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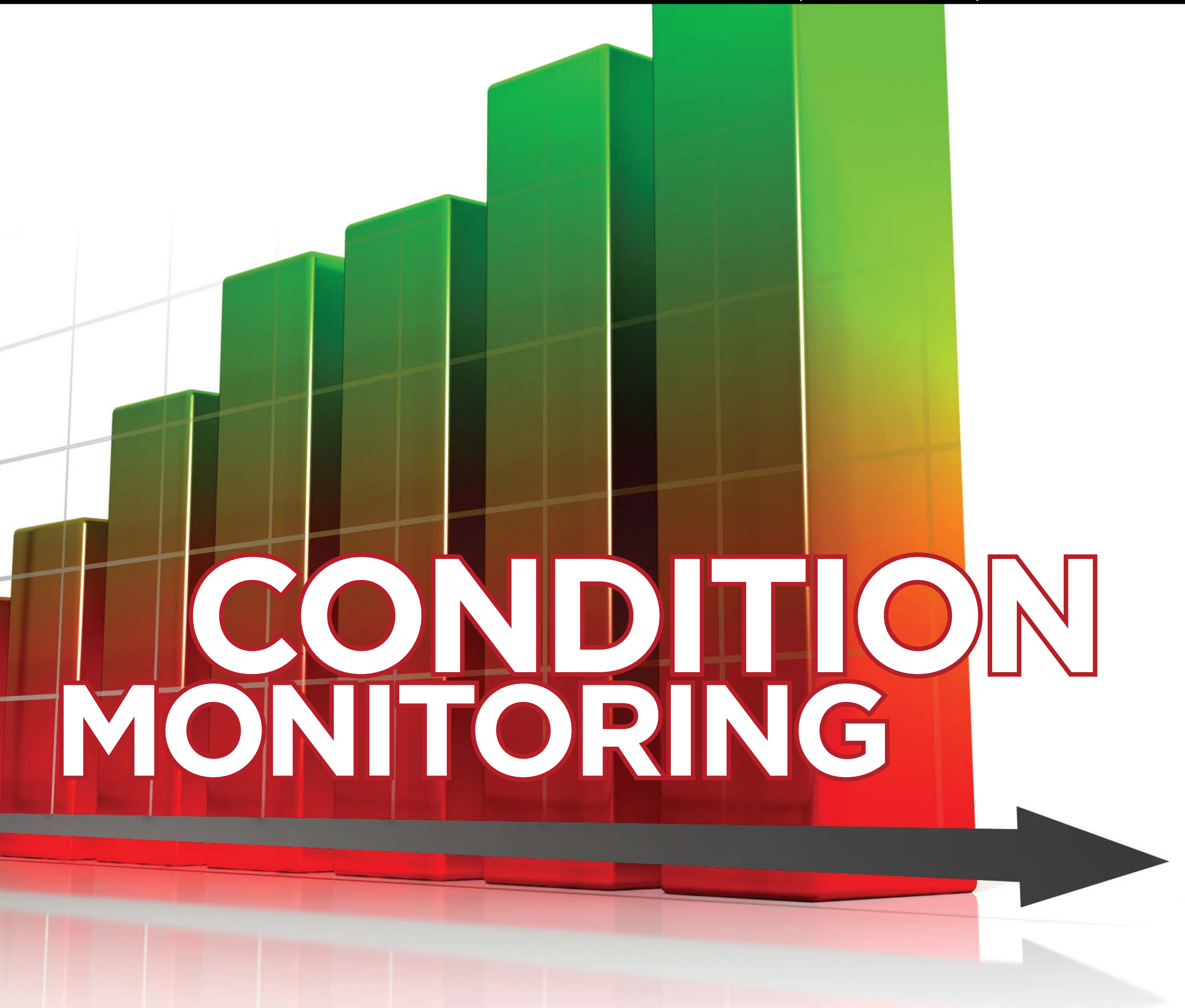

CONDITION MONITORING

IN THIS REPORT:

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SIX STEPS TO CONDITION -BASED MAINTENANCE

An exciting trend in the world of CMMS is the increasing sophistication of condition-based maintenance (CBM) features and functions vendors offer and maintenance professionals actually use. Perhaps we're finally turning a corner on the age-old firefighting mentality, replacing it with a more planned environment.

An exciting trend in the world of CMMS/EAM is the increasing sophistication of condition-based maintenance (CBM) features and functions vendors offer and maintenance professionals actually use. Perhaps we're finally turning a corner on the age-old firefighting mentality, replacing it with a more planned environment. CBM, a form of proactive, preventive or predictive maintenance, can be defined simply as maintenance initiated on the basis of an asset's condition. Physical properties or trends are monitored on a periodic or continuous basis for attributes such as vibration, particulates in the oil, wear and so on. CBM is an alternative to failure-based maintenance initiated when assets break down, and use-based maintenance triggered by time or meter readings.

Vendors have incorporated CBM into their CMMS/EAM offerings in a number of ways. The simplest packages allow manual input of data such as condition readings for triggering PM routines. The more sophisticated CMMS software connects online to PLCs or other shop-floor devices for automated data collection. The software then analyzes incoming data to ensure that trends are on target and within user-defined control limits. When data strays outside limits, the software initiates a work order or takes some other action. It tracks variance from target as well as the worst and best readings.

What comes after RCM? Factors that may impact RCM modeling

- Irregular equipment performance patterns
- Condition Monitoring intervals vs Detection-Failure period
- Cost benefit analysis based on OEE, maintenance, capital requirements however the total cost isn't factored in!
- Cost benefit analysis considers energy efficiency; cost performance predictor

You have assets that run your business — motors, pumps, conveyors, HVAC units, etc. Over time the performance of those assets degrade. Eventually they fail, and corrective, predictive or reliability centered maintenance is performed.Today's CMMS/EAM systems catch the degradation earlier than failure, but at a point where it has already cost you money — telling you to go maintain that asset, but long after its performance has gone downhill and its operating costs have increased due in large part to excessive energy use.

Imagine if you had a new way to alert your maintenance staff of asset degradation long before it has cost you money i.e. even before an asset's performance first begins to go off track. How can you do this? If you track various performance conditions and also track the amount of energy an asset uses it will tell you exactly when that asset is beginning to use more energy that it was designed to use. Energy efficiency is a leading indicator of failure. Far before your asset fails, far before your motor begins to vibrate excessively, or overheats, your motor will begin consuming more energy to operate.

So is EAM/CMMS combined with asset energy usage the next level of condition-based maintenance?

Condition monitoring versus control

Although condition monitoring is, in most cases, better than waiting for a breakdown, CBM isn't the ideal solution. Wherever possible, implement automated control systems, as they minimize human error and significantly improve service levels.

For example, suppose a critical piece of equipment is monitored continuously to ensure that some temperature is within an acceptable range. If the temperature rises above the upper limit, a control loop can activate a fan to cool the overheated area until the temperature returns to an acceptable range.

This is clearly superior to a condition-monitoring system that merely alerts a human that the temperature was too high. It's then up to the human to eliminate the variance condition effectively and efficiently.

However, it isn't always possible to determine the root cause of a variance automatically. Nor is it always possible or cost-effective to take automatic action. In such cases, human intervention is desirable, making a condition-monitoring system preferable over an automated control system.

For example, when a sensor detects a machine vibration level above the upper control limit by a user-defined amount for a user-defined period, it can initiate an alarm condition. A human might be required to determine the many possible root causes of excessive vibration, such as operator error, raw material problems, jammed parts, machine wear and so on. A human might also be required to determine the most appropriate corrective action. Therefore, it's impractical to automate the root-cause detection and subsequent control loop to fix the problem.

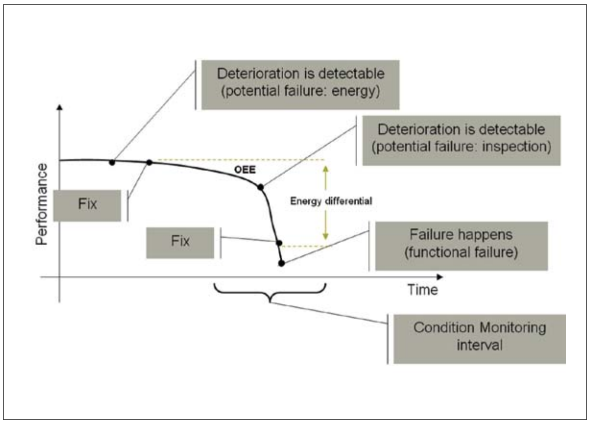

Figure 1. The energy intelligence difference

Six giant steps

There are many permutations and combinations to evaluate when trying to select and prioritize the conditions to monitor, how often, for which components, leading to what actions. Many companies have spent considerable time and money on internal and external resources to make these determinations, and some have been frustrated to the point of abandoning the exercise.

To make the process less onerous, prioritize the assets for which CBM might make sense based on what happens when an asset or component fails. If the consequences of failure are catastrophic (large loss of production, major safety risk), then CBM might be appropriate. Compare the cost of failure or use-based maintenance with CBM for a given asset, and factor in the approximate value of the asset failing to prioritize candidate CBM assets. Apply the six steps below to your prioritized short-list of assets and components. The example provided is for a cooling water system where out-of-range water temperature may have catastrophic consequences.

1. Determine operating context for the asset being analyzed (cooling water system is to maintain water between 40°F and 45°F).
2. Define the asset's functions (maintain water temperature and contain water in the tank).
3. Assess possible failures (water too hot or too cold).
4. Identify possible failure modes or root causes (heat exchanger fouled, valve closed, pump bearing fatigued).
5. Determine the most probable failure effects for each failure mode (inefficient heat exchanger results in higher utility cost, extra cooling tower sections in operation, eventual inability to deliver quality parts).
6. Propose an appropriate maintenance task for each failure mode using failure history, probability and costs to compare financial and technical feasibility of corrective, preventive or predictive actions (monitor heat exchanger efficiency).

If CBM is the most cost-effective solution, select one or more condition indicators and define the frequency of data capture, the control limits, the business rules for triggering an alarm, and the action(s) to be taken for each indicator. Actions can range from an automated control loop, to sending a page to an area mechanic.

Advanced CBM features on a CMMS

Search for a CMMS package that supports CBM and you'll find a variety of features. At a minimum, look for the basics such as the ability to establish upper and lower control limits that trigger an alarm, and notification or simple workflow to initiate a task when a trigger occurs. More sophisticated features include

- Multiple indicators per asset.
- Trigger from one indicator resets all other triggers for a given asset.
- Nesting of triggers with different cycles (cycle A is a 10-point inspection and cycle B = cycle A plus an additional inspection; as opposed to procedure A = 10-point inspection and procedure B = 11-point inspection).
- Combining indicators using Boolean logic to produce consolidated or alternate indicators.
- Recommending corrective action based on condition, i.e., using indicators, Boolean logic and/or setpoints (e.g., oil analysis reveals gas, particulate or temperature trends that necessitate a given PM work request).
- Triggering a PM routine on a preferred day or date if the meter reading is within tolerance.
- Forecasting when the next meter reading should occur based on historical readings.
- PM shadowing to avoid duplicate PMs.
- Overriding or taking credit for corrective work that covers PM work due, to avoid duplication.
- Validating readings with a user-defined validation formula.
- Color-coded alarm tables for indicators.
- Graphic showing component hierarchy and corresponding indicators.
- Hot spots on the graphic for drill-down to details about indicators.
- Visibly distinguished conditions and alarms on the graphic (blinking, color change).
- Acknowledging alarms or conditions easily from within the graphic screen.
- Entering a new condition easily from within the graphic screen.
- Dynamic integration of production activity with equipment and component hierarchy on the graphic screen (issue inspection work order to check out root cause of production line slowdown or pressure drop in vessel).
- Trigger based on calculation of the history of condition readings (average, average variance, sum, median, max or min of last 10 readings must be within certain control limits).
- Using data from anywhere in the CMMS database to establish a trigger (when ultrasonic reading is greater than the nominal wall thickness by a given factor).

By David Berger, P.Eng.

BOLSTER YOUR CONDITION MONITORING TOOLBOX

Take advantage of a variety of techniques to increase equipment uptime.

Global competitive pressures have increased demands to keep plants running better, longer and more cost effectively by reducing unscheduled downtime and boosting uptime for machinery assets. Much of the responsibility to optimize asset efficiency falls on maintenance staffs. Yet they face numerous challenges in achieving the goal. For a variety of reasons personnel may not be able to follow precision maintenance practices to the letter; equipment maintenance is becoming more complicated; and environmental and safety laws have grown stricter.

The result has been sustained interest in proactive maintenance programs to help achieve equipment reliability objectives. Condition Monitoring (CM) can play a crucial role in proactive maintenance.

CM involves regularly measuring physical parameters such as vibration, noise, lubricant properties and temperature via non-invasive methods, usually during normal operation of equipment. CM makes it possible to detect machine and component problems before they can result in unexpected downtime and the high costs associated with interruptions in production.

CM ultimately can serve as a platform for implementing a condition-based maintenance program — scheduling maintenance, inspection and overhaul based on machine condition instead of the calendar. The goal is to trend and analyze data to identify troublesome conditions and detect early stages of component degradation. Then, remedial action can be taken to prevent failures and reduce unanticipated downtime.

Many plants already rely on some CM methods, particularly overall vibration monitoring and lubricant analysis. However, the CM toolbox also includes under-appreciated techniques such as time domain analysis and bump testing. So, we'll look at what various methods involve and the insights they provide.

The sidebar gives some pointers for making the most of these techniques. They (and others) can help promote successful CM programs.

Overall vibration

Vibration can be defined as the behavior of a machine's mechanical components in response to internal or external forces. Because most rotating-equipment problems cause excessive vibration, this operating parameter generally is considered the best to initially assess a machine's condition. Vibration monitoring can detect fault conditions such as imbalance, misalignment, rolling bearing degradation, mechanical looseness, structural resonance and soft foundation.

When analyzing vibration, frequency and amplitude of the signal should be evaluated.

The frequency at which the vibration occurs indicates the type of fault (certain types of faults typically occur at certain frequencies). By establishing the frequency, a clearer picture can emerge regarding cause.

Amplitude typically determines the severity of the fault (the higher the amplitude, the higher the vibration and the bigger the problem). Amplitude depends on the size of the machine and must be considered relative to the vibration level of the fully functioning equipment.

A typical starting point is to trend a machine's overall vibration level. This is the total vibration energy measured within a specific frequency range.

Figure 1. This small hand-held monitoring tool provides a convenient means to collect data on overall vibration.

In the case of a rotor, for example, the overall vibration would be measured and then compared with its normal value to assess any inconsistencies. A higher-than-normal overall vibration reading would indicate that "something" is affecting the rotor. Further analysis can identify the actual cause.

Hand-held units such as low-cost vibration pens (Figure 1), overall vibration meters or more sophisticated portable data collectors (Figure 2) and related instruments combining compact size with data storage capabilities make data collection for overall vibration analysis easy. Other options include online surveillance systems to perform round-the-clock monitoring of machinery, regardless of equipment location. This type of technology has been highly engineered to collect data continuously (or at a predetermined data-collection frequency) from permanently installed sensors. Findings then are transmitted to a host computer for subsequent analysis.

FFT spectrum analysis

Among methods for viewing vibration and noise signals and pinpointing the causes, a Fast Fourier Transform (FFT) spectrum is perhaps the most useful. Vibration and noise signals are broken down into specific amplitudes at various frequencies. Because each equipment component vibrates at a certain individual rate, maintenance personnel by processing these signals can distinguish between several different rates and then determine which rate coincides with which component. The resulting FFT spectrum can point the way to the location, cause and stage of a problem.

Figure 2. Portable unit stores and analyzes data which also can be uploaded to a computer for more detailed analysis.

User-friendly FFT analyzers have been developed to measure vibration and noise signals and separate them into their component frequencies. These tools can display spectrum information in simplified formats to enable a first-pass diagnosis of machinery condition or identify areas for further scrutiny (Figure 3). The placement of FFT analyzer sensors, setup, and the process of taking measurements can be performed without taking machines out of service.

Time domain (or time waveform) signals offer one of the few methods to detect certain types of problems. Time domain analysis also can bolster confidence that data in the frequency spectrum have been properly interpreted; in some instances, it can help confirm a particular problem that simply may have been a "best guess" scenario.

Time domain is the actual data received from machinery and further processed through Fourier Transform to arrive at the frequency domain. This allows personnel to discern actual frequencies and amplitudes of components within a machine and helps target components that may be failing or faulty processes that could have gone undetected until machinery failure.

In general, the time domain is a record of events as they happen and is very similar to looking at recorded sound. A sine wave produced by a signal generator in the lab would appear in the time domain spectrum just as it does on the screen of an oscilloscope. In the real world, though, complications arise because a machine doesn't produce a solitary signal. That's where a time domain signal shines.

For example, an operating motor connected to a gearbox and then to a compressor produces thousands or millions of signals that add and subtract to and from each other based upon their relationships and the influence of external forces.

All ultimately can be separated and discerned from a time domain signal.

The need for time domain data is absolutely mandatory for some applications. These include cracked, broken or deformed gear teeth in gearboxes; rolling bearing defects on very-low-speed (less than 10 rpm) machines; motor startup transient issues resulting in bearing deterioration and winding problems; and, for reciprocating compressors, short-lived impact-type vibration concerns, such as piston slap, main bearings and inlet or discharge valve problems.

Bump testing

One of the generally under-appreciated CM techniques involves a bump (or rap) test. It can provide operators with a quick indication of whether high levels of vibration or noise are due to the dynamic or static parts of a system. This impact test is carried out to excite the structure to allow measurement of natural frequencies, which then can determine whether high vibration or noise levels are due to resonance or a potential problem with the machinery.

A bump test, unlike most other CM methods, requires that the machine be switched off. An accelerometer is placed on the part of the structure suspected of causing significant resonant frequencies. The most likely sources of these will involve parts (such as fan guards, thin panels and pipe work) that "ring" for a long time after being hit.

The structure is repeatedly but gently hit; during these impacts a measurement from the accelerometer records the responding ring. Its frequency content then is compared with norms.

By identifying a shift in the natural frequency, bump tests can help detect mechanical faults such as cracking in metallic components. (Cracked or poorly bonded structures will exhibit less stiffness, resulting in a change in natural frequency.) The test also can identify weak or unstable structures.

Lubricant analysis

Lubricants represent vital sources of information ready to be unlocked and evaluated as part of a CM program. Results enable operators to confirm use of the proper lubricant, prevent potential over- or under-lubrication, track lubricant use and waste, raise flags about quality (including inorganic contamination, debris from wear or lubricant degradation), and contribute to the desired cleanliness and optimized performance of machines and systems.

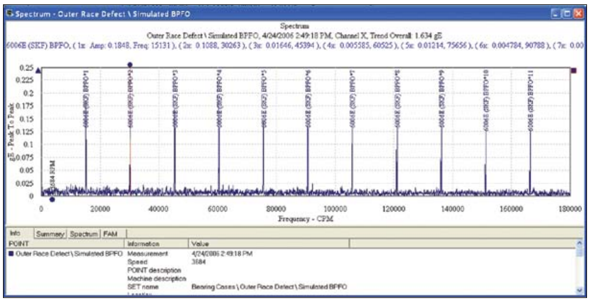

Figure 3. Particular peaks relate to specific equipment components, enabling pinpointing of causes of vibration and noise.

Lubricant analysis can satisfy two primary objectives: detecting a problem and diagnosing its source. Many lubricant suppliers often provide basic lubricant analysis as an added-value service for using their lubricants. However, the analysis only may confirm that the lubricant meets specifications and offer little information regarding machinery health. For this reason, one of the first steps in establishing an analysis program for lubricants is to identify the lubricant testing technology employed to make analytical assessments.

While laboratory analysis of lubricants can play an important role in managing machinery assets more effectively, the good news is that not all testing has to be performed in a laboratory. Many of the important characteristics of working lubricants can be examined visually or with the aid of very simple tools.

For example, you can check clarity and water contamination with a standing sample. A magnet drawn up the side of a glass jar containing lubricant diluted with a solvent can detect ferrous materials (filings and metal dust). A bull's eye sight glass can show flow and discoloration. Simple in-plant tools enable viscosity monitoring. These are good day-to-day observations.

On a broader and more in-depth scale, you should routinely evaluate several critical machine and lubricant parameters including machinery wear particles, contamination, and lubricant or additive degradation.

Truly meaningful lubricant analysis programs encompass testing a wide range of parameters using a variety of methods. Some of the more common test areas are:

- *Color and appearance.* Regularly check these characteristics. For oils too dark for effective appraisal, reduce the volume of oil to a constant depth for proper observation.
- *Viscosity.* Oils found to be outside specification always are considered abnormal. However, a change within a grade also can be a sign of trouble. Watch for changes of 10% from new oil.
- *Base number.* Compare the alkalinity values (base number) of the used diesel engine oil to new oil. As a general rule, change oil when the alkalinity value of the used oil is 50% of the new oil.
- *Acid number.* Acidity varies in new unused lubricating oils based on the concentration of antiwear (AW), antiscuff (EP) or rust additives. Increases above the new oil reference indicate oil degradation. Lubricants having additives such as zinc dithiophosphate and EP generally exhibit higher acidity than those containing only rust and oxidation additives.
- *Emulsion.* Water separability testing is primarily used to evaluate steam turbine, hydraulic and circulating oils susceptible to high water contamination.
- *Foam.* In systems where foam is perceived to be a problem, perform a foam test to confirm whether the lube oil is the source. If the oil isn't the problem, turn your attention to other influencing parameters (mechanical or operational) to resolve the issue.

By Scott Brady, SKF Condition Monitoring

PROTECT YOUR CONDITION-MONITORING **PROGRAM FROM THE RECESSION GUILLOTINE:**

Cutting back on intelligence and efficient approaches to managing your assets is never a good idea. In fact, more intelligence and efficiency is always better, especially when times are tough.

These are cost-cutting times. A recessionary period is partially defined as a time when supply outweighs demand; when we are producing more products than people wish to buy. Depending on the industry, this might not be the appropriate time to discuss availability, uptime and overall equipment effectiveness (OEE), or how we can reduce yearly downtime by a percentage point in order to eke out some additional product. These are times of slowdowns, layoffs and plant closures when we reconcile our overcapacity for production and try to keep our doors open until demand picks up again.

Wherever you find yourself in the spectrum, one thing is for certain: Don't think you are cutting costs by cutting back on condition-based maintenance programs or other intelligent asset-management strategies. Quite the contrary.

Intelligent maintenance not only increases efficiency when the mantra is "Produce! Produce! Produce!" It also saves money when things slow down. Cutting back on personnel might be necessary and outsourcing some of these functions might be the best option, but cutting back on intelligence and efficient approaches to managing your assets is never a good idea. In fact, more intelligence and efficiency is always better, especially when times are tough.

Let's do a quick experiment to prove the point. Imagine an airline is going through difficult times and decides to cut back on maintenance to save some money. What will likely happen? Perhaps nothing will happen for some time, but eventually we can guess the airline will begin to lose track of its assets (knowledge of the mechanical condition of the planes) and, in a best-case scenario, only reliability will suffer. At some point, it is going to cost a lot of time and money to regain control of the situation; more than was saved by shortsighted cuts. When business does eventually pick up, the planes will start breaking down and then the airline will find that it cannot meet demand. This recession will not last forever and, therefore, the question becomes not only how companies survive, but where do they want to be when it is over?

In his book "The 7 Habits of Highly Effective People," Stephen Covey talks about the habit of "sharpening the saw." He suggests that if a saw mill wishes to cut as much wood as possible, it will be more successful if it stops every once in a while to sharpen the saw. Just as one's immediate inclination would be to cut, cut, cut if the goal is to cut more wood, the common business practice of eliminating programs, laying people off and stopping intelligent work when a slow time hits are wrong. A slowdown is an opportunity to "sharpen the saw" and to look for smarter and more efficient ways of running the plant; to slim down and shape up so that you are ready to run when the race begins again.

A slowdown in demand is the right time to invest in greater efficiencies, to streamline maintenance practices and procedures and to remove unnecessary maintenance actions through better understanding of the condition of the assets. These goals can be achieved by adopting condition-based maintenance practices. If you don't have the in-house expertise to carry this out, ask for help. Outsourcing is an efficiency a plant can take advantage of, especially as it allows one to cut back on payroll when times are tough and use manpower only as needed. As the baby boomer generation begins to retire and the industry begins losing in-house experts, there will be even more incentive to take advantage of outside expertise, automation and remote monitoring.

Intelligent maintenance practices — which include predictive maintenance technologies such as vibration analysis, precision balancing and alignment, oil analysis, IR thermography and ultrasound, intelligent lubrication management regimens, process monitoring, root cause failure analysis and reliability techniques — are money-saving efficiencies, not expenses. Why would some choose to cut these programs in hard times instead of embrace them? One answer is that not enough has been done to actually calculate the positive economic effect these programs have had on the plant.

One goal of condition monitoring is to reduce the number of unplanned maintenance actions in the plant. Unplanned maintenance actions negatively effect production schedules and might cause injuries, accidents and collateral damage. When a plant has successfully implemented a condition-monitoring program, the expectation is that the number of instances of these unplanned failures is reduced. This is a fairly easy thing to track and measure. There are a number of other ways to measure the effect of intelligent maintenance regimens on the plant's bottom line, but failure to actually measure and document these positive results can often result in a good program getting cut.

An economic downturn is an opportunity to step back, review internal processes and procedures, engage outside experts and improve the plant's overall operations. As distant as it may seem, you must keep long-term goals in mind despite today's troubled times. When the recession is over, you will need to be ready to compete, not be bogged down by accidents and reliability problems caused by shortsighted cuts in maintenance. When surveying current plant practices and beefing up or implementing intelligent maintenance strategies, it is important to consider the positive economic effect of these programs and develop metrics to measure your success or failure. One simple measurement, but certainly not the only one, is the relative number of planned to unplanned maintenance actions. In any case, good programs often get cut if metrics are not in place to justify them. Now is the time to sharpen the saw and to measure how sharp it is to see how this improves the plant's bottom line.

By Jonathan Hakim

GO BEYOND CONDITION MONITORING

Despite condition monitoring, unplanned outages continue to be an issue, significantly impacting financial performance through lost production and extra repair costs.

In today's environment, chemicals makers face ongoing pressure to operate safely and reliably at the lowest possible cost. Most companies have adopted condition monitoring technologies as a key approach to improve the availability and reliability of process equipment and to proactively avoid downtime.

While these condition monitoring solutions are providing solid value for most plants, unplanned outages continue to be an issue, significantly impacting financial performance through lost production and extra repair costs.

So, in this article, we'll explore the underlying challenges and introduce the concept of condition management — an enhanced approach that helps companies reap the full benefit from their condition monitoring investments. We'll also discuss how to get started in condition management, looking at both business and technical considerations.

Building upon a baseline

For years plants have tracked the health of key equipment. Sites generally have focused on a relatively limited deployment of specific monitoring technologies aimed at protecting critical assets — primarily large rotating equipment. This has become simpler with the widespread availability of highly capable fieldbus-enabled monitoring tools, e.g., for vibration, temperature, pressure, corrosion and fluid analysis.

Now, the advent of intelligent field devices and sensors as well as low-cost wireless units that can be deployed into areas where hard wiring would have been cost-prohibitive is extending these base capabilities and the data they provide.

Unfortunately, plants aren't enjoying the full potential of the data for three reasons:

1. The focus of condition monitoring deployments is too narrow. Sites need to instrument a wider range of assets, so management can look beyond specific equipment to entire process areas or complex asset sets such as heat exchangers, dryers and other plant units.
2. The volume of data available now is huge and will continue to grow exponentially. This creates a significant knowledge management challenge around making sense of the data. Exacerbating the problem, the aging workforce means that plants are losing more and more people with critical operational experience, knowledge and interpretive skills.
3. Many companies still have operational silos. Plant personnel aren't collaborating

to detect, manage and analyze emerging issues. The net result is continued outages, even when the underlying condition or trend had been correctly detected.

Condition management defined

Addressing this set of challenges requires an enhanced, more holistic approach — condition management. Under this approach, the vast array of condition data is the entry point to a five-step process where the data are:

1. aggregated and rationalized;
2. combined to create context and support proper analysis;
3. clearly presented and communicated;
4. systematically managed to ensure the timely, accurate, consistent and effective resolution of the underlying issues; and
5. used as input to an ongoing continuous improvement process.

The first three elements are aimed at turning the data into information, changing the condition information from "noise" in the eyes of operations personnel into useful decision support intelligence for all personnel.

The aggregation and rationalization also need to address the varying types of data, the time element (real-time, near-time and offline) as well as the various access and communication methods utilized by vendors.

Once the data are turned into properly contextualized and actionable information, it's critical to manage the use of the information. It comes back to the fundamental difference between condition monitoring and condition management. Condition management information helps unlock the usefulness of the condition data by:

- driving the appropriate workflow/processes to resolve the issue(s), bringing together the key personnel across operational disciplines (engineering, maintenance, control, safety, etc.).
- . providing input to an ongoing knowledge management process where new situations and their appropriate resolution are systematically captured and documented.

Further, condition management supports Six Sigma or Lean Sigma initiatives by supplying input for an ongoing process where the knowledge base is regularly reviewed and refined.

A telling example

A leading specialty chemicals maker discovered the value of the approach but only after a serious incident. The process uses a significant amount of power, so the company operates a 300-MW captive power plant. The site had deployed condition monitoring tools on assets there — vibration, rpm, and amperage on the pumps in the cooling towers, the manufacturer's monitoring tools on the turbine, and assorted flow and temperature meters throughout the cooling system.

When the primary pump in the cooling tower failed, the control system initiated a cutover

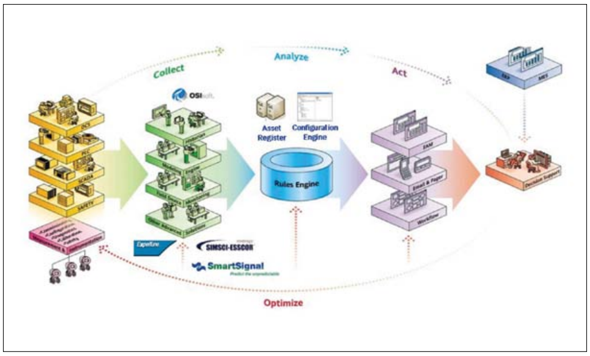

Figure 1. Success depends upon properly using wide variety of inputs from all plant levels.

to a back-up pump and then cleared the alarm. An operator entered the occurrence in the log, where the required follow-up was to have maintenance staff repair the primary pump. Shortly after this initial incident, the operator started receiving alarms that the temperatures in the cooling system were drifting out of range, coupled with pressure warnings. Assuming that this was a "storm" created by the cutover to the back-up pump, the operator acknowledged and cleared the alarm set.

Close on the heels of this second set of indications, the turbine monitoring system flagged a significant temperature variance and recommended an immediate shutdown. Again, on the assumption that this was a blip caused by the cutover, the operator cleared the alarm.

After two minutes, which was the defined "re-alarm" time, the turbine monitoring system reported dangerously high temperatures and again recommended a shutdown. This time, the operator (per the written procedures) contacted the plant manager, who gave approval to proceed with the shutdown.

This caused a production outage that impacted delivery of a critical intermediate to one of the company's key customers. Further, the sequence of events and the elapsed time from initial warnings to shutdown resulted in extreme temperatures within the turbine. This led to significant damage, necessitating the replacement of its main bearings.

The root cause turned out to be that back-up pump had not come online as expected. In doing the situation analysis, the company discovered a number of specific issues:

1. The back-up pump wasn't instrumented in the same manner as the primary one, so there wasn't any critical warning to the operator.
2. Condition information for the primary pump and the back-up pump weren't linked.
3. The pump, temperature/pressure and turbine data weren't connected. Each was handled discretely by the operator in separate areas of the human/machine interface (HMI); the combined elapsed time in dealing with the discrete events exceeded the safe shutdown point for the turbine.
4. No automated communication alerted maintenance, engineering or plant management to the developing issue.
5. The operator didn't have any way of seeing the maintenance status of the primary assets including the pumps — this would have shown that the back-up pump had a pending inspection because of previously reported issues.

Looking at this real-life example in its entirety, no particular action or practice alone could be blamed. Instead, the situation arose because of the lack of context and ineffective use (i.e., management) of available information.

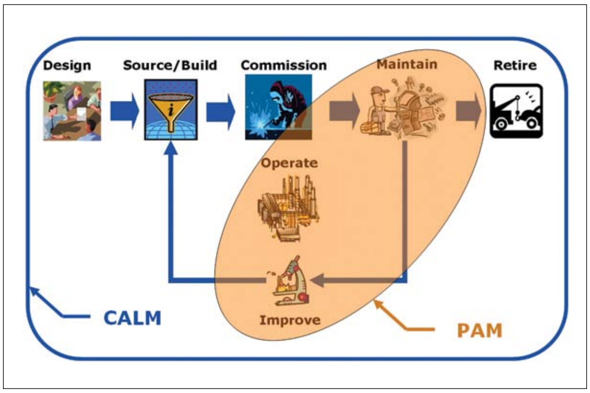

Figure 2. In CALM, the operate/maintain stage offers the largest portion of return-on-asset improvement. Source: ARC

The foundation for success

As the example underlines, effective condition management must address all of the elements together. Specifically this means:

- collecting the right data (condition, process area and system);
- gathering the complete set of data necessary to provide the context needed to accurately assess an issue and its impact;
- automating the response, including actions and escalations; and
- enforcing the post-event analysis and continuous improvement process.

Moving to condition management is ultimately a knowledge management challenge. In many companies, such a move requires a change in both technical and business process practices. This challenge is manageable but firms need to be committed to the change in approach and need the discipline to effectively implement and sustain it.

The process has to include the use of supporting tools and technologies that allow the capture of the institutional knowledge currently existing in plant personnel across all the disciplines.

Condition management fundamentally is a closed-loop model with four main elements — collect, analyze, act and optimize. This model provides the framework for translating the business needs into a solution architecture for a plant. Figure 1 shows the relationships among these elements, starting at the process measurement level through decision support and feeding back to the process.

Getting started

As with any change process, it's critical to understand the starting point. This demands taking a hard look at several areas and asking some tough questions:

Culture. Does the company understand that there are issues and that there's inherent and significant value in resolving them? As a simple test, can people articulate the impact or cost of an unplanned outage? Is the company really willing and ready to change? Effective condition management will include changes to business processes and roles, so these points are fundamental.

Business processes. Are the firm's processes documented? Have they recently been validated or benchmarked against others in the industry and best practices? In many cases, simple process enhancements or better communication can deliver significant performance improvements. Don't apply technology without this process baseline. Note in particular that a formal approach based on root-cause analysis and including continuous improvement efforts is a fundamental requirement.

At a broader level check whether a formal lifecycle management program is in place. A recent survey conducted by the ARC Advisory Group found that companies that had adopted such a program had a significantly better return on assets than those that hadn't. The research also indicated that the largest portion of the gains come from properly managing the "operate and maintain" stages of the lifecycle. It's precisely here where condition management is a key enabler of improvements. The ARC lifecycle model, (Figure 2) shows the relationship between plant asset management (PAM) and an asset lifecycle management scheme.

Corporate knowledge. Does the company have a knowledge management process or tools? What's the current state of the work force? Is a retirement bubble coming up that necessitates immediate action? Does the company really know where the necessary knowledge resides?

Skill base. Does the firm have the essential expertise in areas such as reliability-centered or condition-based maintenance, optimization, advanced process control (APC), and condition monitoring and analysis?

Technology base. To fully achieve the promise of condition management, a wide range of

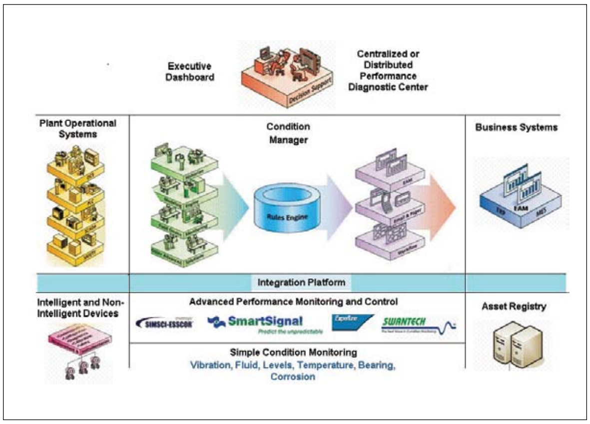

Figure 3. Plant- and corporate-level technologies need to come together effectively.

technologies both in the plant and at the corporate level need to come together (Figure 3).

So, engineers, planners and managers need to work together and ask themselves a series of technology questions that focus on five key areas.

1. *The state of the core automation systems.* Is the distributed control system current? Is the plant using a digital fieldbus with intelligent devices, traditional 4–20-mA analog or both? This will impact what data are available and how to access them.

It's important to understand that the plant doesn't need to be "state of the art." Many new analytic tools can infer conditions from the simple data points that are being collected as part of the control strategy.

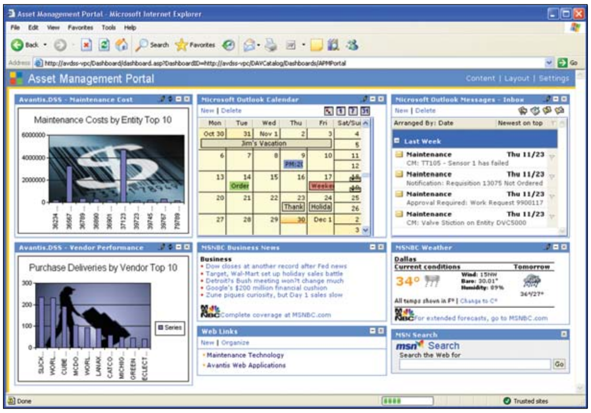

Figure 4. Such a graphical display can often serve as the vehicle for delivering information.

It's also crucial not to confuse alarm management with condition management. Alarm management plays a critical role in dealing with the huge number of discrete input/output points that are part of the control strategy, working in real time at a discrete level. Condition management complements alarm management by performing the advanced analytics that warn of a developing issue long before it becomes a process or system alarm or alarm storm.

2. *The current level of condition monitoring.* What instrumentation is in place? Which assets are addressed? What data can these current tools provide? How are the data currently used? What tools are being used? What processes are in place to deal with the issues identified? Is there any automation of these processes?

Find out if the information already being gathered is handled in systematic or automated fashion and moves across departmental boundaries. One of the major values of condition management is making information useful beyond the realm of the collection point or device — putting it in a broader context.

3. *The current level of APC and process optimization.* Is the company using such solutions? These models can play a key role in identifying and understanding the dependencies and context for the condition data.
4. *Integration infrastructure.* Does the firm have a standardized way for integrating applications at the plant level, applications at the business level and among plant and business applications? This will be critical for gathering the condition information at the plant level and then driving the workflow necessary to resolve issues. For example, if a critical condition is recognized, automated workflow tools should page or email the key personnel, automatically trigger the necessary work requests or work orders to the maintenance team and update the necessary HMIs and management dashboards.
5. *Business intelligence.* Is there an integrated measurement system as well as a vehicle to deliver the information across the company? The vehicle most commonly employed

is some form of portal or dashboard solution such as the one shown in Figure 4.

The next steps

The analysis that establishes the foundation or starting point is the most important step in the path to condition management. It is a comprehensive effort that brings information and, importantly, people, together. It also provides the groundwork for setting priorities and expectations and for understanding the implications on processes and roles.

With the foundation effort complete, a company can better see the possibilities for value and improvement, determine risk/reward and identify which parts of condition management can be implemented first. The success of initial low-risk/high-reward projects, in turn, can fund an ongoing program.

Many chemical makers can gather the information for a condition management baseline from within. This valuable effort can enable them to more clearly understand their resources, processes, limitations and options.

However, the subsequent steps can be complex and likely will involve the assistance of a technology partner familiar with the tools and solutions required for a condition management architecture, not just condition monitoring.

Condition management is an over-arching solution that makes use of the mountains of data generated by individual condition monitoring systems. It combines, rationalizes, presents and communicates decision support information effectively. It truly can help management identify the actions and practices needed to get full benefit from monitoring investments and, in turn, optimize the return from plant asset investments.

By Neil Cooper, Invensys Process Systems

MINING FOR MONEY THROUGH ENERGY MONITORING AND MANAGEMENT

I've always been interested in the connection between reliability management and other functional responsibilities within a manufacturing organization, such as quality and safety. Clearly, reliable manufacturing processes improve quality, one of the three primary elements of overall equipment/business effectiveness (OEE/OBE). Also, when manufacturing processes are reliable and predictable, there is less chance for injury. Lately, I've been giving much thought to the relationship between reliability and energy management. In my opinion, there is a close connection - one that is worth exploring.

Monitoring and managing energy consumption is good for the organization and good for the environment. It's a win all the way around. In the United States, 30% to 40% of the electricity we generate is required to power industrial electric motors! Even a small energy-efficiency gain can significantly increase the aggregated demand for power, reducing capital expenditure to build more power plants and the consumption of fossil fuels and associated emissions. For your firm, spending less on energy translates into real dollar savings. Plus, by reducing strain, wear and tear on your machine assets, manufacturing reliability is improved, creating even more value for your organization.

Outline of Benefits

Over the life cycle of a machine asset that supports manufacturing processes, energy consumed is frequently the largest expense. Some aspects of the cost to energize a machine can't be controlled, but some can.

Let's look at the economics of energizing a 200-horsepower electric motor. Assuming a load factor of 80% and a modest energy cost of $0.06 per kilowatt hour (kWh), it requires more than $57,000 each year to power the motor, assuming an 8,000-hour operating year (Figure 1). A quick scan of the Web revealed that the price for a three-phase, 460-volt electric motor is in the $5,000 to $8,000 range. I'm sure there are motors that cost more or less, but the point is that the cost to energize the electric motor is about 100 times its purchase price, assuming a 10-year life. Carving 5% to 10% off of this cost can profoundly affect the bottom line.

In my example, a 10% improvement in energy efficiency drives an extra $5,700 to the bottom line - and that's for a single, garden-variety 200 hp electric motor! How do you get this savings? I've listed a few items for you to consider. Some have direct, positive effects on operational reliability in addition to the obvious energy cost savings.

1) *Select high-efficiency motors — comparing brand-to-brand performance.* High-efficiency motors cost more money up front. Don't be lulled into accepting the up-front savings. Assuming a regular-efficiency electric motor costs $5,000 at purchase and uses 10% more energy than a high-efficiency motor, you could spend up to $60,000 on a high-efficiency motor and still be ahead money in terms of the economic rate of return over the 10-year life cycle of the asset (assuming an 8,000-hour operating year). Paying a 50% up-front premium for a high-efficiency electric motor yields an internal rate of return of 229%. That's the equivalent of finding a bank that will pay you 229% interest annually on your deposits. A 5% energy efficiency for which you must pay a 50% price premium up front still yields a 115 % internal rate of return. You'll be hard-pressed not to justify this investment if you're employing decision-making tools based on life cycle cost.

Energy Savings Calculator - 200 HP Motor Example	
Horsepower (HP)	200
Load Factor	80%
Kilowatts (kW)	119.36
Hours Used	8,000
kW Hours Consumed	954,880
Cost per kW Hour	$0.06
Annual Energy Cost	$57,293
Energy Consumption Reduction Target (%)	10%
Projected Annual Energy Cost Savings	**$5,729.28**

2) *Design drivetrains for energy efficiency.* Failure to consider energy losses in mechanical drivetrain decisions can significantly affect your overall energy bill for an asset. Sure, we want motors to be efficient, but improving the efficiency of the driver is only half the battle. We need to manage the efficiency of the driven components, too. Selecting energy-efficient gearbox and coupling designs, for instance, can substantially affect the total energy bill. Apply the precision balance, alignment, looseness, resonance and lubrication principles discussed in points 6 and 7 to the entire drivetrain.
3) Manage electrical system integrity. If your motor control center (MCC) has bad connections, degraded or undersized wiring, or shorts, energy efficiency will be compromised. If circuits run hot or become hot, energy isn't being carried efficiently. Moreover, the reliability of the MCC and (in some cases) the motor itself can be compromised. In the case of stray current, the high buildup of potential also can lead to electrical discharge erosion, a wear mechanism often referred to as "fluting." Here again, the loss of energy compromises reliability.
4) *Operate in ideal load range.* Using our electric motor example, operating above or below its rated load range produces poor energy efficiency and decreases reliability. For most electric motors, energy efficiency degrades precipitously when the motor is operated at less than 40 percent of its rated load.
5) *Make optimized rebuild/replace decisions.* When an asset wears out, it gets loose and sloppy, which of course results in energy waste. Getting that last few days, weeks

or months of service may be costing you dearly in terms of energy efficiency.

6) *Manage balance, alignment, looseness and resonance.* Imbalance, misalignment, looseness and resonance all generate mechanical friction. It takes power to create friction — which converts electrical energy into thermal energy - and you have to pay for it. In some instances, friction is desirable. When it's caused by lack of precision in managing balance, misalignment, looseness and resonance, you're literally paying for the energy required to increase wear and reduce the reliability of your machines. Precision maintenance pays off, both in terms of reliability and in energy management.
7) *Employ precision lubrication.* Improper selection of lubricant viscosity can significantly affect both energy consumption and reliability. If the viscosity is too low, surface-to-surface friction occurs. If the viscosity is too high, viscous drag results. Both waste energy. A common mistake is to employ multi-purpose grease in electric motors. The viscosity of this grease is typically around 320 centistokes at 40°C. Most electric motors require grease that is formulated using base oil with a viscosity of 100 to 150 cSt at 40°C. The extra viscosity reduces energy efficiency and compromises the motor's reliability. Likewise, motors frequently are over-greased, further compromising energy efficiency and reliability.
8) *Monitor energy consumption.* Changes in asset condition are frequently revealed with energy monitoring. We traditionally have employed vibration analysis, thermography and other condition monitoring tools to identify and troubleshoot abnormal asset conditions. By definition, if a machine starts vibrating or getting hotter, it is using more energy or converting energy with reduced efficiency, so monitoring energy efficiency is a natural condition monitoring activity. Moreover, it is comparatively easy to do and can be done on a continuous basis. Energy monitoring also enables you to compare the efficiency of various equipment and component designs, helping you make better design and procurement decisions that minimize life cycle cost of ownership and maximize return on net assets (RONA).

It's Worth the Energy

Monitoring and managing energy consumption is a slam dunk. Gaining just 5% improvement can translate to considerable savings for your organization. If you're mismanaging several of the above-named factors, 10%, 15% or more improvement may be possible. Because this wasted energy is frequently converted to heat and/or mechanical displacement (vibration), good energy management policy and good reliability policy are natural allies. To sweeten the pot, there are several government programs that are intended to motivate you to be energy conscious, often covering all or part of the up-front investment required to improve your energy efficiency.

To recap: reduced electric bill, improved reliability, economic support from the government and good environmental citizenship. What's stopping you? Start monitoring and managing energy consumption today in order to minimize life cycle cost of ownership.

By Drew D. Troyer

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