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Condition-Based Maintenance

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Putting it all Together

Communication & Accountability Complete the Puzzle

by

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Forrest Pardue & Dick Hancock

Over the past 20 years, many US plants have invested heavily in condition monitoring technologies such as vibration, oil analysis, thermography, and motor circuit evaluation to provide an accurate prediction of plant equipment problems. These predictive maintenance programs use best of breed technical equipment along with trained and certified analysts, and they often produce solid technical results. Each month valid condition monitoring results are produced and distributed to plant maintenance and operations personnel. So why do critical machines that have been identified as degraded in advance continue to fail in service? Why do many predictive maintenance programs have their funding and staff cut at the first sign of a sales decline?

The problem is actually that plant management implemented condition monitoring without laying the groundwork for Condition-Based Maintenance. What's the difference? Condition monitoring is largely a technology and training issue while Condition-Based Maintenance requires the existence of a reliability culture involving both operations and maintenance. Innovative plants such as Eastman Chemicals in Kingsport, Tennessee have found that a consistent program of communication and accountability have helped them to instill and sustain that type of Condition-Based Maintenance culture.

Condition-Based Maintenance is far more than conducting condition monitoring activities and developing technical proficiency with the tools.

Creating a Condition-Based Maintenance Plant Culture

Typically, top management sets a Condition-Based Maintenance vision:

"Our plant will…

- Eliminate in-service failures on critical equipment,
- Eliminate costly preventive (scheduled) maintenance work when condition analysis shows no need for the work,
- Eliminate basic machinery problems so that less total maintenance is required,
- Extend the life (reliability) of plant equipment while achieving the lowest total lifecycle cost, and
- Measure program results and adjust resources and focus as needed.

The plant then proceeds to either buy monitoring equipment and train personnel, or hire predictive maintenance contractors. So the plant must be doing Condition-Based Maintenance… Right?

Not really – Condition-Based Maintenance is far more than conducting condition monitoring activities and developing technical proficiency with the tools. Those steps are necessary, but so is the need for the organization as a whole to incorporate a mindset that equipment reliability is the shared responsibility of operations and maintenance. Until that shared attitude is made an integral part of plant culture, the reliability improvement initiative is fragile and prone to cutbacks, inattention, and failure. Therefore, top management must buy in to the concept of condition-based maintenance. Someone within the organization must act as a 'champion' of the cause to get the necessary buy-in. The champion can come from any level within the organization. It doesn't have to be one individual, it could be a group of people. The key is for the champion to effectively communicate the benefits of condition-based maintenance – and to do it in a language top management understands. Typically, that language will be more economic than technical. Buy-in at the top is critical, because, ultimately, top management's responsibility must go beyond 'setting the vision' and 'acquiring monitoring technology' to include:

- Creating an effective system for communicating machinery health status, and
- Holding plant employees accountable for follow-up actions & results

Eastman Chemical Facility Kingsport, TN

Effectively Communicating Machinery Health Status

In too many plants poor communication leads to wasted effort by the condition monitoring teams. Condition monitoring results are produced by multiple monitoring technologies, each using a different database and analysis software. This is inevitable as the plant strives to match the best system for a specific technology with the plant's needs, or to select the best PdM contractor for certain technologies. Unfortunately, different technicians using dissimilar systems create reports with different formats and terminologies. These are usually dispersed among a variety of people in different departments based on the technology, and quickly secluded in report binders and long e-mail lists. This piecemeal communication makes it difficult for a broad audience of maintenance and operations personnel to be aware of all known information about a specific asset's health.

For example, Eastman Chemical's Kingsport, Tennessee plant is a large, multi-product chemical facility with over 20,000 rotating machinery trains. The Kingsport plant began performing predictive maintenance in the mid-1980's and developed a predictive maintenance group using multiple technologies such as:

- Vibration Monitoring (Route and Online)
- Infrared Thermography
- Lubrication Analysis
- Ultrasonic Monitoring
- Motor Analysis

By the mid 1990's, this predictive maintenance group was well respected for its technical proficiency, and was credited with preventing a significant number of production interruptions by catching equipment problems prior to failure. However, several people within Eastman's management felt there was room to improve.

First, they realized that the organization was handling condition information as shown in Figure 1. Individual condition reports from different technologies were going to different maintenance contacts for an operations area. These contacts would usually have to negotiate with their operations counterpart over the need for and scheduling of repair activity before being able to forward a request to the maintenance planner. This resulted in delays and "dropped balls" in handling equipment problems in a Condition-Based Maintenance manner. The key issues leading to this result were:

- Few people, if anyone, had a complete picture of all known condition issues on a piece of equipment,
- Operations had very little 'buy-in' to the concept of Condition-Based Maintenance,
- The first notice maintenance managers had about 'dropped balls' was usually a call from operations, after the fact.

In the late 1990's Eastman decided to modify organizational structure and information flow to improve use of equipment condition information and better support a Condition-Based Maintenance mindset.

The organization structure was modified as

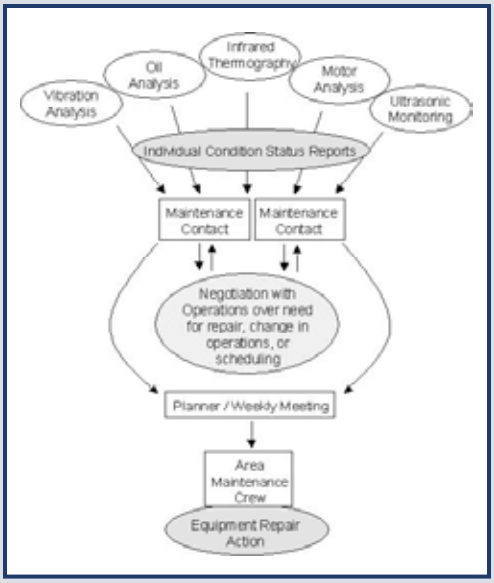

Figure 1 - Old flow of condition based work at Eastman Chemicals

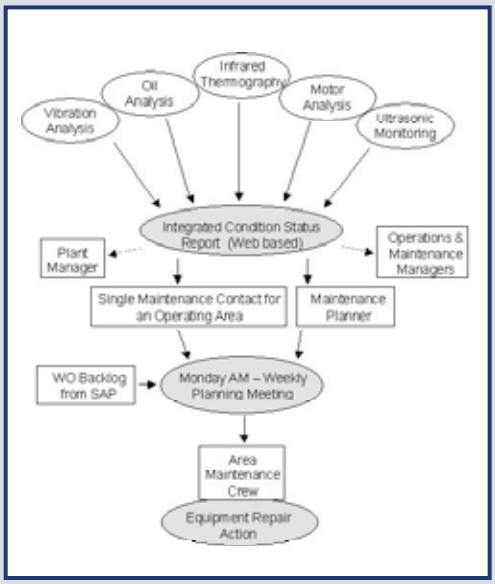

Figure 2 - Modified flow of condition based work at Eastman Chemicals

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Save the serious power for the 10% to 20% of the time when it's really needed. This is for the other 80% of the time.

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2. Small enough for your pocket. (Weighs just 12 oz with handheld computer.)
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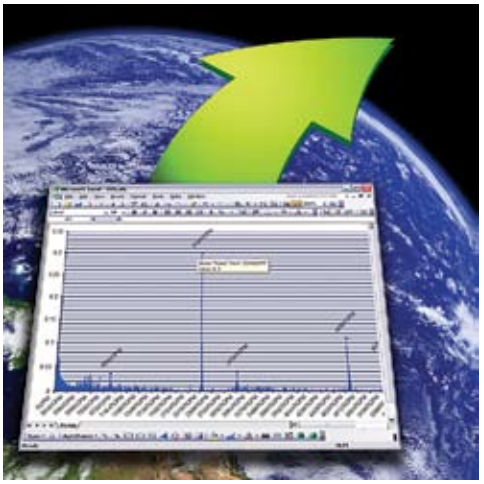

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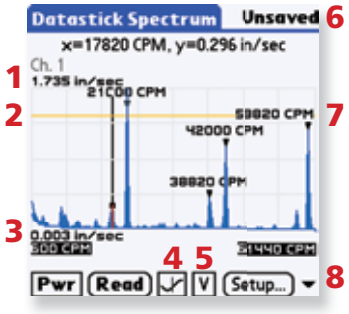

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shown in Figure 2. The key change was assigning a single maintenance contact to each operating area; this contact is the liaison between the predictive maintenance group and operations. They work with operations to evaluate potential equipment problems and scheduling options for maintenance action, and are ultimately responsible for ensuring that timely maintenance action takes place.

Following the organization change, it was also decided that an integrated condition status report was needed to merge findings and recommendations from each of the technologies being used to monitor a problem machine. High priority was put on making the integrated condition results easily available to a wide audience of operations, maintenance, and executive managers. The report had to be asset based rather than monitoring technology based, and it also needed to be accessible without requiring installation of special software by users. That lead to the creation of a web-based Integrated Condition Status Report system.

With the new organization and Integrated Condition Status Report in place, the weekly planning meeting became a focal point for joint responsibility of equipment reliability. Everyone involved, including predictive maintenance analysts, planners, and area operations and maintenance managers, now have access to the same equipment health status information before and while in the meeting. Issues can't be swept under the table or ignored, and the group is able to spend their time focusing on operations scheduling and work order priorities for maintenance action.

High Priority:

Making the integrated condition results easily available to a wide audience of operations, maintenance, and executive managers.

There were several communications issues that had to be tackled in the evolution from technology focused reporting to asset-centered communication of condition monitoring results. The biggest of which were:

1) Integration of health status information from multiple technologies

2) Standardization of reporting format and terminology

3) Distribution of findings, recommendations, and work status to a broad base of plant personnel

Integrating Condition Status in a Web-hosted database

The piecemeal communication described in Eastman's old organization was technology-centered, both in report generation and in who received the reports. Integrating condition results from all technologies under each specific machine location is the first step toward asset-centered communication of health status. Web-hosted database technology offers a solution for asset centered integration. Condition results can be collected in a single web-hosted database, independent from the proprietary databases housing the technical data. In-plant technicians and outside PdM contractors enter plain language findings and recommendations into this web-hosted database via the Internet, bypassing any issues about outside vendors having to cross security firewalls in the plant network. Authorized plant users login via a web browser to retrieve a health report for their area of the plant, without having to install and maintain any special software. Machines with severe health problems are marked with a red light at the top of the list. Eastman Chemicals, Kingsport, uses an asset-centered health status report (as seen in Figure 3) to graphically communicate which machines have significant health issues based on all the monitoring technologies being applied to that machine.

Planners, supervisors, and plant managers can see what may affect operations, then drill down for more detail to support their daily decisions (Figure 4). If they are interested in the technical data behind the analyst's recommendations, they can open linked documents to view the supporting information.

Once planners have generated a work order, they can enter a reference number to the condition entry, so anyone who wants to

Issues can't be swept under the table...

the group is able to spend their time focusing on operations scheduling and work order priorities for maintenance action.

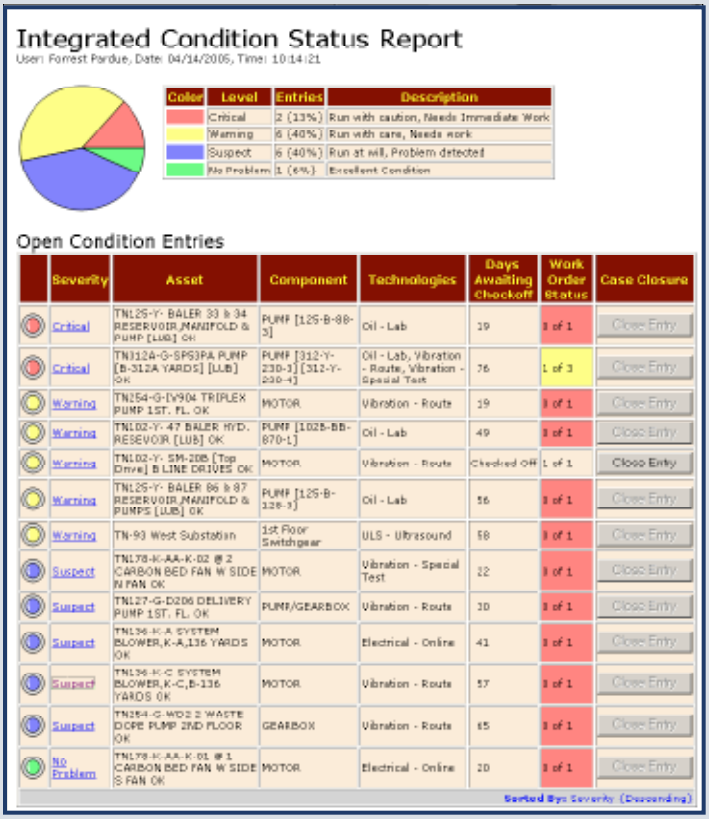

Figure 3 - Multiple technology results integrated for each asset location

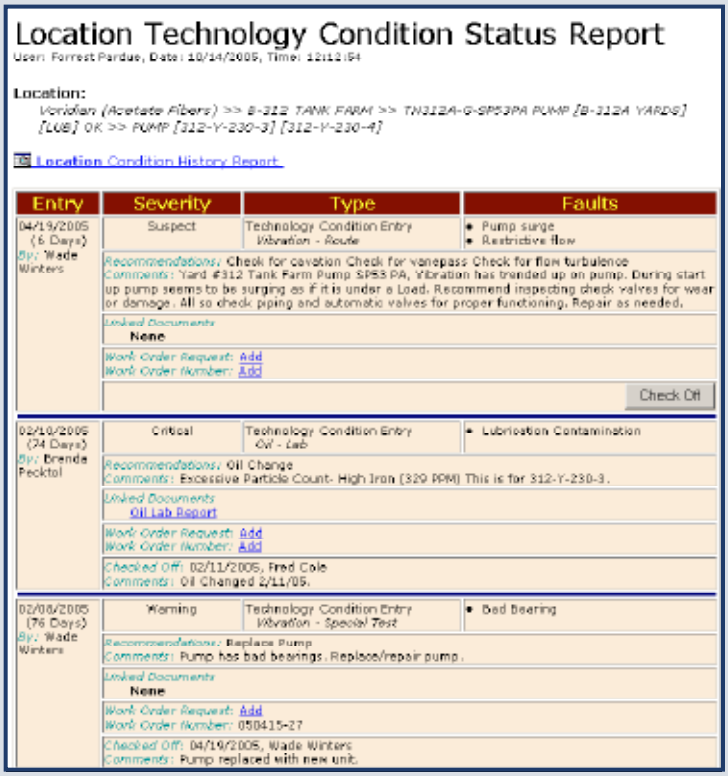

Figure 4 - Drilling down to detailed recommendations & supporting documents

check into work order progress knows where to look it up in the plant's SAP system. Once a work order reference has been entered, the Integrated Condition Status Report also shows how many days the oldest work order for an asset has been open. When the work is complete, the planner can also notify others by 'Checking Off' the condition entry. When that is done, then the Integrated status report also shows a 'Close Entry' button for that condition case, as seen in Figure 3. Eastman's predictive maintenance technician responsible for that entry can then close the case and remove it from the report, in many cases after a follow-up monitoring session to confirm that the problem has been resolved.

Therefore, participants in the weekly planning meeting not only see condition status for problem machines, but they also get a snapshot of response and work status for those health issues. That keeps all departments informed on progress; such broad exposure of Condition-Based Maintenance status also makes it a lot harder to hide shortcomings.

Standardization to Improve Understanding of Information

Just as in human medicine, it is very important that all parties use common terminology when describing machinery health issues. Standardization of condition results means that everyone inputting findings and recommendations uses common equipment location names, faults, and severity levels, and that the output information has a standard look and content regardless of technology, analyst, or whether they're plant employees or an outside contractor.

Again, a single web-hosted database can provide a results entry form (Figure 5) that uses pull down lists to enforce standardized terminology. This screen utilizes a standard pull down list for the selection of faults, recommendations and severity. The pull down lists also enforce brevity to make the information easier to understand; but, an analyst can also write a more comprehensive problem description if needed. Such standardization allows a common look and language between condition technologies, and it also facilitates future mining of the information for common patterns. This simple mechanism for standardizing basic findings and recommendation content does not exclude technical reporting, as supporting data images and documents can be linked to the condition entry, for

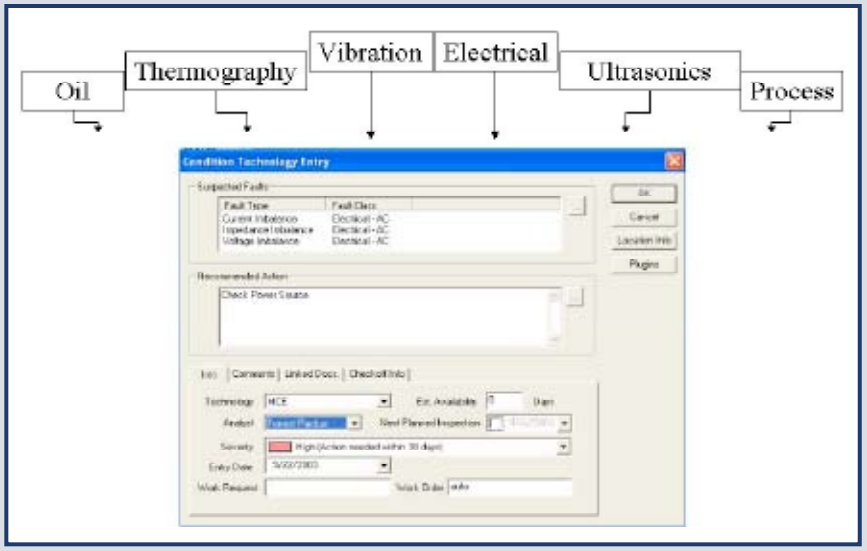

Figure 5 - Standard condition results form

retrieval by interested users.

Distribution to a Broad Plant Audience via Web-browser

Something amazing happens in human organizations when people know that information about their area of responsibility is widely available to others. They tend to care more about what's happening and focus their energy on doing a better job. This applies to executives as well as managers, engineers, and craftsmen.

Web-browser technology is well suited for allowing a broad base of users to access equipment health information with minimum effort, while still providing some control over what information each individual user can view or interact with. Practically all computers have an Internet browser installed, so there's no need to install and maintain specialized software. They only need the correct URL for their web-hosted database, along with an authorized user name and password, to access the current health status of equipment in their area of concern.

One of the Reliability Engineers at Eastman's Kingsport facility credits the wide and persistent visibility of condition results as one of the keys in making operations and maintenance joint owners of equipment reliability. He says that "prompt response to resolve condition-based maintenance issues" has become the way of life because everyone knows that "the bosses care".

Accountability for Results

Good communication of condition status may be essential for guiding work prioritization, but that alone does not mean that the best Condition-Based Maintenance results are being delivered to the plant business.

Personnel must be held accountable for using the information to produce increased reliability results. Two important execution measurements for Condition-Based Maintenance are:

1) If equipment does show health issues, are timely maintenance responses happening?

2) Is condition history being kept and analyzed to spot & address chronic reliability issues?

As has been said many times - "What gets measured gets done!"

In addition to the work response measures available in the Integrated Condition Status Report, Eastman Chemicals has taken advantage of a single database with integrated condition results and work follow-up status to generate several custom reports. One of these trends the timeframe in which condition-based work orders are resolved; the report can be set to cover all condition-based activity or a single technology in a specific operations area. Figure 6 shows that over 90% of work requests generated by vibration monitoring during the first nine months of

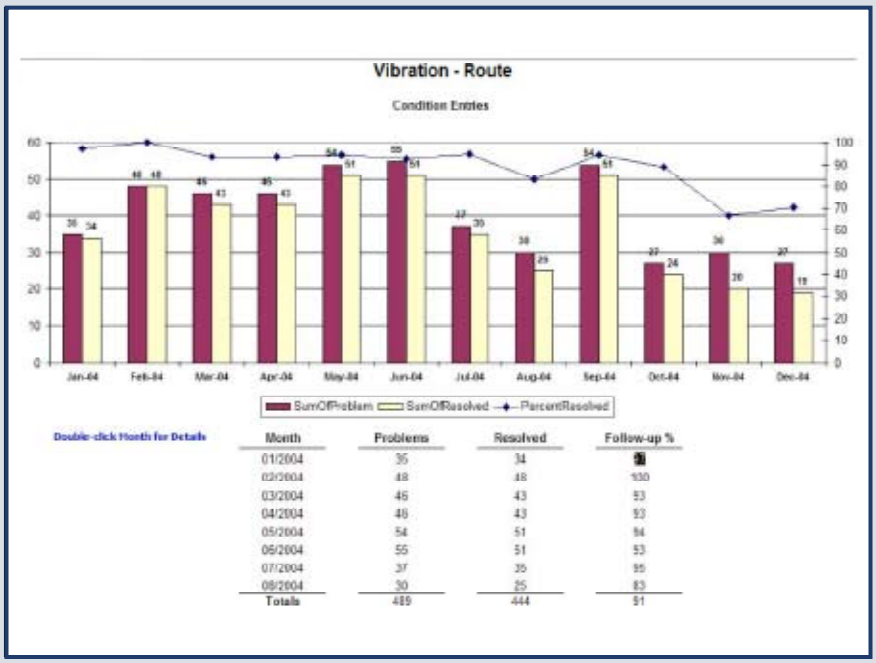

Figure 6 - Customized maintenance follow-up report for condition-based work orders

2004 had been addressed and resolved.

Eastman's Reliability Technology Report (RTP) for vibration monitoring is shown in Figure 7. It tracks resolution of condition-based work requests and is available to area managers for more detail on how well their crews are utilizing information from a specific predictive technology. It shows area operations and maintenance managers how condition generated work orders were handled during the month, and how their area compared to others. Area managers typically focus on the Year To Date '% Corrected' table at the bottom and ask 'what do we have to do to get better?" Predictive maintenance technicians also review these reports to understand which areas may need additional help in using their information.

Reliability Technology Department

Vibration Monitoring - Monthly Report

User Name G K Thursday, May 12, 2005

Area CE&SP Month April Year 2005

Vibration Index this month 0.14 Vibration Index All TED 0.101

449 Machines in Database

241 Machines Monitored This Month

4 Problems Documented This Month — 29 Documented YTD

4 Problems Known Corrected This Month — 13 Corrected YTD

3 Problems Outstanding This Month — 20 Outstanding YTD

Job Sheet Data * May Include Prior Year Jobs

CE&SP	Reported This Month	Reported Y. T. D.	Corrected This Month *	Corrected Y. T. D. *	Corrected This Year
	1	1			0
B- 51 CR. 4210	0	1	0	1	0
D- 65 CR. 4227	1	1			0
B- 81 CR. 4204	0	4	0	1	1
B- 81 CR. 4211	2	7	0	1	1
B-120 CR. 4207	0	2	0	1	1
B-120 CR. 4208	0	10	4	9	3
B-190 CR. 4228	0	3	0	0	0

Year To Date Percentages * May Include Prior Year Jobs

Unit Name	Finds	Follow ups *	Percent *
CE (Acid Con)	8	2	25.0%
CE (CPE-EST)	12	10	83.3%
CE (Film)	4	1	25.0%
CE (Plastics)	5	0	0.0%
Totals	29	13	44.8%

Figure 7 - Customized maintenance follow-up report by individual monitoring technology

Use of Historical Condition Information

Eastman's condition monitoring analysts and reliability engineers are also able to receive custom reports that help them identify chronic failure issues. In Eastman's 'Faults by Component' report, the user selects plant areas, time frame, and monitoring technologies; the example shown in Figure 8 covers all technologies being used across several operating areas for 2005 YTD (through June 2005). Reduction gearboxes quickly stand out with the highest number of faults. Drilling into the report would uncover filter design and lubrication issues that are the greatest common denominators behind the gearbox faults; providing important information for targeting reliability improvement initiatives. For example, over the last several years Eastman has significantly reduced chronic equipment problems such as imbalance, misalignment, lubrication, and installation issues by using historical failure

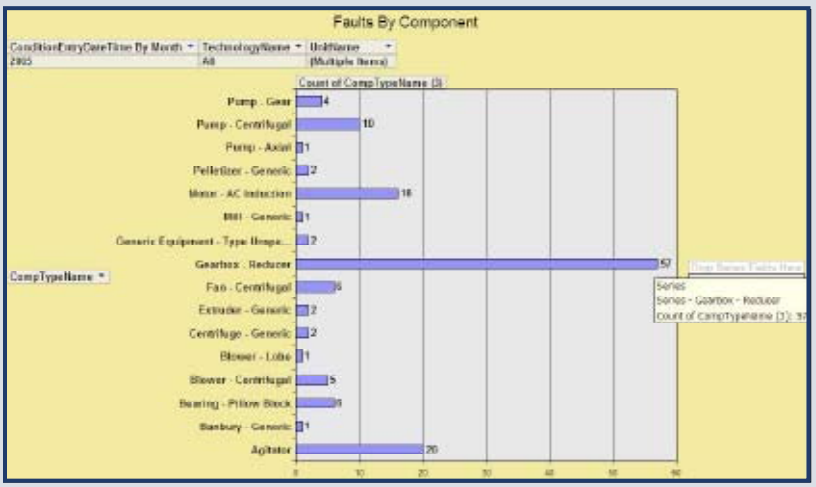

Figure 8 - Customized report for number of faults by equipment type, 2005 YTD

mode information to change procedures and justify special training and tools.

Eastman has also been able to use historical condition information to fine-tune its condition monitoring activities. When a condition monitoring 'find' is defined as leading to a maintenance or repair action, it is generally accepted that condition monitoring programs at industrial plants typically progress according to the trend shown in Figure 9.

A Reliability Engineer at Eastman used the historical information to calculate their 'find %' and found that they were at the 4% level in the mid-90's and reached 2 ½% around 2003. It's probably not a coincidence that the improvement in reliability culture was occurring at the same time. Management's confidence in Condition-Based Maintenance execution contributed to the decision to reduce vibration monitoring frequency for less critical equipment from monthly to every other month or even quarterly. They were then able to shift some manpower from routine monitoring to higher value added root cause analysis activities. It's also probably not a coincidence that over the same time period Eastman's wrench-turning maintenance force has decreased from approximately 1200 employees to around 800, while production capacity has slightly increased.

Summary

At Eastman Chemicals in Kingsport, Tennessee the management vision for Condition Based-Maintenance and equipment reliability has really been embedded in most of the plant's

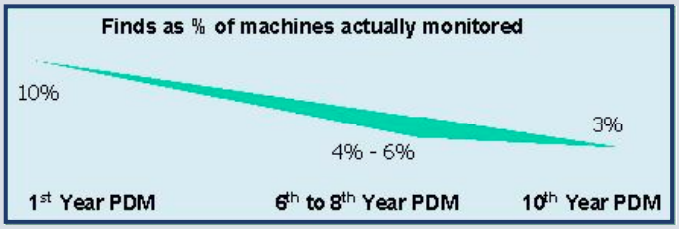

Figure 9 - Typical 'Find %' as PDM Program Matures

culture in the following ways:

- Operating area 'bosses' know and care about what's happening with equipment reliability because they can view current Integrated Condition Status and worker response via their web-browsers.
- A weekly planning meeting is the focal point where operations and maintenance work together to prioritize work based on condition status - to the point that condition surveys conducted on Friday are expected to be entered and responded to in time for the Monday am planning session! Now that's culture change!
- Accountability is consistently based on condition status and work execution rather than informal complaints from operations.
- Condition history is being used to spot chronic equipment problems and focus reliability improvement resources, as well as fine-tune the monitoring activity.

One of the significant contributors to Eastman's Condition-Based Maintenance success is their single database for housing all equipment condition status and web-based distribution of information from that database.

Dick Hancock has over 30 years experience related to industrial machinery and maintenance. In the 1990's he helped CSI grow into the largest manufacturer and marketer of predictive maintenance systems, and following Emerson Electric's acquisition of CSI he served as VP of Marketing. Currently, Dick is a sales and marketing consultant working with 24/7 Systems, Inc. to introduce web-based equipment lifecycle management services.

E. Forrest Pardue is the president of 24/7 systems, a company focused on the development of strategic equipment management software and services. n 1998 Forrest co-founded 24/7 Systems with his partner, Paul Wolfensberger. 24/7 Systems' founders realized that the biggest needs facing industrial maintenance had shifted to the measurement, management, and improvement of plant machinery reliability.
Forrest has worked in the field of vibration analysis and production maintenance for the last 25 years. Forrest was one of the founding members of CSI and has been very actively involved in the technical and market development of predictive condition monitoring technologies. Forrest received his BS in Electrical Engineering from North Carolina State, and his MBA from Lynchburg College

Steve C. Quillen is the Senior Technician in the Rotating Equipment Group of the Reliability Technology Department. He has been with Eastman Chemical Company 28 years and has worked in various roles including Operations, General Mechanic Apprentice General Mechanic, Training Instructor and Relief Supervisor.

Mark Mitchell, P.E., is the Rotating Equipment Group Leader, Reliability Technologies Department.