Reliability Based Maintenance
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What is the Maintenance team’s role in the manufacturing mission? We believe that role is to preserve the physical assets and ensure their availability to perform in a manner as good or better than originally required, using the most cost effective means available. Maintenance is the largest controllable cost within a manufacturing organization. There are two areas where we can deliver these cost savings – (1) Avoiding a loss of production (i.e. reducing breakdowns) and (2) avoiding maintenance costs (parts and labor) associated with a failure.

Maintenance professionals would like to control and manage our machines, and not have them manage our businesses or us. There is a continuum (see Appendix A), which describes the journey to World Class Manufacturing. It begins with Regressive behaviors, where we delay the repair of equipment, or don’t fix it at all. Regressive moves to Reactive behavior, where we “fix it after it breaks.” In this phase we are responding to the machine and allowing the machine to manage our business. From Reactive, we move to Planned. In the Planned phase we identify potential failures and fix them before they break preventing an interruption to our production schedules. The idea here is no surprises. The Planned environment moves forward to Defect Elimination, where we are improving our equipment, identifying the “bad actors,” and engineering them out. The final phase is Asset Optimization.

Reliability Based Maintenance (RBM) provides some techniques and tools, which aid us in delivering on this objective. What is RBM? It is a combination of maintenance techniques. There are three main components to any RBM program.

- **Preventive maintenance** - time based maintenance, like we have been doing for over 50 years.
- **Predictive maintenance** - condition based maintenance using technology to identify and predict equipment failures
- **Proactive maintenance** – applying investigative analysis to extend machine life

Preventive maintenance provides the first level of control of our equipment. It is generally time based – like what you should do on your automobile. After 3,000 or 5,000 miles you should change the engine oil. This is a proven technique to keep your engine operating as near to factory specification as possible. Other “PM” type work would include equipment inspections (by operators or maintenance professionals), instrumentation calibrations, component replacement based on run hours or even machine cleaning.

There are a couple of problems with preventive maintenance activities. One is that we tend to put off some of these maintenance activities due to cost, or conflicting priorities. Our machines may be running exceedingly well or we have “hot” customer orders, so we delay taking the machine down for maintenance. Another problem is that PM activities can be invasive and lead to excessive maintenance and/or premature failure. We may open a large gearbox for inspection and cleaning, but leave a rag inside when we start it back up.

Predictive maintenance is using technology to detect equipment failures before they become serious and impact our business. Predictive techniques allow the condition of the machine to be measured. In that way, maintenance needs can be anticipated, which means they can be better planned. Better planning yields a lower cost to the business and minimal impact to the business (and subsequent customers). Predictive techniques include the following:

- Vibration analysis
- Thermographic analysis
- Oil condition monitoring
- Ultrasonic analysis
- Electric motor current analysis
Proactive maintenance is the application of advanced investigative and corrective technologies to extend machinery life. We are identifying and removing sources of failure (Defect Elimination). Proactive techniques include:

- **Root Cause Failure Analysis (RCFA)** – looking at chronic failures and for systemic roots or key factors.
- **Precision Alignment and balancing** – laser and/or optical alignment of couplings and machine rolling elements.
- **Reliability engineering** – designing reliability in at the beginning or redesigning based on RCFA findings.
- **Developing equipment specifications** for new equipment and spare parts, including standardization.

Now we are all speaking the same language. It is a little intimidating when you look at the entire Reliability based maintenance picture. But, as an ancient Chinese philosopher said – “A journey of 1,000 miles, begins with a single step.” So, which of these would I implement at my facility first?

**Lubrication**

Lubrication is a foundation to build from. It is important to (1) identify every piece of equipment’s lubrication needs, (2) identify which type grease is being used (because of incompatibilities), and (3) who is going to do it. Some plants use their maintenance technicians to perform the routine lubrication. We use two lubrication technicians who have the responsibility to (1) lubricate every piece of equipment on the site, (2) correct and/or report minor oil leaks on gearboxes, (3) collect the oil samples for our Oil Condition Monitoring program, and (4) assist our mechanics when necessary. Some of my best mechanics started as lubrication technicians. Their activity is directed from a route established and monitored by our CMMS.

Our Oil Condition Monitoring program consists of collecting over eighty (80) quarterly samples on our major gearboxes. The samples are sent to a vendor lab for analysis (annual cost of $3500). The lab sends us a report, which trends the results, and helps us gauge the condition of both our lubricant and the components in our major gearboxes. The analysis checks the following:

- **Wear patterns** – checking for various metal particles in the oil aids in early detection of mechanical wear failures.
- **Contamination** – contamination can come from a variety of sources – dirt, dust, water (either condensation or cooling leaks).
- **Chemistry** – checking the viscosity and the acidity levels define the lubricant’s effectiveness.

We used to open our gearboxes for a visual inspection (PM) and cleaning every 4-5 years. Historically, this was a major cost to our business, plus we ran the risk of introducing a failure mode into the box, as it lay open to the elements. Using oil analysis, we can identify failure patterns early enough to plan the corrective action required, and minimize the cost and impact to our business.

**Thermography**

Thermography is a diagnostic technique for measuring the variations in heat emitted from various machine components. Commercially, thermography is being used in tracking energy losses in homes and buildings.

We began using thermography in 1976, but we focused in one specific area – our electrical distribution systems. Using this technique we could identify “hot spots” in our distribution equipment. Hot spots are generally caused by loose or corroded connections, and can cause significant problems if left until failure.

The scope of our survey looks at over 2100 separate pieces of electrical equipment. Several contractors offer this type service, including some insurance companies (as a fire prevention program). We use a DuPont internal resource, and the costs run about $6,000 each year. A report is generated which shows a picture of the component, a thermal image of the component, a recommendation on the severity of the fault, and a suggested cause of the fault. We then make the decision (a) when to shut the equipment down to repair the fault, or (b) to continue monitoring the fault. The advantage is that we know there is a fault and we can now manage the machine, rather than having the machine manage us.
We have also used thermography to locate defective refractory in our steam boilers, verify steam trap operation, identify process thermal problems, and verify/fine tune vibration analysis calls.

**Vibration Analysis**
We have had a vibration analysis program for about the past twenty years. We began with our critical equipment – mostly our film line drive equipment. Vibration analysis allows us to identify bearing or motor faults early enough to plan for the repair before the failure occurs. We have reduced the failures using this technology. However, we had some early issues around buy-in by Operations and Maintenance personnel. We had mechanics with screwdrivers pressed to their ears challenging the technology. In order to gain credibility for the program, we began conducting “show & tell” sessions, where we displayed the failed bearing components.

Currently, we manually collect over 3,000 points of data on plant equipment. Once the data is collected, it is downloaded into a software program that performs a rough analysis. Any point that is in an “alarm” condition will be reviewed by one of our analysts. The analyst then makes the determination for further monitoring or the generation of a work order for a repair.

**Alignment**
A precision alignment program delivers bottom line results to your business. The business results improve with the accuracy of the alignment. Alignment technology runs from pulling a string across components to setting up a laser.

Manufacturing operating costs will decrease with a precision alignment program. Aligned machines run more efficiently, producing an extended bearing life – thus decreased costs to maintain – and reduced energy consumption. Electric motors represent more than 50% of our annual energy costs.

Aligned machines, such as our web-based machines, have fewer quality problems. We perform an alignment every two years on our winding and transport sections. This reduces the winding problems we suffer internally, and ultimately impacts the quality of film we deliver to our customers.

We have the capabilities to use optical or laser equipment to align our machine’s rollers. Historically, we used optical equipment, but recently invested in a roller laser alignment system. This new system delivers as accurate results in less than half the time, resulting in a productivity boost for my predictive team.

**Root Cause Failure Analysis**
RCFA is a common problem-solving tool. Ask the 5 Whys to determine what the root cause is. The idea is to eliminate any defects in our machinery, and/or uncover the reasons for equipment failure. Getting to the true root of the problem and eliminating it provides bottom line results. For example, we know the bearing failed, but why did it fail? Was it a lack of lubrication? Was it improperly installed? Was the mechanic properly trained? Solving these systemic roots will eliminate the problem forever.

We are pursuing a more formal approach to RCFA at Hopewell. Historically, we would perform an analysis on large catastrophic failures. This year, we are focusing the RCFA efforts in two areas – Safety and Cost. We are requiring an RCFA analysis (or Why Tree) for all safety incident investigations, and are beginning to look at the chronic failures – either those small pain in the backside failures that pop up frequently, or those equipment failures that are costly (over time). Both of these cause a drain on our resources – people and money.

**Summary**
The DTF manufacturing organization at Hopewell is moving up the World Class Manufacturing continuum. In 1989, our total maintenance downtime – both emergency and planned – was 9.3% of our time available for manufacturing. We improved our performance to 4.4% in 2001.
Appendix A  World Class Manufacturing Continuum

The Journey to World Class Manufacturing

Behavior:  Careless  Responding  Org. Discipline  Org. Learning  Inventing

Regressive

Don’t Fix It, Delay The Fix

Reactive

Fix it After It Breaks

Fix it Before It Breaks

Planned

Defect Elimination

Don’t Just Fix It, Improve It

Don’t Just Improve It, Optimize It

Asset Optimization

Cost Focus  Productivity Focus  Value Focus  Optimization Focus
CLICK TO RETURN
TO LIST OF
PAPERS AND
PRESENTATIONS