Strategic Component Management Integrating Asset Management, Root Cause Analysis, and Predictive Maintenance

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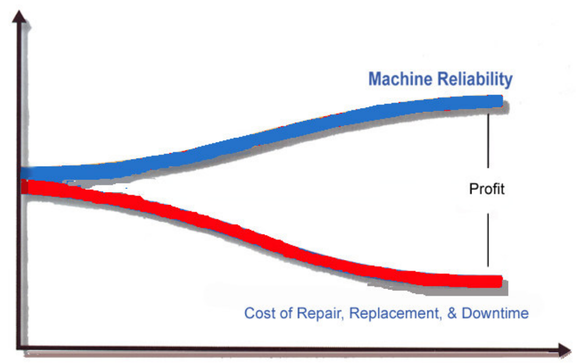
Strategic Equipment Management is an industrial maintenance strategy for actively managing critical high value rotating machinery for highest reliability, lowest life cycles cost, and minimizes production losses. The goal of strategic equipment management is to increase a machine's reliability, lower its maintenance cost, and increase production availability. This strategy, when aggressively implemented, can substantially increase a plant's profit margin.



What is Strategic Component Management?

Many large manufacturing facilities have aggressively implemented predictive maintenance in an attempt to eliminate process downtime and catastrophic machinery damage due to incipient failures. For plants with a commitment to predictive maintenance, the results have been impressive. The implementation of predictive maintenance caused a philosophy change in plant operation such that failures in service were unacceptable and that significant long term cost reductions were more important than maximizing a shift's or day's production.

The shift to predictive maintenance has dramatically reduced process disruptions due to equipment failures, but many plants have not taken the next step to proactive reliability improvement. Predictive maintenance warns of a developing problem before failure occurs. If a machine fails a bearing every 8 months, PdM warns of the problem but does nothing to solve the underlying cause of the failure. The bearing will continue to fail every 8 months. PdM only provides advance warning so that failure in service can be avoided; it does not solve the underlying cause of the frequent bearing problem. Strategic Component Management goes beyond predictive maintenance by **proactively** managing your machines for highest reliability, minimized productions loss, and lowest life cycle cost.

Strategic Component Management takes you beyond predictive maintenance by actively managing your machines for highest reliability, minimized productions loss, and lowest life cycle cost.

This paper provides an overview of Strategic Component Management and several real-world examples of the implementation of the program.
In this paper, a machine train is typically referred to by its driven component, i.e. the Boiler Feed Pump. This train may include multiple components, such as motor, gearbox, and pump. When we refer to component management we are referring to the management of the individual elements of the train such as management of motors, pumps, fans, compressors, etc.

Strategic Component Management has three areas of benefit.

1. Focuses on a strategic reliability and life cycle cost improvement through the installation of a component manager.

2. Increases machine reliability through the systematic application of root cause failure analysis using historic failure information.

3. Manages the predictive condition action on degraded machines, coordinates a countermeasures plan, and assures correction of root cause of failure.

I. The component manager, the essential element.

Many plants utilize a maintenance structure that assigns the authority for machinery maintenance decisions to multiple area maintenance supervisors. This approach, while widely used, is not the best approach if a strategic long-term reliability focus is desired.

To illustrate the component manager's role in machinery maintenance, let's examine a machine maintenance scenario using the area manager's approach, and the component manager's approach:

Situation:

A critical plant component must be removed from service because multiple predictive maintenance technologies have detected a problem. If the machine's history were to be analyzed it would be obvious that this machine fails in the same manner every two years. Plant maintenance and operations have known that machine was degraded for the last month; but it's condition has changed from marginal (yellow) to severe (red) and the PdM analyst recommends immediate action.

Scenario 1: The area maintenance supervisor takes charge

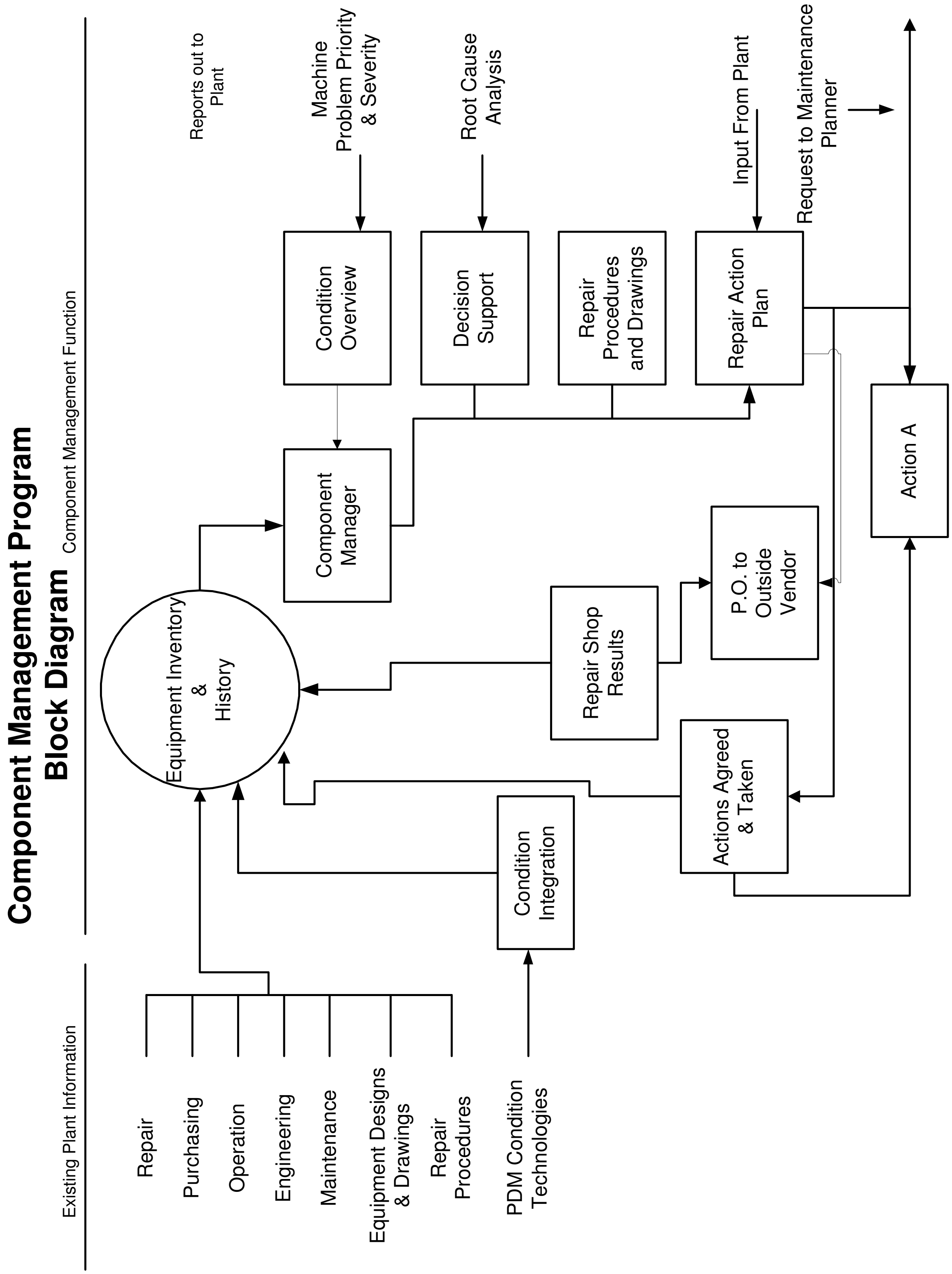
- No planning has been done, and there is a state of near-panic conditions.
- "Somebody find the spare, is it ready to go?" (This is assuming that there's even a spare on site)
- "How soon do we really need to do this?"
- Supervisor alerts production and warns of a temporary shut down.
- Schedule a bunch of people – most likely too many, and may have to find certain people due to task and job knowledge – to change out the component. This brings the risk of more one-time costs and risks personnel.
- Get the planner and put together a quick schedule.
- the component replacement is performed mostly by the seat of one's pants, increasing the chance of further damage to the equipment or injury to personnel.
- Production is constantly stopped and restarted due to repeated machine adjustments.

The key here is that no one person has the total job knowledge (mechanical, electrical, etc.) to remove, install, adjust and start-up the new component.

Scenario 2: A component manager takes charge

- the component manager has been monitoring the machine's status since the first abnormality was noticed and has been in contact with all of the PdM analysts involved. Area maintenance was advised that this component is degrading and is being monitored.
- the component manager, using the component management software, has detected the lower reliability and repetitive nature of this failure. The failure has been discussed with several authorities and modification specified and designed. The replacement component has been modified prior to this need.
- the replacement components have been checked and are ready to go. All necessary parts, tools, and supplies have also been checked and cleared ready.
- the component manager, area maintenance supervisor, and production manager have talked about the problem. The area management has discussed what else needs to be done while this critical component is being repaired and/or replaced. Safety issues have been addressed (tag-out procedures, etc.)
- when the condition degraded toward severe, the component manager called a meeting with the area management involved. All appropriate alternatives for repair/replacement were discussed and a plan of action was agreed to.
- the component manager modified his "canned" procedure for the replacement. This was taken to the maintenance planner, and together they built the final plan. This saved planning time and assured accuracy of the plan.
- the impending repair was discussed with the appropriate shop. The repair shop was given a list of the critical parts that would be sent with the component for repair. If this were a large and/or critical job a copy of a previous repair schedule and specifications would be sent to the shop and reviewed prior to job start. These steps save shop time and repair costs.
- the equipment replacement went as scheduled (saving about 10% of the time previously needed). The equipment was properly adjusted before start-up and production was restarted without problems.

With these two maintenance scenarios in mind, let's examine the fundamentals of Strategic Component Management.


Component Management Program
Block Diagram
Component Management Function
Existing Plant Information
Repair
Purchasing
Operation
Engineering
Maintenance
Equipment Designs & Drawings
Repair Procedures
PDM Condition Technologies
Equipment Inventory & History
Condition Integration
Component Manager
Condition Overview
Decision Support
Repair Procedures and Drawings
Repair Action Plan
Repair Shop Results
P.O. to Outside Vendor
Actions Agreed & Taken
Action A
Reports out to Plant
Machine Problem Priority & Severity
Root Cause Analysis
Input From Plant
Request to Maintenance Planner

I. The Component Manager

As is seen in scenario 2, the role of the component manager is essential to making Strategic Component Management work. The orderly, systematic, and planned approach to component management demonstrated by the difference in the two scenarios is due to the focus and attention gained by employing a component manager. The component manager is to be the single point of authority and responsibility for assuring the reliability and maintenance action for an assigned component.

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For major component types in a large plant, it is strongly recommended that one component manager be assigned to one type of component; in many plants motors, pumps, spindles, and air handling equipment each deserve a separate component manager.

The component manager must be one of the most knowledgeable people in the plant for his assigned component type, usually with many years of experience in the installation, repair, and operation of the assigned component. Because the component manager's position requires a strong ability to coordinate action within the plant and with the repair facilities, it is critical that the component manager have strong "people skills" as well as the technical skills.

From the viewpoint of an outside observer watching the component manager in action, the amount of authority and responsibility given to this position is very striking. The component manager must act as reliability coordinator, purchasing agent, repair coordinator, and liaison between maintenance, production, PdM, and engineering. From the observation of a component manager managing 4000 critical operating machines, the job was strenuous but manageable. The typical work of this component manager is composed of the following:

- Repair and spares coordination by working with repair facilities. Assure that the plant has the correct component replacements such that any impact of a component replacement causes minimum production loss. 20%
- Reliability Improvement by evaluation of root cause issues and improving countermeasures if found inadequate. Maintenance protocols determined by lowest life cycle cost. 30%
- Coordination of predictive maintenance action by reviewing PdM data and assuring that countermeasure actions are appropriate and on track. Make sure condition information is available to the entire plant and action is underway such that the impact on production is minimized. 30%
- Inspect and review preventative and scheduled maintenance work. Inspect critical components during the operation. 20%

The responsibilities of the component manager include:

- Primary contact and relationship with the repair facilities.
- Specification of new or replacement components.
- managing the component spares inventory.
- supervising the routine maintenance and testing programs.
- Reviewing all failures, seeks root cause of failures, and specifies repairs, modifications, or Replacements that eliminate or minimize the root cause of failure.
- Specifying and purchasing (possibly works very closely with purchasing) with the goal of lowest life cycle cost.
- maintaining a close working relationship with PdM staff and techs.
- Visits repair facilities regularly, and know capabilities and latest repair techniques.
- Visits manufacturers regularly and knows their capabilities and practices. Gives feedback on suspect practices and procedures.

Using Strategic Component Management, the component manager must balance the equipment out for repair, the spares inventory, and all new equipment purchases to assure minimum impact on plant production, enhanced reliability, and the lowest life cycle cost. To accomplish this, the component manager must know what component models and what spare parts will be required by the plant over the next few months; he then must make sure the appropriate units are on hand with the proper tools, parts, and procedures for a routinely managed replacement. The tools used by the component manager to accomplish this Herculean effort are predictive condition, historical location failure patterns, and an optimized spares inventory. A good working relationship with component manufacturers and repair shops is required to ensure the highest quality of reworked and new components are available and delivered on time.

When a component begins showing signs of condition degradation, the component manager must go to work well ahead of the failure. He must explore the following questions:

1. Does a pattern of failure in this component or location indicate an underlying root cause of failure?

If the answer to this question is "yes", the component manager must seek a new solution to replace the component with a new or overhauled unit that is modified to defeat the suspected root cause.

2. Should overhaul or replacement be selected for this component?

   How many times has the unit been overhauled? What have previous life cycles been like? Is the amortized cost of a new component with a longer life and higher purchase cost better than an overhaul with it's lower cost but shorter life? These decisions must be made on a case-by-case basis using hard historical evidence of new and overhaul cost and new and overhaul life cycles, and component history.

3. Does a spare exist on-site?

   If the answer is yes, it must be checked to assure it is ready for service. If the answer is no, then the spares inventory of other company facilities, used component vendors, and new component vendors must be searched to find a suitable replacement. The component manager must assure that an inventory of critical spares is available and optimal, such as the same general specification of 1800 RPM, 200 HP, 440v, and 445T frame components will meet the needs of the plant.

4. Are there any installation or maintenance issues to address at replacement to make the component easier to install/remove or maintain over its life?

   Items such as access, hostile conditions, and poor design may make the installation, removal, or maintenance task very difficult. In these situations, a review of ways to change or minimize the situation should be conducted.

II Identifying Root Cause of Failure from Historical Analysis of Machine Failures

There is extensive information existing in many plants that, if analyzed for repetitive patterns, would yield significant insight into machines or applications with a chronic history of poor reliability.

Tracking failure data for a component in the plant along with the manufacturer and overhaul shop, the overhaul details and the location where the component was operating will yield a wealth of reliability information when sorted and analyzed. The reliability of components can be studied by manufacturers to determine which brand component is most reliable by size or application. It can be determined which rebuild shop should do which rebuilds. One can also find out where redesign of the component or application is necessary to improve the reliability. Sometimes replacement is better than repair and vice versa.

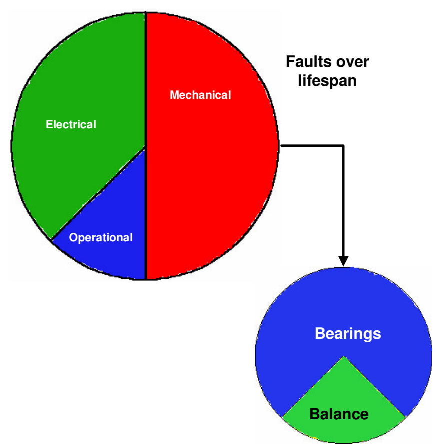
Machine and location history must be maintained such that the history can be searched and sorted to reveal basic failure patterns.

Machine and location history must be maintained such that the history can be searched and sorted to reveal basic failure patterns such as:

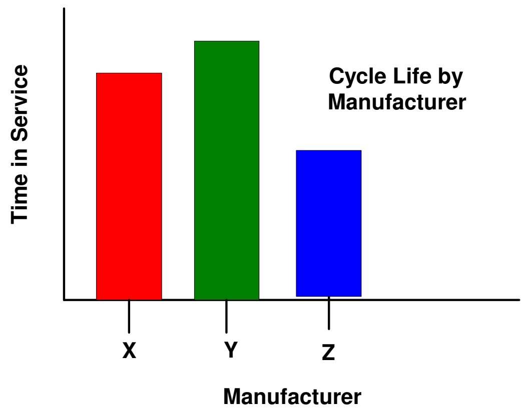
1. **Failures by location**
   Often a plant has multiple identical equipment trains. It is important to understand if there is a common primary failure mode across these locations and seek to eliminate the root cause of failure if the life cycle of a component is less than acceptable.

2. **Failures under warranty**
   Often plants do not process equipment warranty claims because they do not have readily available information on purchase and installation dates.

3. **Failures with less than one year of service**
   There exists a significant number of unreliable machines or locations within the plant that must be identified and aggressively analyzed for root cause of failure.

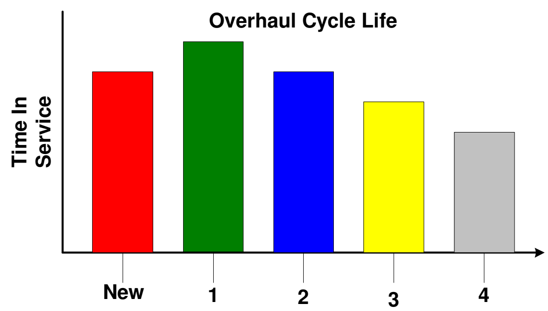


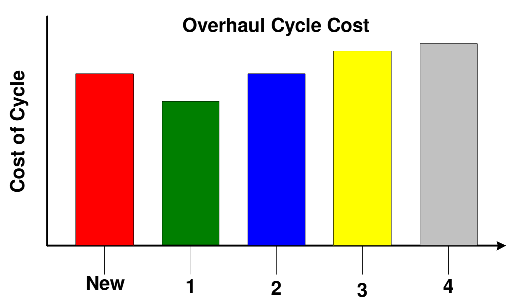
4. **Failures by manufacturer**
   Some manufacturers build a better machine for an application than others. An analysis of the installed machines by manufacturer can focus your replacement towards higher reliability manufacturers.

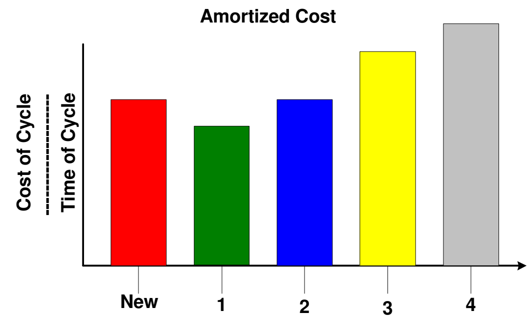


5. **<u>In service life</u>**

Sometimes a specific asset has a reliability problem which needs to be identified and eliminated. Analysis of the in-service life by asset ID can identify these weak components. Another value of in-service life analysis is to examine the life available from each overhaul cycle turn. It is often said that a motor should not be overhauled more than four times. By viewing the in-service life of the motor for each overhaul, a decision on additional overhaul or scrapping the motor can be made.







It is possible, in many cases, to go back into paper records (purchase orders, machine logs, maintenance logs) to put together the historical facts needed to support the correct replacement/repair action today. The history gathered will assist in root cause of failure analysis, and the redesign and/or purchase and/or maintenance specifications that result from this will produce the greatest payback from the program.

III <u>Integrating Condition-Based Maintenance into the Plant Maintenance Organization</u>

Condition-based maintenance, or predictive maintenance, is a very technical science with data acquisition devices, databases, and analysis graphs and charts; all oriented at predicting one aspect of a machine's condition. This technology has proven to be very valuable in identifying failing machines and allowing replacement before catastrophic failure. Where most predictive maintenance programs fall short is in integrating the predictive technologies into one concise condition view of the machine and providing integrated recommendations for machine maintenance to the entire plant, and tying the maintenance action back to the original PdM calls.

1. **<u>Integrating predictive recommendations from multiple technologies.</u>**

In many plants, predictive maintenance has not been well integrated into the overall plant maintenance organization. Strategic Component Management utilizes the component manager to provide the link between the technical data oriented results of PdM and the action based recommendations that are needed by plant maintenance and operations people.

Strategic Component Management requires that the results of the predictive technologies be integrated and an executive recommendation be issued in clear maintenance language regarding the machine's problem severity, expected availability, and corrected action. The component manager should be the person responsible for issuing the component's recommended repair action.

Integrating predictive recommendations from multiple technologies

Let's say that each technology analyst is making great recommendations for action based on their area of expertise. This is still not adequate for good maintenance decisions. Plant maintenance and operations people cannot easily work with data, actions and recommendations issued by each independent technology. Rather, they need a single integrated recommendation that provides information about the machine and it's condition in a clear, concise manner.

Converting PdM technology data into action-based recommendations is not an exact science. The common question "When will it fail" cannot be accurately answered because of the many unknown aspects of machine failures. Strategic Component Management utilizes the color code severity index where the action based on severity is clear. These are:

Red – Machine is not reliable and could fail at any time.

Yellow – Machine is definitely degraded, but should reliably operate for over a month longer.

Blue – An early stage fault is suspected. Corrective action may be taken to extend the machine's life. The machine should reliably operate for over three months.

Green – The machine is fully reliable and shows no sign of degradation.

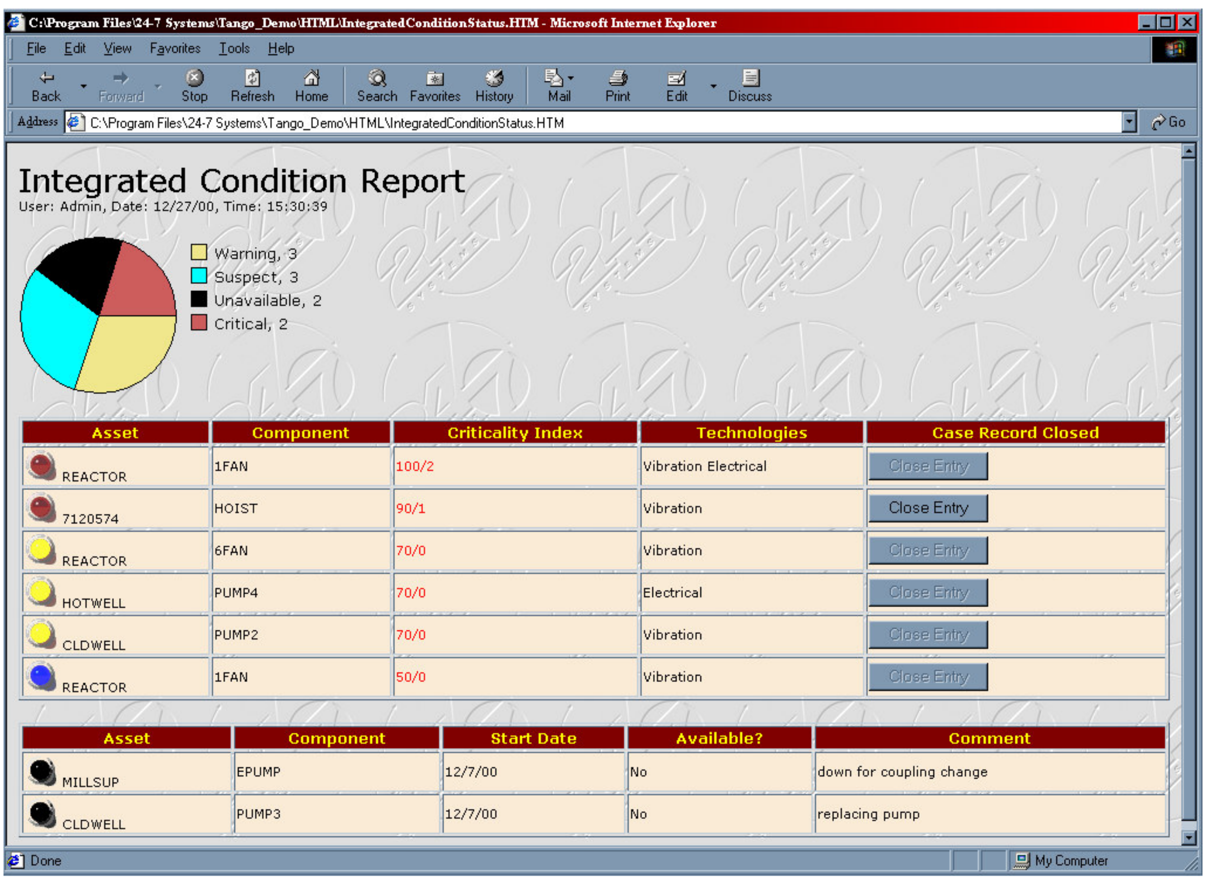


Figure 1

Benefits & Payback

The payback from Strategic Component Management can be very significant. Typically, payback is obtained from:

1. **Reduced machinery life cycle cost**

   The most significant cost savings from this technology is the lowering of a machine's life cycle cost by increasing it's usable life between replacements or overhauls. Many poor reliability machines can be increased in life several-fold with the application of root cause failure analysis and precision corrective maintenance technologies.

2. **Lower repair/replacement cost**

   The reduction in overhaul and replacement cost is accomplished through building a partnership with the overhaul or component manufacturers; which allows volume cost reductions and the imposition of stringent quality requirements. The standardization of spares to allow more widespread use of a single class of motor provides significant savings.

   One large facility reported a 40% reduction on repair and replacement cost when comparing their annual cost from before implementing strategic component management and

   three years after the implementation of the program.

3. **Increased production from higher availability**

   Increasing machinery reliability has a direct effect on increasing production. Having more reliable machines means less maintenance downtime and more production availability.

   One plant, after having implemented Strategic Component Management for several years notes an increase of up to 8 hours a week of increased production.

4. **Providing integrated recommendations to the plant**

   In many manufacturing facilities, predictive condition monitoring is performed on thousands of machine components. Typically an exception report of machines ranked by severity is issued by each technology. Usually this report is issued on hard copy or in e-mail and followed up with a phone call for the most critical and severe cases.

   Typically in most plants the maintenance responsibility is broken down into areas or component types. Area maintenance only wants to see the condition of "their" machines. Strategic Component Management recommends that an integrated condition report be available broadly over the plant computer network, and allow each maintenance person to only view the machines they are interested in or responsible for. Figure 1. shows an example integrated condition report.

5. **Completing the loop – tying maintenance action back to the PdM call.**

   It is typical in most plants that the predictive maintenance technologists do not get very good feedback on repairs and findings from the maintenance repair organization. PdM needs this information to:

   - Close out the fault case.
   - Verify the quality of predictive calls.
   - Trigger the collection of certification measurements to assure a good repair.
   - Establish a new machine baseline.

6. **Component Replacement & In-Place Spares**

   Major component replacement and In-place repairs are led by the component manager. This reduces the stress and workload of area maintenance management, planning, and parts expeditors. This ensures a top quality job completed on-schedule.

Action:

1. Install a component manager.

2. Utilize a component management software package and set up an inventory of what components are installed in which locations, their installation date and nameplate and design data. Include any history from plant documentation.

3. Use equipment and location history to identify poor reliability components, component groups, and locations. If equipment and location history are not available, begin to accumulate that data.

4. Select preferred vendors and negotiate preferred pricing, quality, and warranty terms (terms include run time from installation date).

5. Establish criticality, component repair specifications, and component purchase specifications.

6. Integrate PdM data and distribute plant-wide by an intranet browser report.

7. Analyze failures and determine root cause.

8. Improve and customize purchase and repair specifications to eliminate the root cause of failure.

Appendix A

If your plant operates like this, you need Strategic Component Management

- Each plant functional area is doing it's own thing.
- Multiple relationships exist between the plant and it's repair shops; the plant appears as multiple customers to repair shops. Sometimes even within one area the repair shop is given different directions on repairs. This writer has personally seen a repair shop given different directions from shift to shift at a plant.
- "Identical" components are repaired to different standards making it difficult to share spares across the entire plant. This is also difficult for the repair shop to know what to do, and a critical component could get repaired in such a way that it will not work in a critical application.
- There are possible excess spare components in the plant since the spares are not shared among the areas.
- Each area or possibly each shift within an area will have their own stash of parts and spare components. These critical components or parts are inches away, but the people on shift don't know about it or can't get to it.
- Generally, repairs are made based on a time decision (who can do what fastest), not a quality decision (what repair will make the component run the longest)
- Warranty claims are lost because no good records are kept to substantiate the installation date, the failure date, and the required maintenance work during the installation of the component.
- The person in charge is generally not a master of the component that failed on his shift; therefore, the best decisions are not always made with regard to repair/replacement.
- Little or no condition monitoring is being performed; therefore, equipment is operated in the run to failure mode (crisis management).

No failure analysis is performed unless failures become an overly large problem; henceforth, repetitive problems are rarely fixed. The repair shops and component suppliers are happy.

Some Real World Examples of Strategic Equipment Management in Action

Example 1:

Working with the overhaul shop to improve a location's reliability.

The cooling towers water pump drive motors were failing once per year. Component Management Software data indicated that a step change occurred in the life cycle, and all the latest failures were winding failures. Analysis of the system showed that the motors were continuously running at 110% of rated load due to a pump modification. Working with the overhaul shop, it was determined that the winding could be redesigned to reliably achieve a 220 horsepower load. This fix cost 25% of the cost to purchase 250 horsepower (the next NEMA size above 200) motors for these four locations.

Example 2:

Working with the overhaul shop and component manufacturer to correct an equipment design flaw.

Multiple applications of 50 horsepower combustion blowers (multi-stage turbine mounted on a long motor shaft). The arrangement as supplied was unreliable, failing as least once per year. Component management software data confirmed that all failures were motor bearings and this was common across all applications of these fans. Also, all motors, regardless of brand, used the same bearings. In addition, the fan assembly and balancing costs exceeded the motor repair costs. The solution was to work with a motor vendor who supplied a 75 horsepower motor frame with a 50 horsepower motor inside. The fan housing was modified at the overhaul shop to accept the larger motor frame.

Example 3:

Component manager involved in motor installation improves design for easier installation.

The component manager and maintenance realize that a flexible bus connection to some large motors, instead of the existing bolted joint solid bus connectors would allow a much faster installation. The component manager designed and specified the change and saved the plant over one hour on each motor installation.

Example 4:

Component manager involved in motor replacement improves internal motor connections.

A 1500 horsepower DC motor had six connections that had to be made during installation. Following the wiring diagrams, making the connections, and double-checking resulted in four hours work. The component manager worked with the repair shop to redesign the existing bus and replace the cable with bus such that the connections were ready for bolts when the mechanical assembly of the motor was complete. This redesign saved three hours of installation work and the possibility of an incorrect connection causing immediate motor failure during startup.

Example 5:

Working with the overhaul shop to improve motor manufacturing insulation systems.

Modern design AISE mill auxiliary motors were failing to ground every 16 to 18 months. Reviewing insulation failure in a component management program revealed that all failures were in the same location. The insulation system was redesigned at less than 1/3 the cost of a new motor. The installed life of the motor is now in excess of 5 years.

Example 6:

Working with the PdM techs to determine root cause of bearing failure.

The opposite drive end bearing of a 250 HP NEMA frame motor was repeatedly failing in a group of like motors in like applications. The bearing problems were detected by vibration specialists and removed from service before complete failure. Detailed analysis of this failure led to checking for shaft currents. The shaft currents were found and now the opposite drive end bearing is insulated during the first repair and checked during all subsequent repairs. The bearing failures have been eliminated and windings are the current failure mode. This information was added to all like motors in the motor management database so the proper modifications and checks would be made in the future.

Example 7:

Component manager knowing motors design and repair procedures and analyzing winding failures.

Several two-speed two-winding motors were supplied by a machine manufacturer, all having an installed life of less than one year. Detailed analysis of the winding design revealed that the root cause of failure could not be fixed economically. The OEM motors are scrapped and replaced with ones of different manufacture. Information to scrap this brand and type of motor was entered in the motor management database.

Additional spare motors were ordered to cover needs entered until these motors were all scrapped.

Author Biographies

E. Forrest Pardue

Education:

BSEE: North Carolina State
MBA: Lynchburg College

Experience:

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 route-based, online, and status monitoring technologies.

In 1998 Forrest co-founded 24/7 Systems with his partner, Paul Wolfensberger. 24/7 Systems is focused on the development of strategic component management software and services.

Alan Mueller

Education:

BSEE: University of Akron

Experience:

Alan was employed by ALCOA for 30 years. For the first 10 years of his employment, he was responsible for electrical and utility maintenance at the Lancaster Penn plant. For the next 20 years, until he relinquished the position in 1998, he worked at the ALCOA Tennessee operations center in Motor and Generator Maintenance.

Starting in 1980, Al assumed the role of Component Manager for Motors and began developing a motor management software program that, by the mid 1980’s, was used to manage over 4,000 critical motors and 700 spares.

Al strategically began a program of motor reliability improvement, during which motor repairs declined from about 20 per week in 1980 to about 5 per week in 1988. By the mid 1990’s repairs of critical motors averaged 4-5 per month.