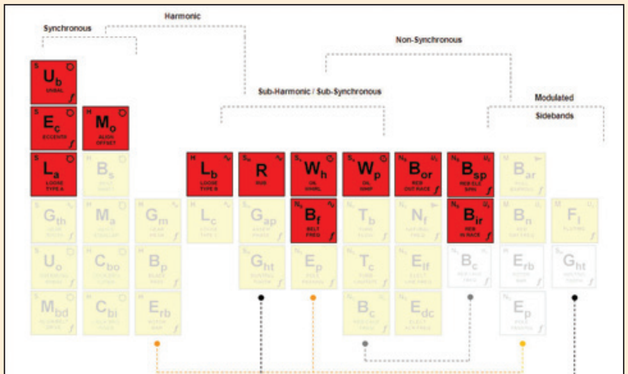


Figure 8

The Radial Response Group

The *radial response group* shown in Figure 8 is a powerful tool because out of the 35 basic faults presented on the table, only one third have a dominant radial preference. In horizontally mounted machines, the mechanical looseness types A and B signatures will most often induce response only in the vertical direction. Likewise, rolling element bearing faults are best detected in the vertical measurement direction in the vicinity of the bearing load zone. The remaining faults in this group can be detected in either the vertical or horizontal (radial) directions.

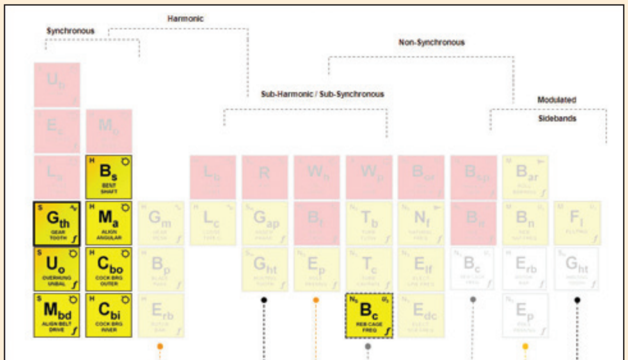


Figure 9

The Axial Response Group

The *axial response* directional fault group in Figure 9 is an even smaller group than the radial faults on the ***Vibration Analysis Periodic Table***. This grouping includes only five truly axial faults and another three that can be predominantly axial based on design (gears) or by fault severity (bent shaft and overhung rotor unbalance).

Remember, if we are analyzing measurement signatures, we have already narrowed down the fault based on frequency content. If the data indicates that the remaining possibilities also include a predominantly axial response, the final group is reduced very quickly.

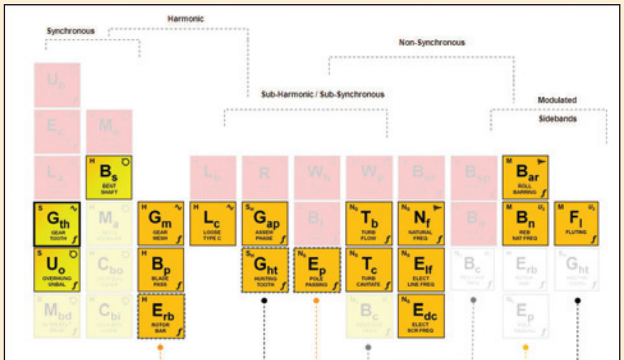


Figure 10

The Axial and/or Radial Group

This group includes faults that are either axially or radially inclined are covered in Figure 10. The set defines 18 potential faults. Again, at this point, the analyst has already screened the measurement by frequency response. Additional knowledge that the fault is NOT purely "radial" or purely "axial" will eliminate several possible fault sources.

An Effective Screening Tool

Hopefully at this juncture, the effectiveness of the Vibration Analysis Periodic Table as a screening tool is becoming obvious. To this point, we have used the frequency and directional response category groupings to eliminate many potential faults, but note that we have NOT looked at an example spectrum on a wall chart or reference book.

Let's face it, it's not likely that our unique machinery problem is neatly duplicated in a book. Even if it were, with the number of variables involved, it's unlikely that we would be able to find it! The "hunt and peck" method of analysis is not an efficient use of the analyst's time.

Additional Table Resources

We are not finished with the periodic table just yet. You may note that the table includes additional information within the colored blocks that defines each vibration problem. The upper left-hand corner notes the frequency content category with a letter: S, H, SS, NS, or M (see Figure 11).

Figure 11: Icon detail information

The lower left-hand corner provides a reference page number for the Vibration Fault Guide (VFG) (See Figures 12a-c). As we narrow down the possibilities, we can turn to the VFG for additional information and distinguishing aspects of the potential machinery fault.

The upper right hand corner includes a symbol for the appropriate diagnostic test that can be performed to provide insight to the potential fault.

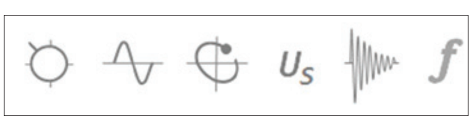


Figure 13: Diagnostic test icon references

The first five icons shown in Figure 13 represent the following diagnostic tests:

Phase Analysis – Traditionally used to distinguish faults with identical frequency response signatures. The chart includes 10 potential faults where a phase analysis may be appropriate.

Time Waveform Analysis – Time waveform is essential as the singular method of detection for gear tooth fault problems. It is also used for corroborating evidence in looseness and alignment problems, as well as rub events and beat frequency problems.

Orbit Analysis – Considered essential in the analysis of fluid film (journal) bearings to detect instabilities and loading issues.

U_S **Ultrasonic Spectrum Analysis** – Most commonly used to detect early rolling element bearing fatigue and lubrication problems. This tool is helpful in gear train problems as well.

Impact Natural Frequency Testing – Defines structural natural frequencies, resonance margin, damping and mode shapes.

f The final symbol in Figure 13 is found in the lower right-hand corner of some select faults on the table. The symbol indicates that there is a formula, calculation, or table that can provide additional insight into the fault.

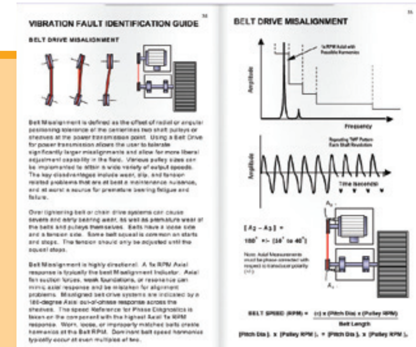


Figure 12a: Vibration Fault Guide (VGF) - belt drive misalignment

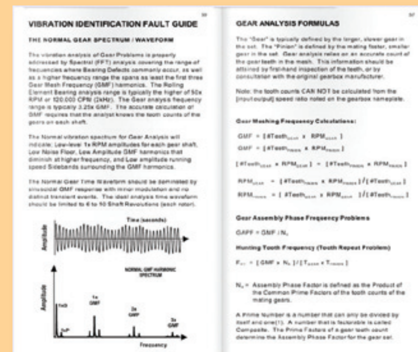


Figure 12b: VGF - gear meshing frequency

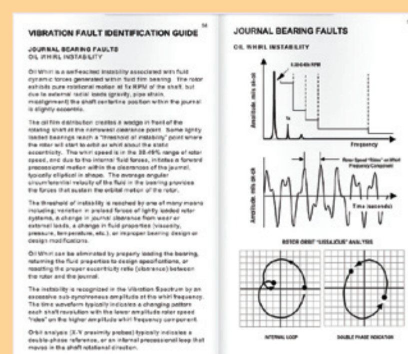
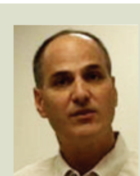


Figure 12c: VGF - oil whirl instability

Moving Forward

The Vibration Analysis Periodic Table concept has been in work for over a year since the publication of this article. The construction has been peer reviewed in several venues, however, with wider exposure, it is likely that readers will notice a lacking element or limitation that needs to be addressed. These critiques are welcome.

The long-term vision for the Vibration Analysis Periodic Table is for it to become a self-guided computer training platform where the analyst can drill down into each fault and experience machinery information, animations and case histories at will. The concept is currently being implemented into all of the training courses at Full Spectrum Diagnostics.



Dan Ambre, P.E., is a Mechanical Engineer and founder of Full Spectrum Diagnostics, PLLC, a full-service Predictive Maintenance Consulting company. Dan is also a Certified Software Training representative for Vibrant Technology, Inc., the creators of ME'scope VES software tools. Full Spectrum Diagnostics' ODS and Modal Analysis training targets the In-Plant Vibration Analyst. www.fullspec.net

Operator-Driven Reliability Best Practices Series:

"Change Is Good, You Go First"

Dave Staples

In our continued series, we focus on the topic of change management. The better job a company does putting in an infrastructure to deal with the elements of changing the operator's role, the more likely ODR will continue enhancing asset and process reliability.

Operator-driven reliability (ODR) programs change the role of operations, making operators responsible for the reliability and mechanical integrity of the equipment they operate. Operators take on tasks to maintain and clean their equipment, ensuring machinery is in top condition to perform at its best. Operators collect observations, measurements and inspection data that can help identify impending issues so they can resolve them before they become a production impediment.

Many companies have delayed changing the role of operations by implementing ODR. This, unfortunately, has put them in a position where they now have to change in order to regain competitiveness and avoid being closed. They could have taken former General Electric CEO Jack Welch's advice, "Change before you have to."

Figure 1: Evidence of resistance to change (note nail used as a stylist)

It's best to be proactive and prepared to tackle human nature's resistance to change. It is rare for an ODR implementation not to have some level of push back, with some worse than others, including sabotage of the mobile devices. Resistance to change can manifest itself in a variety of ways, such as:

"It's not safe for me to have my hands that close to rotating equipment while it's running."

"I can't do my rounds because the PDA doesn't work."

"It's not in my job description."

"It's not in our union contract."

There are a number of ways to deal with managing change, and companies may have to use more than one strategy. A great place to start is using change agents. These are company employees at all levels, usually natural born leaders trained in change management skills. These leaders may have to implement a temporary system of rewards or recognition to reinforce expected behavior.

Rewards or incentives are important tools for reinforcing behavioral changes and are an integral part of cultural change programs. In contrast, recognition helps to reinforce the operator's new role by highlighting results of ODR programs.

Rewards or incentives are particularly useful during implementation. Many are used, but the most effective are those that personally impact employees. Examples include profit sharing, cash, trips, gift certificates, hats, T-shirts, cups, "operator of the month," or "save of the month." Ultimately, you have to eliminate the rewards to some extent as wanted behavior becomes required behavior.

Conversely, program recognition must continue forever, as it justifies the value ODR is delivering to the business. An operator certification program can be used to transition from rewards to recognition. Certifications can be used to validate operator rank or even wage structure. Recognition can be documented qualitatively and quantitatively. However, quantitative recognition measures - those with real dollars tied to them - need to be tracked closely. The important thing is to keep recognition visible to everyone by posting key performance indicators (KPIs) or using newsletters, slogans and other corporate broadcasts.

Another key to managing change is to treat ODR as a process, not a project. Projects end, while processes live on, expanding and, most importantly, improving. Regularly reviewing ODR scorecards (KPIs) and assessing your ODR program will drive continuous improvement activities. Program goals and expectations should be set higher on an annual basis.

One tactic that can be used to prevent ODR programs from fizzling out is the concept of "making it law." This concept weaves ODR principles and matrices into your daily structure. This means the program's status, round compliance, operator findings and corrections are regularly talked about as part of operational review meetings. A great example is the facility manager who asks, "What did the ODR data show?" after an upset has occurred. Nothing reinforces the importance of the program more than this action. New roles and responsibilities must be documented. ODR content must be included in job descriptions, operating procedures, training programs and work processes. ODR tasks should be integrated into your quality manuals, maintenance instructions and job plans. And always include ODR data as part of your root cause analysis process.

Remember, ODR lives long after implementation. How well a company manages change will dictate how long the program continues to grow and, ultimately, sustains itself.

Dave

Dave Staples, Business Development Manager, SKF Reliability Systems, has over 20 years of industrial experience specializing in asset reliability technologies and asset management services. For the past six years, Dave has been focused on helping customers implement and sustain Operator Driven Reliability programs. www.skf.com

Loyalty

In 2012, Tim retired from Cargill Inc., where he was Worldwide Reliability and Maintenance Leader and has been involved in Cargill's reliability improvement processes for the past 20 years. Cargill Inc. is one of the world's largest food and agricultural processing companies with over 1,200 processing facilities and 139,000 employees worldwide.

Timothy Goshert

"Being Loyal" is a popular phrase used for many years in our society, workplaces and lives. Airlines, hotels and automobile companies, among others, have loyalty programs designed to give frequent flyer and/or guest benefits for continued use of their products and services. These programs are designed to create win-win relationships and to benefit both parties.

Personal loyalties are also valued in life. These relationships are built and earned on years of mutual trust between the parties. Some examples may be between a husband and a wife, father and daughter, a mentor and mentee, or maybe just between colleagues at work. It may develop between individual people, groups of people, or even entire organizations. Loyalty to a person, group, or organization is often tested in times of change, upheaval and difficulty. This requires a person, group, or organization to step up to higher responsibilities to help an individual through the present situation at hand.

Loyalty [loi-uhl-tee] *noun*, plural loy·al·ties.
1 the state or quality of being loyal; faithfulness to commitments or obligations. **2** faithful adherence to a sovereign, government, leader, cause, etc. **3** loyalty definition translations: Spanish:lealtad, Portuguese: lealdade, German: Loyalität, Dutch: Loyaliteit, Polish: Lojalność, French:fidélité, Italian: Fedeltà, Danish: Loyalitet, Finnish: Uskollisuus, Norwegian and Swedish: Lojalitet, Romanian: Loialitate, Bulgarian: Лоялност, Czech: Věrnost, Croatian: Vjernost, Russian: лояльность, Chinese: 忠诚, Japanese: 忠誠心, Korean: 충성, Greek: Αφοσίωση, Hebrew: נאמנות
Arabic: ءالو

I have seen many examples of loyalty shown over the years. First, I would like to share a personal example:

My wife is one of the most loyal people I know. She has been my partner in life for the past 28 years. She has supported my efforts passionately over the years. During this time, she also has been a great mother and teacher of life to our two daughters. One example of her ultimate loyalty has been supporting her mother. Her mother was suffering from advanced dementia and three years ago it became evident she needed around-the-clock care. My wife took her into our home and cared for her needs 24 hours a day until she recently passed away. By necessity, this work required my wife's full attention while her mother lived with us. She tended to her mother's needs cheerfully and wanted no praise or attention for it. Her sole concern was for the comfort and happiness of her mother. I am grateful for this experience as it has taught my daughters and me great life lessons in being loyal.

Loyalty to others is the right thing to do morally and has a long-term payback. People will remember and pay it forward when you are in need of help.

Next, I will address how loyalty can benefit one in the work of reliability in industrial plants. Several examples of applying the loyalty principle to the world of reliability are outlined below:

- Customer Supplier Partnerships: It is important for a customer to be honest, upfront and have no hidden agendas. The customer needs to create an environment in which suppliers can honestly express their thoughts (positive and negative) to strengthen the partnership and create win-win agreements. Being loyal to the agreement and partnership is paramount for the long-term success of both parties.
- Employees and Employers: The job-hopping and downsizing culture in today's workplace is alarming and detrimental, I believe, to the long-term success of the employer and employees. Employees should strive to be team players, actively support the goals of the organization and work to create value for the employer. There should be an effort to make the pie larger, as opposed to fighting for the same piece of the pie. As the organization becomes more successful, the employer can invest in new ventures. This provides future opportunities for employees to grow and have new roles and jobs.
- Peers and Colleagues: I believe helping one's peers and colleagues meet their collective goals is the ultimate way to show loyalty. This positive role replaces the negative behavior of backstabbing and backdoor politics to "get ahead" of one's colleagues. Helping others succeed will be noticed, appreciated and reciprocated when in need.
- Acquaintances, Competitors and Others: A popular phrase is, "Today's foe is tomorrow's friend." I have experienced this several times in my career. Treating all people with courtesy and respect is not only the right thing to do, but it also pays back in the future when paths cross in business. Your reputation will precede you and people will remember.

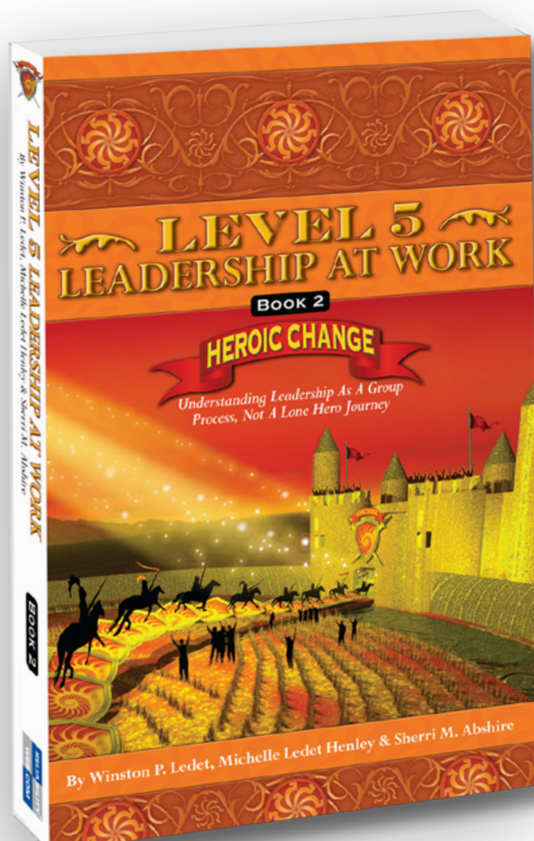
In summary, loyalty to others is the right thing to do morally and has a long-term payback. People will remember and pay it forward when you are in need of help.

Timothy Goshert,CMRP, has 33 years of experience working in the food processing industry. He has extensive experience in plant operations management, project engineering, construction management, and maintenance & reliability management. Tim holds a B.S. in Chemical Engineering from Pennsylvania State University. Tim is an active member of the Society of Maintenance & Reliability Professionals (SMRP) and has served on its Board of Directors for the past eight years. He has served as SMRP Chairman in 2008. He has represented SMRP on the establishment of Global Forum on Maintenance and Asset Management (GFMAM) and has served on the executive committee as treasurer and vice chair. Additionally, he has served as Chairman of Society of Maintenance & Reliability Professionals Certification Organization (SMRPCO) in 2005. Tim joined the Allied Reliability Group in 2012 as Principal. He is responsible for strategic customer account satisfaction.

LEVEL 5 Leadership At Work

Authors: Winston Ledet, Michelle Ledet Henley & Sherri Abshire
Reviewed by: George Mahoney

"George, you've done such a great job improving maintenance in Factory 12 that we want you to lead this effort across the rest of the site."



As these words were coming from my boss's mouth, all I could think was "piece of cake." I had already created a recipe for success, so implementing this in other areas was going to be simple. Besides, my team had achieved such huge gains, I couldn't imagine how anyone else would not want to copy exactly what we did.

Within two weeks, I realized I could not have been more wrong. Not only were my colleagues unreceptive to our program, many were taking my "Call to Change" as a personal insult. I did not know it then, but I was in true need of a book that had the solutions to my problems - *Level 5 Leadership At Work*.

Level 5 Leadership At Work is the second installment of the Heroic Change series created by Winston Ledet, Michelle Ledet Henley, and Sherri M. Abshire. The book is written in a novel format that easy to read and impossible to put down. While the story takes place in a fictitious manufacturing company, everyone who reads the book can make a direct connection to the obstacles they are currently facing in their own organization.

In the first installment, *Don't Just Fix It, Improve It,* plant manager James Emery had incredible success changing the quality, safety, and culture of his plant by empowering the workforce to focus on Defect Elimination. He did such a good job, that he was promoted to the role of Corporate Reliability Champion. In his new role, he was to take what he learned at his site and use it to gain the same success at every other site in the company.

Just as I had learned the hard way, James also finds out that people are not very receptive to a "Call for Change." Not only did he have to deal with egotistical plant managers, he had to go against competing initiatives, such as Six Sigma and Standardized Operations. In a few instances, he actually had sites that were willing to change. Unfortunately, they either lacked the leadership skills or the business urgency to make it happen.

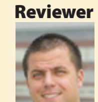
James comes to realize that there is no cookie-cutter approach to implementation. Given the different financial and cultural situations at each site, there is no way for him to dictate the details of the *Don't Just Fix, Improve It* mentality. Rather, he needs to develop a set of non-negotiable principles that each site can leverage and at the same time, maintain its sense of ownership.

As James moves forward on this journey, he discovers the most important element needed for change is "Level 5 Leadership." As you read this book, I challenge you to find out if you have the qualities of a Level 5 Leader. Are you willing to empower your employees? Do you have no fear of losing power and authority? Are you willing to put the success of the site in front of your own glory? In other words, are you willing to "check your ego at the door?"

Level 5 Leadership At Work and the first book in the series: Don't Just Fix It, Impove It! can be purchased at www.mro-zone.com

Winston and his co-authors are currently hard at work on the next book in the Heroic Change series. www.HeroicChange.com

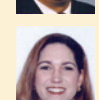
Reviewer



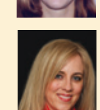
George Mahoney has worked in almost every facet of maintenance and engineering over the past 10 years. He currently acts as a mentor, sponsor and instructor for Lean Six Sigma.

Authors

Winston Ledet has 27 years of experience with E.I. DuPont de Nemours. He is one of the creators of The Manufacturing Game and has his own consulting firm, Ledet Enterprises, Inc.



Michelle Ledet Henley has worked with The Manufacturing Game since 1998 as a developer of new simulations and training material.



Sherri M. Abshire has been an employee of Ledet Enterprises since 2001. Sherri works closely with the company president, Winston P. Ledet, on numerous writing, research and development projects.