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IMPACT OF MAINTENANCE

Maintenance costs, as defined by normal plant accounting procedures, are normally a major portion of the total operating costs in most plants. Traditional maintenance costs (i.e., labor and material) in the United States have escalated at a tremendous rate over the past 10 years. In 1981, domestic plants spent more than $600 billion to maintain their critical plant systems. By 1991, the costs had increase to more than $800 billion, and they were projected to top $1.2 trillion by the year 2000. These evaluations indicate that on average, one third, or $250 billion, of all maintenance dollars are wasted through ineffective maintenance management methods. American industry cannot absorb the incredible level of inefficiency and hope to compete in the world market.

Because of the exorbitant nature of maintenance costs, they represent the greatest potential short-term improvement. Delays, product rejects, scheduled maintenance downtime, and traditional maintenance costs—such as labor, overtime, and repair parts—are generally the major contributors to abnormal maintenance costs within a plant.

The dominant reason for this ineffective management is the lack of factual data that quantify the actual need for repair or maintenance of plant machinery, equipment, and systems. Maintenance scheduling has been and in many instances still is predicated on statistical trend data or on the actual failure of plant equipment.

Until recently, middle and corporate level management have ignored the impact of the maintenance operation on product quality, production costs, and more importantly on bottom-line profit. The general opinion has been "maintenance is a necessary evil" or "nothing can be done to improve maintenance costs." Perhaps these were true statements 10 or 20 years ago. However, the developments of microprocessor or computer-based instrumentation that can be used to monitor the operating condition of plant equipment, machinery, and systems have provided the means to manage the maintenance operation. They have provided the means to reduce or eliminate unnecessary repairs, prevent catastrophic machine failures, and reduce the negative impact of the maintenance operation on the profitability of manufacturing and production plants.

Maintenance Philosophies

Industrial and process plants typically utilize two types of maintenance management: (1) run-to-failure, or (2) preventive maintenance.

Run-to-Failure Management

The logic of run-to-failure management is simple and straightforward. When a machine breaks, fix it. This "if it ain't broke, don't fix it" method of maintaining plant machinery has been a major part of plant maintenance operations since the first manufacturing plant was built, and on the surface sounds reasonable. A plant using run-to-failure management does not spend any money on maintenance until a machine or system fails to operate. Run-to-failure is a reactive management technique that waits for machine or equipment failure before any maintenance action is taken. It is in truth a no-maintenance approach of management. It is also the most expensive method of maintenance management.

Few plants use a true run-to-failure management philosophy. In almost all instances, plants perform basic preventive tasks (i.e., lubrication, machine adjustments, and other adjustments) even in a run-to-failure environment. However, in this type of management, machines and other plant equipment are not rebuilt nor are any major repairs made until the equipment fails to operate.

The major expenses associated with this type of maintenance management are: (1) high spare parts inventory cost, (2) high overtime labor costs, (3) high machine downtime, and (4) low production availability. Since there is no attempt to anticipate maintenance requirements, a plant that uses true run-to-failure management must be able to react to all possible failures within the plant. This reactive method of management forces the maintenance department to maintain extensive spare parts inventories that include spare machines or at least all major components for all critical equipment in the plant. The alternative is to rely on equipment vendors that can provide immediate delivery of all required spare parts. Even if the latter is possible, premiums for expedited delivery substantially increase the costs of repair parts and downtime required for correcting machine failures. To minimize the impact on production created by unexpected machine failures, maintenance personnel must also be able to react immediately to all machine failures.

The net result of this reactive type of maintenance management is higher maintenance cost and lower availability of process machinery. Analysis of maintenance costs indicates that a repair performed in the reactive or run-to-failure mode will average about three times higher than the same repair made within a scheduled or preventive mode. Scheduling the repair provides the ability to minimize the repair time and associated labor costs. It also provides the means of reducing the negative impact of expedited shipments and lost production.

Preventive Maintenance Management

There are many definitions of preventive maintenance, but all preventive maintenance management programs are time driven. In other words, maintenance tasks are based on elapsed time or hours of operation. Figure 1.1 illustrates an example of the statistical life of a machine-train. The mean time to failure (MTTF) or bathtub curve indicates that a new machine has a high probability of failure, because of installation problems, during the first few weeks of operation. After this initial period, the probability of failure is relatively low for an extended period of time. Following this normal machine life period, the probability of failure increases sharply with elapsed time. In preventive maintenance management, machine repairs or rebuilds are scheduled on the basis of the MTTF statistic.

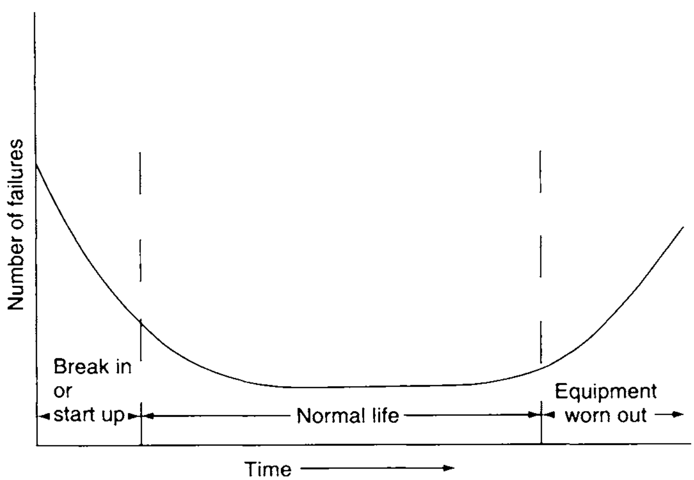

Figure 1.1 Bathtub curve.

The actual implementation of preventive maintenance varies greatly. Some programs are extremely limited and consist of lubrication and minor adjustments. More comprehensive preventive maintenance programs schedule repairs, lubrication, adjustments, and machine rebuilds for all critical machinery in the plant. The common denominator for all of these preventive maintenance programs is the scheduling guideline. All preventive maintenance management programs assume that machines will degrade within a time frame typical of its particular classification. For example, a single-stage, horizontal split-case centrifugal pump will normally run 18 months before it must be rebuilt. When preventive management techniques are used, the pump would be removed from service and rebuilt after 17 months of operation.

The problem with this approach is that the mode of operation and system or plant-specific variables directly affect the normal operating life of machinery. The mean time between failures (MTBF) will not be the same for a pump that is handling water and one that is handling abrasive slurries. The normal result of using MTBF statistics to schedule maintenance is either unnecessary repairs or catastrophic failure. In the example, the pump may not need to be rebuilt after 17 months. Therefore the labor and material used to make the repair was wasted. The second option, use of preventive maintenance, is even more costly. If the pump fails before 17 months, we are forced to repair by using run-to-failure techniques. Analysis of maintenance costs has shown that a repair made in a reactive mode (i.e., after failure) will normally be three times greater than the same repair made on a scheduled basis.

Predictive Maintenance

Like preventive maintenance, predictive maintenance has many definitions. To some, predictive maintenance is monitoring the vibration of rotating machinery in an attempt to detect incipient problems and to prevent catastrophic failure. To others, it is monitoring the infrared image of electrical switchgears, motors, and other electrical equipment to detect developing problems.

The common premise of predictive maintenance is that regular monitoring of the mechanical condition of machine-trains will ensure the maximum interval between repair and minimize the number and cost of unscheduled outages created by machine-train failures. Predictive maintenance is much more. It is the means of improving productivity, product quality, and overall effectiveness of our manufacturing and production plants. Predictive maintenance is not vibration monitoring or thermal imaging or lubricating oil analysis or any of the other nondestructive testing techniques that are being marketed as predictive maintenance tools. Predictive maintenance is a philosophy or attitude that, simply stated, uses the actual operating condition of plant equipment and systems to optimize total plant operation. A comprehensive predictive maintenance management program utilizes a combination of the most cost-effective tools—that is, vibration monitoring, thermography, tribology, etc.—to obtain the actual operating condition of critical plant systems, and based on these actual data, schedules all maintenance activities on an as-needed basis. Including predictive maintenance in a comprehensive maintenance management program will provide the ability to optimize the availability of process machinery and greatly reduce the cost of maintenance. It will also provide the means to improve product quality, productivity, and profitability of our manufacturing and production plants.

Predictive maintenance is a condition-driven preventive maintenance program. Instead of relying on industrial or in-plant average-life statistics (i.e., MTTF) to schedule maintenance activities, predictive maintenance uses direct monitoring of the mechanical condition, system efficiency, and other indicators to determine the actual MTTF or loss of efficiency for each machine-train and system in the plant. At best, traditional time-driven methods provide a guideline to normal machine-train life spans. The final decision, in preventive or run-to-failure programs, on repair or rebuild schedules must be made on the bases of intuition and the personal experience of the maintenance manager. The addition of a comprehensive predictive maintenance program can and will provide factual data on the actual mechanical condition of each machine-train and operating efficiency of each process system. These data provide the maintenance manager with actual data for scheduling maintenance activities.

A predictive maintenance program can minimize unscheduled breakdowns of all mechanical equipment in the plant and ensure that repaired equipment is in acceptable mechanical condition. The program can also identify machine-train problems before they become serious. Most mechanical problems can be minimized if they are detected and repaired early. Normal mechanical failure modes degrade at a speed directly proportional to their severity. If the problem is detected early, major repairs, in most instances, can be prevented. Simple vibration analysis is predicated on two basic facts: all common failure modes have distinct vibration frequency components that can be isolated and identified, and the amplitude of each distinct vibration component will remain constant unless there is a change in the operating dynamics of the machine-train. These facts, their impact on machinery, and methods that will identify and quantify the root cause of failure modes will be developed in more detail in later chapters.

Predictive maintenance that utilizes process efficiency, heat loss, or other nondestructive techniques can quantify the operating efficiency of non-mechanical plant equipment or systems. These techniques used in conjunction with vibration analysis can provide the maintenance manager or plant engineer with factual information that will enable him to achieve optimum reliability and availability from the plant.

There are five nondestructive techniques normally used for predictive maintenance management: (1) vibration monitoring, (2) process parameter monitoring, (3) thermography, (4) tribology, and (5) visual inspection. Each technique has a unique data set that will assist the maintenance manager in determining the actual need for maintenance. How do you determine which technique or techniques are required in your plant? How do you determine the best method to implement each of the technologies? If you listen to the salesman for the vendors that supply predictive maintenance systems, his is the only solution to your problem. How do you separate the good from the bad? Most comprehensive predictive maintenance programs will use vibration analysis as the primary tool. Since the majority of normal plant equipment is mechanical, vibration monitoring will provide the best tool for routine monitoring and identification of incipient problems. However, vibration analysis will not provide the data required on electrical equipment, areas of heat loss, condition of lubricating oil, or other parameters that should be included in your program.

Role Of Maintenance Organization

Too many maintenance organizations continue to pride themselves on how fast they can react to a catastrophic failure or production interruption rather than on their ability to prevent these interruptions. While few will admit their continued adherence to this breakdown mentality, most plants continue to operate in this mode. Contrary to popular belief, the role of the maintenance organization is to maintain plant equipment, not to repair it after a failure.

The mission of maintenance in a world-class organization is to achieve and sustain optimum availability.

Optimum Availability

The production capacity of a plant is, in part, determined by the availability of production systems and their auxiliary equipment. The primary function of the maintenance organization is to ensure that all machinery, equipment, and systems within the plant are always on line and in good operating condition.

Optimum Operating Condition

Availability of critical process machinery is not enough to ensure acceptable plant performance levels. The maintenance organization has the responsibility to maintain all direct and indirect manufacturing machinery, equipment, and systems so that they will be continuously in optimum operating condition. Minor problems, no matter how slight, can result in poor product quality, reduce production speeds, or affect other factors that limit overall plant performance.

Maximum Utilization of Maintenance Resources

The maintenance organization controls a substantial part of the total operating budget in most plants. In addition to an appreciable percentage of the total plant labor budget, the maintenance manager, in many cases, controls the spare parts inventory, authorizes the use of outside contract labor, and requisitions millions of dollars in repair parts or replacement equipment. Therefore, one goal of the maintenance organization should be the effective use of these resources.

Optimum Equipment Life

One way to reduce maintenance cost is to extend the useful life of plant equipment. The maintenance organization should implement programs that will increase the useful life of all plant assets.

Minimum Spares Inventory

Reductions in spares inventory should be a major objective of the maintenance organization. However, the reduction cannot impair their ability to meet goals 1 through 4. With the predictive maintenance technologies that are available today, maintenance can anticipate the need for specific equipment or parts far enough in advance to purchase them on an as-needed basis.

Ability to React Quickly

Not all catastrophic failures can be avoided. Therefore the maintenance organization must maintain the ability to react quickly to the unexpected failure.

Evaluation Of The Maintenance Organization

One means to quantify the maintenance philosophy in your plant is to analyze the maintenance tasks that have occurred over the past two to three years. Attention should be given to the indices that define management philosophy.

One of the best indices of management attitude and the effectiveness of the maintenance function is the number of production interruptions caused by maintenance-related problems. If production delays represent more than 30%

of total production hours, reactive or breakdown response is the dominant management philosophy. To be competitive in today's market, delays caused by maintenance-related problems should represent less than 1% of the total production hours.

Another indicator of management effectiveness is the amount of maintenance overtime required to maintain the plant. In a breakdown maintenance environment, overtime cost is a major negative cost. If your maintenance department's overtime represents more than 10% of the total labor budget, you definitely qualify as a breakdown operation. Some overtime is and will always be required. Special projects and the 1% of delays caused by machine failures will force some expenditure of overtime premiums, but these abnormal costs should be a small percentage of the total labor costs. Manpower utilization is another key to management effectiveness. Evaluate the percentage of maintenance labor as compared with total available labor hours that are expended on the actual repairs and maintenance prevention tasks. In reactive maintenance management, the percentage will be less than 50%. A well-managed maintenance organization should maintain consistent manpower utilization above 90%. In other words, at least 90% of the available maintenance labor hours should be effectively utilized to improve the reliability of critical plant systems, not waiting on something to break.

Three Types of Maintenance

There are three main types of maintenance and three major divisions of preventive maintenance, as illustrated in Figure 1.2.

Maintenance Improvement

Picture these divisions as the five fingers on your hand. Improvement maintenance efforts to reduce or eliminate the need for maintenance are like the thumb, the first and most valuable digit. We are often so involved in maintaining that we forget to plan and eliminate the need at its source. Reliability engineering efforts should emphasize elimination of failures that require maintenance. This is an opportunity to pre-act instead of react.

For example, many equipment failures occur at inboard bearings that are located in dark, dirty, inaccessible locations. The oiler does not lubricate inaccessible bearings as often as he lubricates those that are easy to reach. This is a natural tendency. One can consider reducing the need for lubrication by using permanently lubricated, long-life bearings. If that is not practical, at least an automatic oiler could be installed. A major selling point of new automobiles is the elimination of ignition points that require replacement and adjustment, introduction of self-adjusting brake shoes and clutches, and extension of oil change intervals.

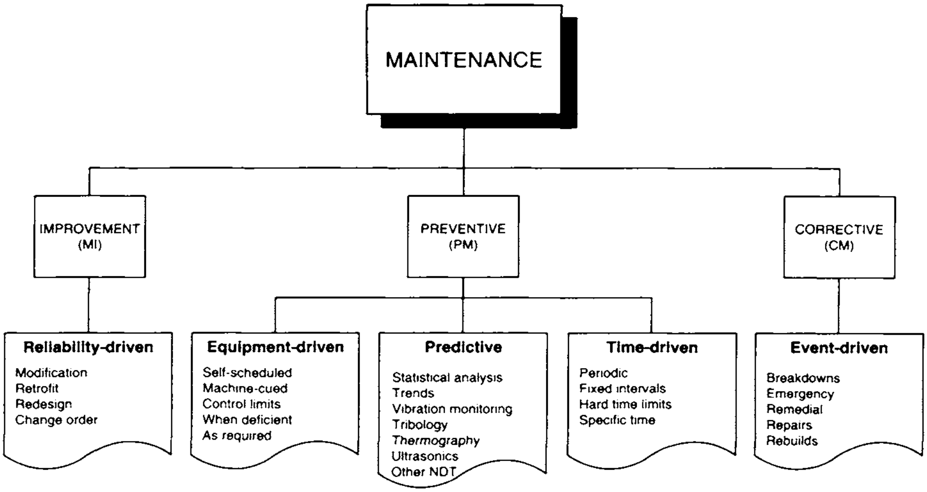

Figure 1.2 Structure of maintenance.

Corrective Maintenance

The little finger in our analogy to a human hand represents corrective maintenance (emergency, repair, remedial, unscheduled). At present, most maintenance is corrective. Repairs will always be needed. Better improvement maintenance and preventive maintenance, however, can reduce the need for emergency corrections. A shaft that is obviously broken into pieces is relatively easy to maintain because little human decision is involved. Troubleshooting and diagnostic fault detection and isolation are major time consumers in maintenance. When the problem is obvious, it can usually be corrected easily. Intermittent failures and hidden defects are more time consuming, but with diagnostics, the causes can be isolated and then corrected. From a preventive maintenance perspective, the problems and causes that result in failures provide the targets for elimination by viable preventive maintenance. The challenge is to detect incipient problems before they lead to total failures and to correct the defects at the lowest possible cost. That leads us to the middle three fingers the branches of preventive maintenance.

Preventive Maintenance

As the name implies, preventive maintenance tasks are intended to prevent unscheduled downtime and premature equipment damage that would result in corrective or repair activities. This maintenance management approach is predominately a time-driven schedule or recurring tasks, such as lubrication and adjustments that are designed to maintain acceptable levels of reliability and availability.

Reactive Maintenance

Reactive maintenance is done when equipment needs it. Inspection with human senses or instrumentation is necessary, with thresholds established to indicate when potential problems start. Human decisions are required to establish those standards in advance so that inspection or automatic detection can determine when the threshold limit has been exceeded. Obviously, a relatively slow deterioration before failure is detectable by condition monitoring, whereas rapid, catastrophic modes of failure may not be detected. Great advances in electronics and sensor technology are being made.

Also needed is a change in the human thought process. Inspection and monitoring should include disassembly of equipment only when a problem is detected. The following are general rules for on-condition maintenance:

- Inspect critical components.
- Regard safety as paramount.
- Repair defects.
- If it works, don't fix it.

Condition Monitoring

Statistics and probability theory provide are the bases for condition monitor maintenance. Trend detection through data analysis often rewards the analyst with insight into the causes of failure and preventive actions that will help avoid future failures. For example, stadium lights burn out within a narrow range of time. If 10% of the lights have burned out, it may be accurately assumed that the rest will fail soon and should, most effectively, be replaced as a group rather than individually.

Scheduled Maintenance

Scheduled, fixed-interval preventive maintenance tasks should generally be used only if there is opportunity for reducing failures that cannot be detected in advance, or if dictated by production requirements. The distinction should be drawn between fixed-interval maintenance and fixed-interval inspection that may detect a threshold condition and initiate condition monitor tasks. Examples of fixed interval tasks include 3,000-mile oil changes and 48,000-mile spark plug changes on a car, whether it needs the changes or not. This may be very wasteful, because all equipment and their operating environments are not alike. What is right for one situation may not be right for another.