chapter 12
MAINTENANCE

The Future Capable Company must fully understand the scope of physical asset management and the maintenance process. Maintenance for the Future Capable Company combines reliability, predictive maintenance, and preventive maintenance to create high levels of uptime and productivity, anticipate potential problems, and minimize future problems. Maintenance and operations must be integrated and function as a supportive team through improved planning, scheduling, and cooperative team-based continuous improvement efforts.

In many organizations, the maintenance function does not receive proper respect. The naïve perception is that maintenance does not add value to a product, and thus, the best maintenance is the least costly. Armed with this false perception, traditional manufacturing companies have:

- Underemphasized preventive, corrective, and routine maintenance
- Not addressed predictive maintenance and reliability improvement
- Not properly trained maintenance personnel
- Not properly developed effective maintenance leadership

Maintenance is not an insurance policy or a security blanket; it is one of the Requirements of Success for the Future Capable Company. Without effective maintenance, machines and systems will fail. When failure occurs, the following will happen:

- Uncertainty will be the norm. The Requirements of Success state that certainty must be maximized.
- Balance will not be obtainable. The Requirements of Success state that all operations must be balanced.

The Future Capable Company cannot tolerate process failures. To minimize such failures, maintenance must be a top priority.

This chapter stresses the importance of the maintenance process as a profit center and reviews the key requirements for supply chain maintenance success. It examines three of the maintenance best practices (reliability, preventive maintenance, and predictive maintenance) and presents an overview of planning for maintenance excellence.

25 REQUIREMENTS FOR EFFECTIVE MAINTENANCE LEADERSHIP

When a Future Capable Company prepares for continuous improvement, it should include the evaluation and improvement of its current maintenance processes. There are a number of key principles and best practices that are fundamental to continuous improvement. Understanding the following 25 Requirements for Effective Maintenance Leadership should provide measurable benefits for the Future Capable Company's total operation.

1. View maintenance as a priority. The process of performing maintenance and managing physical assets should be a priority in the Future Capable Company. Maintenance should be viewed as another area that contributes directly to the bottom line when a strategy for continuous maintenance improvement is adopted. The Future Capable leader should understand best practices and should have identified priority areas for improvement based upon a total benchmark evaluation of the maintenance operation. Investments should be made to implement best practices.
2. Develop leadership and technical understanding. Maintenance leaders must understand the challenges of maintenance and provide effective maintenance leadership with a vision of continuous maintenance improvement. Maintenance leadership must continually develop the skills, abilities, and attitudes necessary to lead maintenance into the future. They should understand the 25 Requirements for Effective Maintenance Leadership and develop

priorities for action. In addition, they should foster understanding within the organization about maintenance and develop a vision of continuous maintenance improvement shared throughout the organization.

3. Develop PRIDE—People Really Interested in Developing Excellence in maintenance. Maintenance operations in the Future Capable Company should experience fundamental improvements in work ethics, attitude, values, job performance, and customer service to achieve real pride in maintenance excellence. Successful maintenance operations should have leadership that instills PRIDE and creates inspiration, cooperation, and commitment throughout the organization. Tangible savings and improvements should occur as a result of continuous maintenance improvement.
4. Recognize the importance of the maintenance profession. Maintenance should gain greater importance as the role of chief maintenance officer (CMO) becomes established during the early stages of the new millennium. Maintenance leaders should be recognized as critical resources necessary for the success of the total operation. The CMO in large multisite operations should create and promote standard best practices. The complexity and importance of maintenance and physical asset management will continue to grow because new technologies and added responsibilities will require more knowledge and skills.
5. Increase capability of maintenance personnel. A significant upgrade in the level of maintenance personnel should take place to keep pace with new technologies and responsibilities. Successful maintenance operations should continually upgrade the skill level of crafts people through effective recruiting with higher standards and through more effective craft-training programs. Pay increases should be more directly linked to performance and demonstrated competency levels in required craft skills.
6. Initiate craft skills development to enhance human capital. Successful maintenance operations should continually assess craft training needs and provide effective skills development through modern technical learning systems and competency based development of required skills. A complete assessment of craft training needs should be accomplished to identify priority areas for skill development. Skill development should be competency based to

provide demonstrated technical capabilities for each craft skill. The successful maintenance operation should develop an ongoing program for craft skill development. Continuous maintenance education based on modern technical learning systems should be viewed as a sound investment and an important part of continuous maintenance improvement.

7. Develop adaptability and versatility. The maintenance crafts work force should become more versatile and adaptable by gaining value with new technical capabilities and multicraft skills. The development of crafts people with multiple skills should occur to provide greater versatility, adaptability, and capability from the existing workforce. Multiskilled personnel should have added value. Crafts people should become more adaptable, versatile, and valuable as a result of ongoing programs for craft skill development.
8. Promote teamwork as a Future Capable Company strategy. Maintenance staff should be team players and maintain a leadership-driven, team-based approach to continuous maintenance improvement. Maintenance leadership should accept its role as a top-priority operation and should set the example as team players within the organization. The strategy for continuous maintenance improvement should be a leadership-driven, team-based approach that captures the knowledge, skills, and ideas of the entire maintenance work force. Cross-functional teams with representatives from maintenance, operations, and engineering should be formally chartered to address improvements to equipment effectiveness, reliability, and maintainability.
9. Establish effective maintenance planning and scheduling. Customer satisfaction and the utilization of available craft time should improve through more effective planning and scheduling systems. Developing better systems should be a top priority for the Future Capable maintenance operation. As reductions in breakdown repairs occur through effective preventive and/or predictive maintenance, the opportunity to increase planned maintenance work should result. Maintenance and operations should work closely to schedule repairs at the most convenient time. Maintenance should become more customer-oriented and focus on achieving greater customer satisfaction by completing sched-

uled repairs on time. The utilization of craft time should increase as levels of planned work increase and as the uncertainties and inefficiencies associated with breakdown repairs are reduced.

10. Maintenance and manufacturing operations should be a partnership for profits. Maintenance and manufacturing operations should become integrated and function as a supportive team through improved planning, scheduling, and cooperative, team-based improvement efforts. Operations should be viewed as an important internal customer. Improved planning and scheduling of maintenance work should provide greater coordination, support, and service to manufacturing-type operations. Maintenance and manufacturing operations of all types should recognize the benefits of working together as a supportive team to reduce unplanned breakdowns, to increase equipment effectiveness, and to reduce overall maintenance costs. Manufacturing should be viewed as an important internal customer and gain greater understanding of the 25 Requirements of Maintenance Leadership. It should also accept its important partnership role in supporting maintenance excellence.
11. Develop pride in ownership. Equipment operators and maintenance should develop a partnership for maintenance service and prevention and take greater pride in ownership through operator-based maintenance. Equipment operators should assume greater responsibilities for cleaning, lubricating, inspecting, monitoring, and making minor repairs to equipment. Maintenance should provide training support to operators to achieve this transfer of responsibility and help operators with early detection and prevention of maintenance problems. Operators should develop greater pride in ownership of their equipment with their expanded responsibilities.
12. Improve equipment effectiveness. Maintenance and manufacturing operations should use a leadership-driven, team-based approach to totally evaluate, and subsequently improve, all factors related to equipment effectiveness. The goal is to obtain maximum availability of the asset for performing its primary manufacturing function. Continually improving equipment effectiveness should address major losses due to equipment breakdowns, setup/adjustments, idling/minor stoppages, reduced speeds,

process defects, and reduced yields. Reliability Improvement Teams should be established to meet on a regular basis to identify and resolve equipment-related problems. They should work constructively as cross-functional teams to exchange and implement ideas for improving equipment effectiveness. They should use techniques such as Continuous Reliability Improvement (CRI) and Reliability Centered Maintenance (RCM). Chronic problems should be analyzed using tools such as statistical process control, graphs, process charts, and cause-and-effect analysis. Maintenance operations within successful Future Capable Companies should use a total team effort by operators, engineering, operations staff, and maintenance to identify and resolve root causes of equipment problems.

13. Maintenance and Engineering: A partnership for profitable technology application. Maintenance and engineering should work closely together during systems specification, installation, start-up, and operation to provide maintenance with the technical depth required for maintaining all assets and systems. Engineering should provide technical resources and support to ensure maintenance has the technical capability to maintain all equipment and systems. Engineering should support maintenance in improving the effectiveness of existing equipment. Maintenance and engineering should work closely together in developing specifications for new equipment. During installation and start-up, maintenance and engineering should also work closely together to ensure operating specifications are achieved.
14. Continuously improve reliability and maintainability. Machines and systems should be specified, designed, retrofitted, and installed with greater reliability and ease of maintainability. Equipment design should focus on maintainability and reliability, not just performance. Design for maintainability is an accepted philosophy that fully recognizes the high cost of maintenance in the life-cycle of equipment. High life-cycle costs can be reduced by applying good maintainability and reliability principles during design. Identify potential problems before they are designed into the equipment. Equipment design should include a higher level of internal diagnostic capabilities and provide greater use of expert systems for troubleshooting. Maintenance should work closely

with equipment designers to share information about problems with existing equipment. They should provide possible maintenance-prevention solutions during the design and/or specification process for new equipment.

15. Design for modularity. Physical assets and systems should be modularly designed so that failures are quickly identified and repaired. Overall maintainability should be further improved through modular design of physical assets and systems. Highest-failure parts and components should be the most accessible, easily identified, and designed for easy repair. Components should be designed for easy disassembly and reassembly using the lowest skill level possible. Modularity should be an important part of the design.
16. Manage life-cycle cost and obsolescence. The life-cycle costs of physical assets and systems should be closely monitored, evaluated, and managed to reduce total costs. During the equipment's operating life, systems should be developed to continually monitor equipment costs. Information should be available to highlight equipment with high-maintenance costs. A complete history of the equipment's repair costs should help maintenance in deciding on equipment replacement, overhaul/retrofit, and overall condition.
17. Create value-adding redundancy. Critical assets and systems should have backups so that if something fails, a secondary asset or system takes over. Critical operations and constraints to throughput should be identified. Redundancy of critical equipment and systems ensures continuous operation during failure. Maintenance should focus on critical operations to increase equipment effectiveness, reduce unplanned breakdowns, and increase the effectiveness of preventive/predictive maintenance.
18. Minimize uncertainty and eliminate root causes. Uncertainty should be minimized through effective preventive/predictive maintenance programs and through continuous application of modern predictive maintenance technology and expert systems. Effective preventive/predictive maintenance programs should be used to anticipate and predict problems to eliminate uncertainty of unexpected breakdowns and high repair costs. Predictive maintenance should not be limited solely to detecting failure but should proactively identify and eliminate the root causes of chronic

problems. Preventive/predictive maintenance programs should be adequately staffed to cover all major assets within the operation. Maintenance should maintain current technical knowledge and experience for applying a combination of predictive technologies best suited for the specific asset.

19. Maximize use of Computerized Maintenance Management and Enterprise Asset Management. Systems that support the total maintenance operation should improve the quality of maintenance and physical asset management and be integrated with the overall business system of the organization. Computerized Maintenance Management Systems (CMMS) should provide greater levels of manageability to maintenance operations. CMMS should cover the total scope of the maintenance operation and provide the means to improve the overall quality of maintenance management. Enterprise Asset Management (EAM) should provide a broader scope of integrated software to manage physical assets, human resources, and parts inventory in an integrated system for maintenance management, procurement, inventory management, work management, asset performance, and process monitoring. Vast amounts of data associated with maintenance tasks should be computer-controlled and available as key information for planning, scheduling, backlog control, equipment history, parts availability, inventory control, performance measurement, and downtime analysis.
20. Use maintenance information to manage the business of maintenance. The maintenance information system and database should encompass the total maintenance function and provide real-time information to improve maintenance management. Implementing CMMS and EAM provides the opportunity for improved maintenance information systems. With CMMS and EAM, the maintenance information system can be developed and tailored to support maintenance as a true “business operation.” Information to support planning, scheduling, equipment history, preventive/predictive maintenance, and storeroom management can be established to improve decision-making and overall maintenance management. Improved maintenance information should allow for open communication between all departments within the organization. It is important that maintenance become an

integral part of the overall information flow and be kept well-informed about current and future operational plans.

21. Ensure an effective maintenance storeroom operation. The storeroom for Maintenance Repair Operations (MRO) should be orderly, space- and labor-efficient, and responsive and should encourage maintenance excellence. Initial storeroom design or modernization should provide a layout that ensures efficient inventory control and includes maximum loss-control measures. It should be professionally managed and maintained. The trend should be toward larger, centralized storerooms with responsive delivery systems to eliminate crafts people waiting or traveling to get parts. An effective maintenance storeroom catalog should be maintained to provide a permanent cross-reference of all storeroom items and to serve as a tool for identifying and locating items.
22. Establish the spare parts inventory as the cornerstone for effective maintenance. The proper quantity of spare parts should be on hand, as a part of progressive MRO procurement and internal storeroom controls, to support maintenance excellence. The implementation of CMMS and EAM should include an inventory system that supports the requirements of maintenance and the storeroom. Maintenance inventory should be managed to ensure that the right part is available at the right time without excessive inventory levels. Information from all available sources should be used to determine optimum stock levels. Continuously review stock levels to eliminate excess inventory and obsolete parts. Inventory reductions should be achieved through more partnerships with suppliers and vendors who establish joint commitments to purchase based on responsive service and fast delivery. Positions within MRO material management and procurement should increase in their importance and level of technical knowledge to perform effectively.
23. Establish a safe and productive working environment. Successful maintenance operations should be safe, clean, and orderly because good housekeeping is an indicator of maintenance excellence. Maintenance leaders should provide a working environment where safety is a top priority. This in turn, sets an example throughout the organization. Good housekeeping practices in maintenance

provide the basic foundation for safety awareness. Maintenance should provide support throughout the organization to ensure that all work areas are safe, clean, and orderly.

24. Aggressively support compliance with environmental, health, and safety requirements. Maintenance must provide proactive leadership for and support of regulatory compliance actions in the Future Capable Company. U.S.-based maintenance leaders must maintain the technical knowledge and experience to support compliance with all state and federal regulations under OSHA, USEPA, FDA, the U.S. Department of Transportation, and the Americans with Disabilities Act. Non-U.S.-based companies and American businesses operating abroad must comply with all standards of the nation they are operating. Indoor air quality must receive constant attention to eliminate potential problems. Maintenance must work closely with quality and safety and other groups to provide a totally integrated and mutually supportive approach to regulatory compliance.
25. Continuously evaluate, measure, and improve maintenance performance and service. Broad-based measures of maintenance performance and customer service should provide a continuous evaluation of the maintenance program. CMMS and EAM should allow for a broad range of measurement for maintenance performance and service. Investment in maintenance best practices should ensure a valid return on investment. Projected savings should be established, and the results should be validated. Measures should be developed in areas such as labor performance/utilization, compliance to planned repair, and preventive/predictive maintenance schedules, current backlog levels, emergency repair hours, storeroom performance, and asset uptime and availability. Leaders of successful maintenance operations should continuously evaluate performance and service to manage maintenance as a business.

The 25 Requirements for Effective Maintenance Leadership provide the foundation for developing maintenance excellence. An effective maintenance process is essential to the Future Capable Company. It all starts with a total commitment to a strategy of continuous maintenance improvement, with maintenance as a top pri-

ority. That means realizing that maintenance is a key contributor to an organization's profit and that maintenance best practices, plus people, plus MRO assets, plus information technology all combine for the success and improvement of the total maintenance operation.

RELIABILITY

Reliability means focusing on how to improve maintainability and reliability, not on asset performance. This can be accomplished by applying RCM and CRI. The key elements of RCM include:

- Analyzing and deciding what must be done to ensure excellent performance
- Defining the users' expectations for primary performance parameters such as output, throughput, speed, range, and carrying capacity
- Defining what users want in terms of risk, process and operational safety, environmental integrity, quality of output, control, comfort, economy of operation, and customer satisfaction
- Identifying the state of failures, ways that assets can fail, and the consequences of those failures
- Conducting Failure Modes and Effects Analysis (FMEA) to identify all the events likely to cause each failed state
- Identifying a suitable reliability management policy for dealing with each failure mode in light of its consequences

CRI goes well beyond the traditional approaches found in RCM, which focuses primarily on the physical asset. CRI is a total maintenance improvement process that supports the Future Capable Company. To focus the team processes on continuous reliability improvement opportunities, CRI considers the following:

- Physical asset: Use of reliability improvement technologies; reliability-centered maintenance, preventive/predictive maintenance, and knowledge-based expert systems for maintenance of the physical asset. Asset facilitation is used to gain maximum capacity at the lowest possible life-cycle cost.
- MRO material resources: Effective MRO parts, supplies, and materials for quality repair with effective storeroom operations and procurement processes.
- Information resources: Quality information resources for maintenance management and control from CMMS, EAM, ERP,

vendor, and customer.
- Craft resources: Quality craft skill improvements for the people who support customer satisfaction throughout the Future Capable Company.
- Operator resources: The added value of equipment operators instilled with pride in ownership to support maintenance at the most important level—the manufacturing shop floor.
- Synergistic team processes: Leadership-driven groups providing effective teaming that multiplies people assets.

The goal of reliability is not only to reduce failure rates, but also to eliminate root causes of failure. This means identifying a suitable reliability improvement policy that includes two of today's best practices: predictive maintenance and preventive maintenance. The difference between preventive and predictive maintenance is simply the differences between an interval-based system (preventive maintenance) and a condition-based system (predictive maintenance). Management has two basic choices for a maintenance repair strategy:

1. Run to Failure. Continue to operate with a high level of uncertainty by running equipment or operating facilities at required capacity and shutting down only for emergency repairs. Continue to gamble with the costs of maintenance and unexpected downtime.
2. Planned Maintenance with Preventive Maintenance. Reduce the uncertainty of unplanned downtime and emergency repairs with a program of planned inspections, adjustments, lubrications, and testing/monitoring with predictive maintenance tools and techniques.

PREVENTIVE MAINTENANCE (PM)—AN INTERVAL-BASED SYSTEM

PM is an interval-based surveillance method in which periodic inspections are performed on equipment to determine the wear on components and sub-systems. When wear has advanced to a degree that warrants correction, maintenance is performed on the asset. The corrective maintenance can be performed at the time of the inspection or later as part of planned maintenance. The decision depends on the length of shutdown required for the repair.

Consider the impact of shutting down the operation for the repair vs. how immediate the need is for repair. If the worn component allows the asset to operate without major damage, then repairs may be postponed until they can be planned and scheduled. A PM system increases the probability that the equipment should perform as expected without failure until the next inspection.

Determining the interval between inspections requires considering the history of maintenance for the equipment in each unique operation. Ultimately, intervals between PM inspections should be guided by a number of resources. These include manufacturer's recommendations, feedback information from repair history of breakdowns, and the subjective knowledge of the maintenance crafts people and supervisors who maintain the asset on a daily basis. Equipment operators may also be a good source of information in some operations.

A central characteristic of preventive maintenance is that in most major applications, the asset must be shut down for inspection. The inspection process requires a discrete amount of downtime for the asset. The loss of operational time when significant preventive maintenance inspections are made is one of the reasons PM programs are often less than successful. This is especially true in applications where there are few redundant units and equipment must operate at 100 percent of capacity. In some situations the loss from shutdown is considered too high a penalty, and preventive maintenance inspections are resisted. The truth is, that preventive maintenance, when properly applied, unquestionably increases overall equipment availability and is a key contributor to improved reliability.

PREDICTIVE MAINTENANCE (PDM)—A CONDITION-BASED SYSTEM

In contrast to preventive maintenance, predictive maintenance is a condition-based system. PdM measures some output from equipment that is related to the degeneration of the asset, a component, or subsystem. For example, vibration analysis equipment might measure metal fatigue on the face of a rolling element bearing. As deterioration progresses, the amplitude of vibration increases. At some critical value, the vibration analyzer concludes that corrective action should be taken to avoid catastrophic failure.

Predictive maintenance usually permits discrete measurements,

which may be compared with some predefined limit (baseline) or tracked using statistical control charting. When an anomaly is observed, warning is provided in sufficient time to analyze the nature of the problem and take corrective action to avoid failure. Thus, predictive maintenance contributes to the same central objective for increased reliability. With early detection of wear, you can plan for and take corrective action to retard the rate of wear, prevent or minimize the impact of failure, and predict failure. The corrective maintenance restores the component or sub-assembly, and the asset operates with a greater probability of trouble-free performance.

The enhanced ability to trend and plot numbers collected from PdM measurements gives this method greater sensitivity than traditional preventive maintenance methods. The technique yields earlier warning of severe wear and thus provides greater lead-time for maintenance to react. Corrective actions may be scheduled so that they have minimum impact on operations.

A principal advantage of predictive maintenance is the capability it offers the user to perform inspections while the equipment is operating. In fact, in order to reflect routine operating conditions, the technique requires taking measurements when the equipment is normally loaded in its production environment. Since the machine does not need to be removed from the production cycle, there is no shutdown penalty.

The nature of the operation should determine which methods are most effective. In practice, it takes some combination of preventive and PdM to assure maximum reliability. How much of each should vary with the type of equipment and the percent of the time these machines are operating. When comparing the cost advantages of PdM over PM, consider production downtime costs, maintenance labor costs, maintenance materials costs, and the cost of holding spare parts in inventory.

PLANNING FOR MAINTENANCE EXCELLENCE

Planning for maintenance excellence requires planning at both the strategic level and at the shop-floor level. Without effective planning and scheduling, maintenance operations continue to operate in a reactive, fire-fighting mode that wastes their most valuable resource—

craft time. Gambling with maintenance costs is not an option for Future Capable Companies. A world-class operation requires a world-class maintenance program. Effective planning and scheduling of valuable craft skills and labor resources is an essential best practice in the Future Capable Company's plan of action.

The ultimate success of maintenance planning and scheduling should be determined by whether or not the customer is satisfied. All preliminary work to develop a plan and to coordinate the scheduled repairs is wasted if execution of the schedule does not occur. The customer (operations) should determine the true success of the planning process. The entire maintenance workforce must understand how they serve operations. As a formal planning process is implemented, an increased focus on customer satisfaction must be established. Operations should expect improved satisfaction, and maintenance must commit to providing it.

Effective planning and scheduling also requires that reasonable estimates and planning times be established for as much maintenance work as possible. Planning times provide a number of benefits for the planning function. They provide a means to determine existing workloads for scheduling by craft areas and the backlog of work in each area. They allow the maintenance planner to balance repair priorities against available craft hours and to realistically establish repair schedules that can be accomplished as promised. Planning times also provide a target for each planned job, and that, in turn, allows for craft performance measurement.

With an understanding of best practices such as reliability, preventive and predictive maintenance, and maintenance planning, the CEO or CMO of a Future Capable Company should be well equipped for the future. Application of the 25 Requirements for Maintenance Leadership and implementation of the following six-step plan of action should ensure success of maintenance and the total operation:

- Evaluate the current state of maintenance
- Determine strengths and weaknesses
- Determine potential results from improvement opportunities
- Develop and implement a strategic maintenance plan
- Validate results and return on investment
- Continually improve reliability

SUMMARY AND CALL TO ACTION

The Future Capable Company has a firm understanding of the physical asset management and maintenance process and its important role. It recognizes the contribution of maintenance to Total Operations' success and profitability. Effective maintenance and physical asset management are closely linked to enterprise-wide performance success and profitability.

The 25 Requirements for Maintenance Leadership provide the foundation for the maintenance strategy, which is part of overall business planning. Today's best maintenance practices are being used within Future Capable Companies. The results of continuous maintenance improvement are being measured, and the results and ROI are being continuously validated.

Maintenance is forever. To meet the Maintenance Requirements of Success, the Future Capable Company must recognize that maintenance is a key contributor to total supply chain success.