MAINTENANCE PROGRAM EVALUATION

INTRODUCTION

Maintenance programs seek to avoid structural failures and unplanned equipment outages by managing the aging process. Maintenance begins with operational tasks, such as cleaning, lubrication and on-line monitoring. It continues with the scheduling of outages for inspection and for taking corrective action before failures occur. Finally, it involves stocking parts, identifying alternate means of production, and otherwise being prepared for the "unpreventable" accident.

A proper maintenance program is a formal and fully documented plan, as described in *OVERVIEW*. Those plans which have proven effective are based upon the principles of preventive maintenance. They contain elements of planned maintenance, predictive maintenance and pre-failure planning. To be of value, a maintenance program must have visible and unmistakable management support.

Risk assessment and continuing review are vital elements of good maintenance. The most serious fault of many maintenance programs is the tendency to maintain items that are easy to maintain rather than those which are important, or those items which are highly visible rather than those which are most prone to failure.

POSITION

Every facility should have documented management programs for maintenance. Maintenance activities may be performed and managed by the facility owner or a contractor. In all cases, means should be provided for monitoring, control and support by top management.

The maintenance program should include the following elements:

- A **written maintenance policy**, which has the unequivocal support of all levels of management including the highest in the organization. The maintenance and inspection department(s) should report directly to top management. If either or both of these functions report to or through production management, there should be an aggressive audit and control program installed by top management to ensure that maintenance schedules are followed and that conflicts are not routinely resolved in favor of production.
- An experienced **maintenance manager**, dedicated to loss prevention, of sufficient stature within the organization to be credible in disputes with production staff, who has authority over all maintenance activities, whether they are performed by maintenance staff, production staff or contractors.
- Detailed **maintenance procedures** describing what is to be maintained, how it is to be maintained, and how often it is to be maintained, including standards to be met and the quality controls to be used. All safety-related and key equipment will have operational, predictive and

preventive maintenance principles applied. The procedures should include restoration of all systems and equipment to a normal lineup. All contracts for maintenance work should require compliance with these procedures.

- A computer-based **maintenance information system**.
- An **impairment program**, similar to the RSVP Impairment Handling program (see *OVERVIEW* Section 1 [PRC.1.1.0]), to control conditions of compromised protection. It should be rigorously followed to ensure notification of management, operating staff and other concerned persons when safety-related components and systems are not in service for maintenance or any other reason. These procedures should include persistent follow-up to ensure that this equipment is restored to service as soon as possible and that appropriate safety precautions are taken in the interim.
- Documented **maintenance personnel training programs**, including specialty and periodic refresher training where appropriate. (See *OVERVIEW* Section 4 [PRC.1.4.0].)
- Maintenance department sign off on new construction and facility modifications to help ensure that maintainability and loss control features are not neglected. (See *OVERVIEW* Section 5 [PRC.1.5.0].)
- Input from the Hazard Identification and Evaluation (see *OVERVIEW* Section 13 [PRC.1.13.0]) to set priorities by identifying critical components and systems and promptly establishing procedures to oversee their integrity.

While by no means a complete list, the maintenance program for any facility should address:

- Maintenance and inspection of fire protection equipment, as outlined in Section 12 of *OVERVIEW* [PRC.1.12.0].
- Jurisdiction-required inspections of boilers, pressure vessels, refrigeration systems and piping.
- Infrared examination, insulation resistance monitoring and trip calibration of electrical equipment.
- Conventional and gas chromatography analysis of transformer and circuit breaker insulating fluids.
- Vibration monitoring for all critical rotating equipment and for any rotating equipment larger than 1000 hp (750 kW).
- Standards for recommissioning of equipment which has been idle.

AXA XL Risk Consulting is convinced that a maintenance program appropriate to a facility will have a sufficient payback in loss prevention and control, however, such benefits are difficult to measure. Installing a proper maintenance program may increase overall maintenance costs for 12 to 18 months, but should substantially reduce them thereafter. Intangible benefits include:

- Improved morale in the work force.
- Better reputation in the community.
- More reliable delivery of product or service.

DISCUSSION

The ultimate objective of a maintenance program is to keep a facility operational. A good maintenance program will employ the techniques of management to prevent losses and to minimize the scope and consequences of those that do occur. Such a program will also minimize maintenance and repair expenses. The distinction is necessary because even facilities that practice “breakdown maintenance,” or operation of equipment to failure, seek to keep equipment on line.

A good maintenance program will reduce costs because it will:

- Anticipate failures, allowing down time to be scheduled when it will cause the least disruption.

- Assess the consequences of failures, allowing maintenance resources to be targeted in a manner to minimize the probability of occurrence of the worst consequences.
- Prevent failures if the consequences are intolerable or more costly than the effort to prevent them.
- Expedite repairs in the most effective way and identify alternate means of production to be used when failures occur. (See *OVERVIEW* Section 7 [PRC.1.7.0].)
- Provide the tools for self-diagnosis and correction where the program is ineffective.

Breakdown Maintenance

Breakdown maintenance refers to the practice of operating until failure occurs. The following characteristics of breakdown maintenance should be considered before selecting it for anything that does not have at least one installed spare:

- Maintenance is scheduled by the machine; maintenance activity will more likely occur on premium time than on straight time.
- Due to machine loading and possibly operator fatigue, breakdowns are most likely when production demands are greatest.
- There is no reason to expect that breakdowns will limit themselves to the capability of the work force. In other words, a staff of any size and collection of skills will almost always be either swamped or looking for work.
- Failure to correct minor and incipient problems often increases the probability of the eventual breakdown being catastrophic.

It is generally not economical to have a program which attempts to prevent all breakdowns of all components of all pieces of equipment in all systems. While most maintenance programs are combinations of preventive and breakdown maintenance, the latter should be confined to parts which are considered expendable and the failure of which will not cause unacceptable consequences or an outage of unacceptable duration.

The determination of expendability is a management decision which involves price, availability, and the consequences of failure. Critical and safety-related components certainly should not be considered expendable. Components whose failure does not cause significant loss or increase the facility's exposure to loss may be considered expendable if management determines that the cost of maintenance exceeds the cost of unscheduled failure. For a meaningful analysis, the costs must include the cost of maintaining a sufficient stock of replacement components and in-process product to cover the expected failure rate.

Preventive Maintenance

The philosophical opposite of breakdown maintenance is preventive maintenance. This is an excellent name, because, in addressing the shortcomings of breakdown maintenance, preventive maintenance prevents, or at least tends to minimize, maintenance. Preventive maintenance tools include operational, planned and predictive maintenance, maintenance records analysis, quality control, pre-emergency planning (*OVERVIEW*, Section 7 [PRC.1.7.0]), and maintenance input into equipment specifications and designs.

Operational Maintenance

Operational maintenance refers to activities performed while equipment is in service. Typical activities include:

- Lubrication.
- Changing duplex filters or strainers.
- Testing alarms and other safety features.
- Tightening loose bolts and joints.
- Vibration monitoring.

- Watching and listening for signs of trouble.

For most equipment, it will include maintaining logs of:

- Important parameters.
- Maintenance and preservation activities.
- Any changes and significant observations.

An effective log program should include:

- Regular gathering of information.
- Collection of enough information for intelligent interpretation.
- Periodic review of data.

Operational maintenance is often the province of the operating staff, however, the logs and records should be subject to review by the maintenance department. Performance of operational maintenance should be verified by audit.

Planned Maintenance

Planned maintenance systems (PMS) are those in which maintenance is scheduled based on elapsed time or on a specific number of operating cycles. Selecting correct intervals between performances of maintenance tasks is critical to the success of the program. If the intervals are too large, breakdown maintenance results. If too small, the shutdown of equipment to replace good parts quickly results in the perception that the program is nothing more than “going through the motions.” Sooner or later, the persons responsible for the tasks will do nothing but “go through the motions,” or worse, feel free to document work not actually performed. Breakdown maintenance will again result.

When intervals in a PMS have been selected, extensions should not be allowed without compelling reasons, supported by sound engineering and based upon analysis of the equipment. Valid support for such an extension might include documenting a careful review of operating parameters to detect any subtle deterioration, an analysis by an outside consultant, or an “on the fly” borescope or other examination of critical areas. Requests for extensions should be documented and require the approval of top management. Production convenience must not be permitted to dictate.

Inspection frequencies should be assigned based upon:

- The importance of equipment and the consequences of its failure.
- Previous inspection results and failure history.
- Service conditions.
- Time in service.
- Jurisdictional requirements.
- Loss prevention company recommendations.

Predictive Maintenance

Predictive maintenance is similar to planned maintenance, however, activities are performed upon the deterioration of a selected parameter rather then upon lapse of time or number of operating cycles (though maximum values must be established). Examples of appropriate parameters are vibration amplitude for rotating machines, differential temperature for heat exchangers, and insulation resistance for electrical windings. Management support for taking the necessary maintenance action whenever the selected value is reached, regardless of the elapsed time, is crucial to the success of a predictive maintenance program.

Both planned and predictive maintenance systems depend upon feedback through a maintenance information system. If the conditions found during maintenance operations are collected and monitored over time, there will be a sound basis for adjustments to maintenance intervals or critical parameter values, increasing the effectiveness of the maintenance program and reducing its cost.

Maintenance Information Systems

A maintenance information system should allow the maintenance manager to gather data that will be used to evaluate all maintenance decisions. It will include equipment failure data which may be fed back to designers or manufacturers, used for process hazard evaluation (see *OVERVIEW* Section 13), or sent to the purchasing department to support changes to specifications or the selection or avoidance of vendors or equipment types.

A computer-based maintenance information system should be installed to provide:

- An easily retrievable historical record for each piece of equipment, group of similar pieces of equipment or system.
- Schedules for the scope and frequency of inspection and service for all equipment.
- A method of persistent follow-up to ensure that inspection and maintenance services are being performed according to schedule.
- A means of assigning priorities to equipment repair or maintenance tasks.
- Specifications for special replacement parts and materials. A list of qualified suppliers for these items should be available by cross-reference.

A computerized information system can easily and routinely focus attention on areas of need by identifying, for each machine, component or group, statistics such as:

- Highest/lowest cost to maintain, overall and per unit.
- Highest/lowest downtime and failure rate.
- Spare parts usage.
- Lost production hours or units.

Analysis of data may reveal various equipment and failure modes which are not preventable by planned or predictive maintenance. Events which occur at random intervals or which give no outwardly measurable symptom prior to failure may, depending upon their consequences, require:

- Process redesign.
- Redundant equipment or containment boundaries.
- Automatic shutdown systems.
- Fixed fire or explosion protection.

Solutions of this nature are also necessary when some components of a facility are demonstrated to require shorter inspection or maintenance intervals than the facility as a whole or various critical operating units. Utility equipment, such as boilers, deaereating feed tanks, transformers and switch gear, well pumps and compressed air systems require careful consideration in this regard, because most of these must operate if any part of the facility is on line.

Contract Maintenance

The arguments for contract maintenance are persuasive. Tasks can be performed by personnel who specialize in them and perhaps do no other work. This is attractive to smaller facilities which cannot keep most specialists busy at their specialties. The arguments against contract maintenance are also persuasive and often emotional. Having vital plant functions performed by outsiders does not appeal to some.

The need for a contract service must be carefully analyzed. The contractor must be carefully selected, considering competence, hiring practices, compatibility, financial responsibility and safety record. All the areas of responsibility of the contractor and of the facility personnel must be clearly specified by the contract, particularly the requirement that the contractor adhere to all facility safety and quality control procedures.

It must be clear from the beginning of negotiations and be constantly reinforced by planned oversight and audit that management is committed to the highest standards of performance and of loss

prevention. In particular, management should retain the right to discipline contractor personnel who violate loss prevention regulations. This should include the right to exclude individuals from the premises and to terminate the contract if violations persist.

For additional information on control of outside contractors, see Appendix B to *OVERVIEW* Section 5 and Appendix C to *OVERVIEW*, Section 11.

Maintenance Quality Control

Failure of equipment shortly after overhaul can give maintenance a bad reputation, reinforcing the erroneous notion that it is always better to let a smoothly running piece of machinery continue to operate than to open it for inspection and risk causing problems. The fact is that properly performed maintenance contributes to reliability.

Just as top management insists upon quality in production, management from the highest level downward should insist upon quality in maintenance. The following should apply to all maintenance, whether performed in house or by contractors:

- Loss prevention is paramount. This requires hot work permits, proper fire protection impairment procedures, and shutdown or additional staffing of operating equipment whose protection is compromised by any activity.
- Maintenance management has the authority to take the time to do the job correctly the first time. It trains its staff in proper practices and insists that they are followed.
- Maintenance activities are performed in accordance with detailed written procedures, updated in response to any problems encountered and to reflect advancements in the state of the art.
- Deviations from written procedures for any reason must have the prior written approval of facility management.
- Access to areas, such as gear and turbine casings, switchgear cabinets, boilers and vessels, is strictly controlled, such that no person, tool or material can enter without being documented in a log to ensure proper disposition. Lanyards are used when appropriate to keep tools from being dropped into inaccessible areas.
- Installation and removal of safety devices, such as valve gags, switch and shaft locks, jacks and wedges used for personnel and equipment protection during maintenance activity, are documented.
- No “design modifications,” such as reinstalling only a fraction of the bolts in a flanged connection, are made without sound and documented engineering analysis.

Maintenance Inspections

Inspections are a necessary part of all maintenance systems. They determine the degree and rate of equipment deterioration. An inspection program, aided by computer analysis, can predict the probable time of failure for most equipment so that prior replacement or repairs can be made. If inspection reveals no deterioration, unnecessary maintenance may be avoided.

The maintenance or inspection department may also provide quality control monitoring of work in progress and oversight of contracted services. This activity should include audits to verify that plant and vendor personnel are adhering to written procedures, corporate standards, jurisdictional requirements, and good engineering practice.

Spare Parts

Efficient performance of most maintenance activities requires a facility to have a stock of spare parts on the premises or otherwise to be readily available. Some parts, such as seals and bearings, regularly require replacement due to normal wear. Other parts, such as valves and small drive motors, are replaced from stock and reconditioned so that the downtime can be minimized. Major machinery units, such as turbines, may require a spare rotating element because the lead time to obtain a replacement is excessive.

Spare parts should be available so that important components or systems that fail will be returned to service as quickly as possible. For other equipment, management of spare parts will depend upon the consequences of failure, and the cost, availability, and lead time for the parts.

The parts should be maintained and should be managed by an inventory control system. The control system should include written procedures for proper storage of large, complex or sensitive parts, such as turbine rotors, electric motors or coils, or electronic modules.