Maintenance Management for Water Utilities

James K. Jordan

Third Edition

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Preface

Success in any project requires careful planning, design, implementation, and monitoring. Establishing an effective maintenance program is no different. Many significant advances have been made in recent years in maintenance management systems, including the introduction of a number of software packages that simplify the task of designing a good maintenance operation and the application of geographic information system and global positioning system (GIS/GPS) technology to facilitate the location of plant equipment and distribution system components. Still, the fundamental requirements for establishing an effective program remain the same. A maintenance manager who initiates a project to establish or improve a program must:

1. Develop a clear statement of the scope of the work with cost estimates.
2. Sell the merits of the project to senior management.
3. Carefully design the program to include all necessary elements, including planning for future expansion.
4. Solicit the cooperation and recommendations of upper management, operations personnel, and field maintenance technicians.
5. Develop an implementation plan and schedule.
6. Plan techniques for monitoring and reviewing the program after implementation.

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The establishment or improvement of a maintenance program must be a high priority for any maintenance manager. The benefits to a water utility of an effective maintenance program are well established, and senior managers generally support implementing improved programs for maintenance. The maintenance manager and staff are key members of a utility staff who contribute to the effective operation of a water utility by ensuring that equipment runs smoothly and facilities and grounds are safe and functional workspaces.

This book was prepared to provide guidelines to help water utility maintenance managers develop and analyze their maintenance management programs. The text systematically covers the primary components of effective maintenance management and suggests actions that a maintenance manager can take to improve the operation of the maintenance section.

While this book continues to emphasize the importance of performing preventive maintenance and of carefully planning new and modified maintenance systems, this edition introduces newer concepts involving the use of GPS technology and asset management. In particular, the application of computer technology has expanded from generating and tracking work to integrating maintenance data with the utility's financial and inventory systems. The use of the Internet to provide training for maintenance staff is also introduced as an additional resource for maintenance managers to consider.

The author thanks manuscript reviewers Kenneth C. Morgan, PE, Water Distribution Superintendent, City of Phoenix, Ariz.; and Robert Garcia, City of Peoria, Ariz. The author also wishes to acknowledge the important contribution that maintenance managers and technicians make to the success of their water utility. This acknowledgment extends to those operations staff, particularly in smaller water utilities, who perform many of the maintenance tasks that are essential for the efficient operation of a water utility.

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CHAPTER 1

The Need for Maintenance

When a piece of equipment is first placed in service, it generally operates near its maximum efficiency. For example, a new automobile, assembled with new parts, is at its operating peak, with the engine running smoothly and according to the specifications of the designers and manufacturers. The shock absorbers, springs, and tires produce the best ride that the vehicle is capable of delivering.

The same principle applies to a water pumpset and its auxiliary equipment. Assuming proper design, construction, and installation, the volume of water pumped immediately after a system has been commissioned is at or near its design capacity. This principle holds true whether the equipment for transmitting the water is a hand pump located in a village or farm or a 50-mgd centrifugal pumpset providing water to a large community.

Also, of course, all equipment with moving parts eventually wears and must be replaced. The owner of the car, the farm with the hand pump, and the utility using large-capacity pumping equipment all must recognize this fact and develop plans to correct inevitable equipment wear.

A water utility is among the most capital intensive of all utilities. A utility of any size must allocate sufficient resources to perform those maintenance functions needed to protect its investment in equipment. In larger utilities, a separate maintenance group is usually required;

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for smaller utilities, staff, for example, plant operators, may perform all duties critical to the operation and maintenance of the system. Only through effective maintenance management can a utility fulfill its responsibility to provide high-quality water to the community it serves.

Role of the Maintenance Department

A water utility's primary function is to provide safe, high-quality water to its customers in sufficient quantities and at a reasonable cost. The performance of the utility's maintenance department plays a key role in the success of this endeavor. In general, the maintenance group provides support services to other departments within the organization. Maintenance is responsible for keeping the equipment, vehicles, and structures of the utility in good operating condition. The services provided by maintenance personnel range from routine tasks such as replacing light bulbs to critical ones such as repairing equipment necessary for production of finished water. Whatever the nature of the work, efficient completion of these tasks requires a planned approach.

Responsibilities

The specific responsibilities of the maintenance group include the following:

- Repairs to equipment, vehicles, distribution system components, and buildings—planning and executing repairs to restore the equipment and structures to acceptable standards
- Preventive maintenance (PM)—developing and implementing a program of regularly scheduled work designed to maintain equipment operation and prevent major problems. In addition, predictive maintenance techniques are now standard procedure in many water utilities
- Communications—developing methods to keep operations personnel, upper management, and other departments aware of maintenance activities
- Budget—preparing realistic budgets detailing labor and material needs

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- Inventory—ensuring that the parts and material necessary to perform maintenance tasks are available and can be accounted for
- Supervision—developing techniques for monitoring the activities of maintenance personnel
- Training—providing opportunities for both supervisory and field personnel to improve their skills and performance
- Safety—developing safety education programs for maintenance personnel and implementing techniques to improve the safety of the workplace
- Contract management—preparing contract specifications and inspecting the work of independent contractors to ensure compliance with requirements
- Construction—reviewing plans for new facilities and installation of new equipment
- Record keeping—maintaining up-to-date information on equipment and plant services, including files containing operations and maintenance (O&M) manuals and water system plans

The facilities maintenance department of a water utility bears major responsibility for ensuring the efficient and reliable delivery of water. To fulfill this responsibility, the maintenance department must develop and implement a maintenance management program consistent with the needs of the utility.

Maintenance Department Management

The prevailing image of "seat-of-the-pants" management in the maintenance department is changing. The rising cost of equipment, spare parts, and supplies along with the increasing complexity of contemporary water treatment processes have drawn the attention of upper management to the operation of the maintenance department. Consistent equipment reliability and cost control require a maintenance manager who combines professional skills in both technical and financial fields with people management abilities. Increasingly, water utility managers are learning that the head of maintenance must possess both technical and managerial skills.

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Advances in Maintenance Management

A number of significant advances have been made in maintenance management in the last thirty years. The most important of these is the use of personal computers to schedule and track maintenance work. The new tools have made the manager's job easier by gathering information that has never been so readily accessible. At the same time, the availability of a large number of techniques requires careful selection to find the proper alternatives for the facility over both the short and long terms.

The role of maintenance technician is also changing. The task of maintaining large, complex equipment requires extensive knowledge of troubleshooting and repair methods. There is increasing emphasis on the importance of the first-line maintenance supervisor, who must be able to effectively use the skills of the technicians.

Recently, maintenance departments have added new members to their teams: the professionals responsible for the development, implementation, and maintenance of information systems. The advent of packaged information systems coupled with increasing demands by upper management for timely, accurate data on maintenance activities have resulted in the need for staff who can troubleshoot basic software problems, develop reports from computer-generated data, and communicate effectively with companies offering MMS-related software and hardware.

A key responsibility of the maintenance manager is to determine what data to gather and how to accomplish this task.

Maintenance Management Information Systems

The term *maintenance management information system* (MMIS) is generally used to describe a program designed to schedule, assign, and track maintenance tasks. The program can also be structured to provide information on other aspects of maintenance activities, such as inventory and budget control. An MMIS may use either manual methods or computers, making it a computerized maintenance management system (CMMS). In fact, a maintenance department may use several different information systems to control its operations. Some water utility programs process information entirely manually, while

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others involve visual aids such as schedule boards. CMMSs can be programmed for use in mainframe or personal computers.

The development of numerous packaged programs has brought computer-assisted information systems within the reach of almost any water utility in North America. The significant developments in information gathering, processing, and reporting justify a full chapter, chapter 4, on this component of maintenance operations.

Relationship Between Operations and Maintenance

Although the maintenance department interacts with virtually all other personnel in the water utility, the relationship between operations staff and maintenance staff is a particularly close one. Operations and maintenance are frequently considered a single function (O&M), and operations personnel frequently perform minor maintenance tasks as part of their regular duties. The two staff groups are strongly dependent on each other, but they differ substantially in their objectives.

In general, *operations* is defined as a series of actions by operators to make equipment and systems do the work they are intended to do. This process includes, for example, operating water pumps, opening valves, and backwashing filters. In a water utility, operations is usually associated with activities related to the processing and delivery of water.

Maintenance is defined as a series of activities intended to ensure that equipment, systems, and facilities are able to perform as intended or to provide an environment conducive to effective work. Examples are troubleshooting electrical gear, repairing and replacing components of a water pump, repairing a water main break, and repainting a room.

General Maintenance Functions

The maintenance department takes care of all equipment and facilities necessary to effectively serve the water utility's customers. However, system components require specialized maintenance activities that balance the use of available resources for reacting to problems after they occur with those for preventive measures. Maintenance managers must be aware of varying approaches to maintenance and how they affect the strategy for maintaining the water utility's components.

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The activities carried out by the maintenance department are divided into three categories: preventive (including predictive), corrective, and breakdown maintenance.

- *Preventive maintenance* (PM) actions are performed on a regular schedule to keep equipment or structures operating effectively and to minimize unforeseen failures. These actions consist of inspections and/or maintenance tasks.
- *Corrective maintenance* (CM) actions are taken to either repair or restore malfunctioning equipment or structures to effective operating condition through either scheduled or unscheduled work. These actions may result from problems discovered during PM or as a result of failures during operation. CM actions are scheduled if they can be carried out as part of the normal work plan. They are unscheduled if immediate intervention is needed to correct a fault, a process often called emergency maintenance.
- *Breakdown maintenance* actions differ from CM in that preventive measures are minimized or entirely omitted. Actions are taken to repair or restore equipment or structures to effective operating condition only after they fail to operate. Any maintenance manager who recognizes this type of maintenance as a normal mode of operation needs to consider the methods of maintenance management detailed in this book.

These three maintenance methods differ with respect to handling maintenance of equipment, pipelines, and facilities, depending on cost factors; availability of practical methods to assess maintenance needs; and the importance of the equipment or structure needing maintenance.

Balancing Maintenance Requirements

A large utility's maintenance department is frequently organized into four sections to accommodate different O&M requirements:

- Electrical and mechanical (E/M) equipment maintenance
- Distribution system maintenance

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- Building and grounds (B&G) maintenance
- Vehicle maintenance

A particular water utility's maintenance function may, of course, be structured in another manner, but all utilities need to recognize that physical structures and equipment do have different maintenance characteristics and requirements.

Electrical and Mechanical Equipment

E/M equipment consists of all of equipment operated electrically, mechanically, or pneumatically to draw water from the utility's source and deliver it from the discharge point(s) of the utility's treatment works. Also included are similar components at booster pumping stations and water storage facilities. Depending on the size and complexity of the operation, maintenance may be required, for example, on pumps for source water and finished water; chemical-feed equipment; flocculation, sedimentation, and filtration units; process instrumentation devices (such as flowmeters and other telemetry components); and transformers, motor control centers, and protective relays.

Since E/M equipment incorporates a multitude of moving parts (e.g., bearings and contacts) subject to wear, it requires effective PM for reliable and economical operation of treatment plants and pumping stations. However, PM is not cost-effective for all E/M equipment—some equipment is generally operated until it fails. For example, unless a fractional horsepower motor is driving a critical piece of equipment, PM for it is probably not cost-effective. The motor will be replaced when it fails. Even under a good PM program, other equipment will fail on occasion simply because of faulty components. Thus, provision for CM must be made in the work schedule. An effective PM program will cover 70–80 percent of maintenance for E/M equipment.

Distribution Network

Transmission and distribution mains together with lateral connections to individual customer facilities constitute the distribution network. The pipelines that transmit water from the treatment works to the consumer are included in this category. Also included are the valves that control the flow of water in the pipeline, such as those used to reduce system

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pressure or to isolate sections of the network for repair. Consumer water meters and fire hydrants are also distribution components.

Increasingly, sensing and transmitting devices are being installed in pipelines to monitor water quality, to detect breaks, and for other purposes. This places additional responsibilities on the instrumentation maintenance group. For example, the city of Ann Arbor, Mich., installed and tested an online monitoring system that involved several types of devices that would effectively detect the release of chemical contaminants or biological agents into the distribution system. The utility's maintenance department would likely be charged with the responsibility for maintaining this new equipment (Skadsen et al. 2008).

Nevertheless, the maintenance of pipelines is primarily a reactive process. Maintenance crews must be available to respond to water line breaks, valve leaks, and reports from customers of nonavailability of water. These same crews are also responsible for flushing fire hydrants in the case of cloudy or other water quality issues. These types of tasks constitute the bulk of distribution network maintenance, approximately 75 percent of them handled as corrective maintenance. This section of the department can, however, carry out some regular, scheduled maintenance work, including exercising valves, testing fire hydrants, and controlling leaks in the system. Programs for cleaning and relining pipelines may also be the responsibility of this group.

Building and Grounds

Maintenance activities involving the utility's B&G include renovations requiring carpentry, painting, and masonry work, planning and execution of building modifications, as well as groundskeeping and general housekeeping.

Very little of the work carried out by this section is unscheduled CM. Generally, only responses to problems related to safety or security issues fall outside of planned work. Responding to conditions caused by weather may also be the responsibility of this group. Maintenance of the utility's grounds is a regularly scheduled activity, depending on seasonal conditions; it can be described (loosely) as PM. Facility housekeeping is handled in a similar manner.

Aesthetic upgrades to buildings (e.g., painting and flooring replacement) are also scheduled work, though the intervals between such activities are measured in years rather than weeks or months.

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The B&G group may also be responsible for relocating personnel within the utility when work assignments change and when the facility is modified because of reorganization, expansion, or other reasons. This type of work should be planned, but its occurrence can usually be predicted only a few weeks, or possibly months, in advance. Many utilities contract with outside firms to handle this type of work.

Vehicle Maintenance

Servicing automobiles, trucks, and specialized mobile equipment (e.g., cranes and backhoes) is the responsibility of the vehicle maintenance section. Vehicle maintenance is a vital component of effective utility O&M activities, but it requires a separate publication. Therefore, this subject will not be covered in this book.

Summary

Maintenance managers and personnel must recognize that structures and equipment require different approaches for well-organized maintenance. Staffing, record keeping, budgeting, work monitoring, and other functions are affected by differences in maintenance requirements among the electrical/mechanical, distribution, buildings and grounds, and vehicle maintenance sections. Analysis of the organizational requirements for a water utility's maintenance department is the first step in establishing an effective maintenance management system.

Reference

Skadsen, J., R. Janke, W. Grayman, W. Samuels, M. Tenbroek, B. Steglitz, and S. Bahl. 2008. Distribution system on-line monitoring for detecting contamination and water quality changes. *Journal AWWA,* 100(7):81–94.

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CHAPTER 2

Organization of the Utility

Before investigating the organization of the maintenance group, it is important to understand that this group does not stand alone in a water utility. To make maintenance programs a success, maintenance personnel must interact with personnel from all other departments within the utility.

Organization-Wide Involvement in a Maintenance Program

To appreciate the importance of this concept, it is instructive to review the key elements of an effective maintenance program and note the participation of other groups within the utility.

Institutional Support

Senior management's active support is an essential element of an effective maintenance management program. The *Journal AWWA* has been carrying, for several years, articles in which this important point is highlighted (see, e.g., Jordan 1987). This support extends beyond allocation of adequate funds for maintenance. Participation often includes reading and reacting to management reports on maintenance activities. Visits to maintenance sites by senior managers can also signal the value given to this function. Such support must come from all levels of

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management, including the utility's top managers. Failure to provide such support will almost certainly result in an ineffective maintenance management system.

Maintenance Organization and Management

Skilled maintenance personnel are a must for the effective maintenance of equipment and structures. Well-defined staff responsibilities and access to maintenance tools are other requirements.

Spare Parts and Supplies

An effective inventory control system is essential for efficient maintenance. Because another department usually handles inventory, efficient purchasing and inventory management requires close coordination between the departments concerned.

Logistics

Staff members must ensure that vehicles and structures required by the maintenance department are available. Coordinated activities can guarantee provision of vehicles selected to carry out particular maintenance functions and workshops equipped for preventive maintenance (PM) and corrective maintenance (CM) work.

Finance

The funds needed to support the maintenance program, particularly PM, are frequently the first targets of a utility anxious to reduce costs. While maintenance management must be a cost-conscious function, significant cuts in funding for maintenance usually result in increased equipment downtime, and in the long term, more costly maintenance and utility operations.

Records

Up-to-date and accurate records must be kept for all water utility maintenance operations. The type of system determines the types and number of records that are kept and reports that are developed.

Human Resources and Training

The continuing development of skills through training is an essential element for a successful maintenance program. Management and

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technical training are provided through close coordination with the utility's training group.

Comprehensive Organization for Maintenance

A review of these key elements reveals the extent to which the maintenance department must rely on other groups within the utility. Departments responsible for purchasing, budgeting, information management, transportation, and other functions play key roles in a well-run maintenance department. Some are more closely allied with maintenance than others, and varying relationships require that maintenance personnel make special efforts to ensure that mutual goals are achieved.

Effective Organization Models

Clearly, the maintenance department requires numerous resources to carry out its function effectively, including spare parts, transportation, and tools. However, the most important resource of the department is its personnel, who have the responsibility to maintain the utility's equipment and structures. If maintenance personnel lack the knowledge and skills needed to plan and execute their duties, the other resources available to them will be poorly used at best; at worst, improper use of resources can result in serious interruptions in water processing and delivery. Equally important, a utility must organize and locate maintenance department personnel in a manner that reflects their function. For example, some electrical/mechanical (E/M) maintenance personnel should be stationed at plant sites, while the group responsible for pipeline and valve maintenance should be located nearer to the central point of the distribution system.

Decisions on two other important issues must precede planning for the size and type of organization and the locations of maintenance personnel:

1. The role of operations personnel in the maintenance function
2. The amount and type of work assigned to private contractors

These issues will be addressed later in this chapter.

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Organization of Large Water Utilities

A water utility may be considered large because it either operates in a large service area or operates a large facility (e.g., 70 mgd), or both.

Generally, separate divisions or departments are organized to handle the maintenance of the distribution system—systems maintenance—and the maintenance of plant and office structures—electrical and mechanical maintenance. These divisions are shown in the organization chart in Figure 2-1. This structure is necessary because the types of maintenance skills required by the field staff are quite different. Systems maintenance staff is, for example, frequently required to excavate and repair damaged pipelines and valves, whereas E/M staff is called upon to repair equipment and monitoring/recording/transmitting devices. In addition, some organizations combine their E/M groups into a single division, with the field staff performing both functions.

Building and grounds staff also report to the maintenance department. Maintenance departments require the services of one additional division not shown in the chart: purchasing and receiving. This group has the responsibility for purchasing, receiving, inventory control, and warehousing, all of which are vital components of a successful maintenance management program.

Division/Section Level. The systems maintenance division, particularly in utilities with large service areas, needs to be decentralized to reduce the travel time to job sites because most of its work is performed in response to emergency situations, for example, broken water mains. Generally, this division establishes a separate group within its organization to receive, process, and track requests for work. The term *maintenance management* is often applied to this group. This effort is an essential step in the development and implementation of a maintenance management information system for automated monitoring of tasks carried out by the division.

The electrical, mechanical, and instrumentation sections provide services to filtration plants, pumping stations, and other sites. As seen in chapter 1, on-site monitoring of distribution systems will require the instrumentation staff to maintain various telemetry devices. As shown in Figure 2-2, the electrical maintenance division consists of three sections: instrumentation, plant electrical, and off-site electrical.

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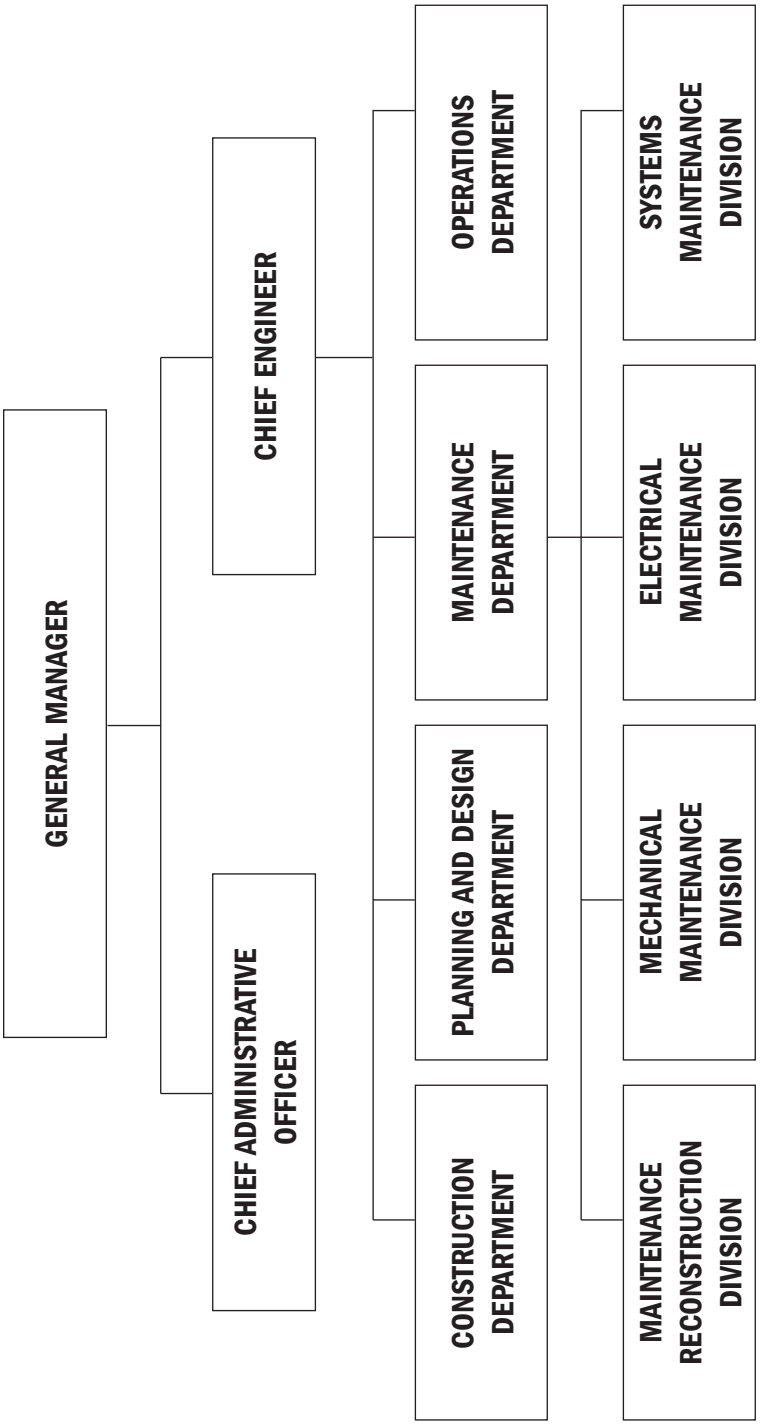

Figure 2-1 Sample large water utility—general manager/chief engineer's office/ technical departments

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Field personnel likely to be stationed at either a plant or an off-site office include the following:

- Supervisor
- Electrician
- Mechanic
- Electrical and mechanical helpers
- Instrument technician
- Inventory clerk
- Planner/scheduler

Other Maintenance Organizations

Other water utilities have organized their maintenance groups in different but equally successful ways. Two perspectives seem to determine how a maintenance organization is structured.

1. Management may believe that the maintenance group, particularly personnel responsible for equipment maintenance, should be directly controlled by the plant superintendent of the water treatment facility. In this case, responsibility for plant operations, including maintenance, will be decentralized to the lowest practical management level.
2. The size of the utility is an important consideration. A utility with a relatively small service area, operating a single treatment plant, usually finds that the most cost-effective and manageable structure is to align all maintenance functions under the authority of the plant manager. This arrangement includes building and distribution system maintenance as well as that for E/M equipment. As noted earlier, larger utilities may find it more efficient to have a separate distribution system maintenance group.

Maintenance Personnel

A water utility's maintenance department needs personnel with a variety of skills. Among the maintenance manager's most important responsibilities is to properly identify the department's personnel needs and to create an environment in which competent people are selected

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Figure 2-2 Sample maintenance organization—division/section levels

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for all maintenance positions and then adequately rewarded for good performance. The *Journal AWWA* devoted a significant portion of its August 2008 edition to presenting various aspects of the importance of employing, training, and retaining good staff in the years ahead. The issues raised by these articles apply particularly well to the utility's operations and maintenance (O&M) staff (Isbell et al. 2008, Blankenship and Brueck 2008, Roy 2008). The general theme of these articles is that water utility workforces are aging and what steps can be taken to cope with this issue. Specific topics and advice included:

- Recruiting great employees
- Retaining employees
- Alternatives to employee retirement, e.g. reduction in hours worked
- Planning for knowledge retention
- Learning and training about the organization's best practices

Supervisory Staff

The maintenance department of a typical water utility with multiple plants will require several levels of management for effective operation. These levels will range from the maintenance managers responsible for the different types of activities described earlier in the handbook to regional maintenance supervisors and crew leaders. In the example given earlier, the highest level of management overseeing all maintenance work is in the maintenance department.

Functional Maintenance Manager. The responsibilities of the functional maintenance manager (e.g., the head of the electrical section in Figure 2-2) include:

- Establishing effective PM, predictive maintenance (PDM), and CM programs
- Supervising regional maintenance supervisors
- Preparing and monitoring budgets
- Determining proper staffing levels for regional sites
- Monitoring personnel and program effectiveness
- Developing and implementing new programs
- Developing effective maintenance information systems
- Applying and monitoring personnel policies and procedures
- Informing senior management of group progress and problems

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In general, managers at this level must maximize the effective utilization of personnel and physical resources.

Regional Manager. The regional managers, on the other hand, are generally not involved in specific maintenance tasks. Instead, they provide hands-on direction to the field crews assigned to the regional office. This role involves implementing maintenance programs by

- preparing work schedules;
- assessing the effectiveness of crews;
- ensuring that spare parts, materials, and transport are available;
- interacting with other utility organizations, particularly with operations personnel; and
- ensuring compliance with safety programs.

Crew Leaders. The crew leader plans the work of other crew members. Depending on the number of subordinate personnel and the work procedures of the organization, the crew leader may participate in the work of the crew. The leader is likely to be a working member if the crew has only two or three members. For larger crews, the primary responsibility of the crew leader is to organize work to achieve maximum productivity. This leaves little time for physical work.

Field Staff

The field staff required to maintain water utility resources range from equipment operators (e.g., backhoe operators) to painters and electricians. The amount of experience and training needed by a maintenance person may vary from minimal experience with common tools to an extensive background in the field. The primary responsibilities of field staff include:

- Carrying out assigned duties in a professional manner
- Completing all required paperwork
- Reporting any operational problems, including any that do not directly affect their units
- Communicating regularly with their immediate supervisors
- Following work rules

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Technical Support Staff

A large utility typically employs an engineering staff attached to the maintenance group, particularly for functions involving design and construction activities. Engineers who work in equipment maintenance need expertise in troubleshooting operational problems. They also must review design drawings for new construction with a view to ease of maintenance after the equipment is placed in service. In some cases, they assume responsibility for executing small projects as construction managers. Using information on the history, location, and type of water main breaks and their own experience, the engineers working on distribution system maintenance can provide valuable insight on the need for replacement or relining in analyzing stretches of pipeline.

In any case, the maintenance manager must justify the level of engineering support that the maintenance group needs and determine whether the work warrants full-time engineer positions or reliance on other sources. For example, a consulting firm may complete the engineering required for a particular job more cost-effectively than a technical staff could do it. This situation is likely to arise in small utilities and for work requiring specialized technical skills.

Nontechnical Support Staff

Maintenance departments have only recently added some of the personnel in this category. While maintenance organizations frequently include stockroom clerks, and possibly, work order clerks, the data entry clerk has become a regular member of staff. The introduction of automated information systems has placed new demands on maintenance managers, who must now balance the advantages of access to previously unavailable information with the cost of the equipment (e.g., computers) and particularly the personnel to operate this equipment.

This issue will arise again later in this book, but it clearly indicates the need for new skills on the part of the manager. These duties may involve investigating and possibly communicating the need for new support staff.

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Maintenance Personnel Policies

The multitude of personnel needed to staff the maintenance department points to the need for clearly stated rules and regulations with respect to personnel.

General Principles

Since staff members play such an essential role in carrying out a successful maintenance management program, a maintenance manager should view the utility's human resources department as a valuable contact within the organization. Clear and comprehensive rules and regulations are essential for effective management of staff. In general, employees need to understand

- their specific job responsibilities,
- how their performance will be judged,
- what opportunities are available for advancement,
- rules of conduct, and
- the overall goals and objectives of their system.

Job Descriptions

Job descriptions must be prepared for all members of the maintenance team. These documents inform personnel about their particular duties and provide a basis for annual performance evaluations.

Job descriptions, such as the one shown in Figure 2-3 for an electrical mechanic, also denote the skills and experience needed by an employee in order to be eligible for promotion or lateral transfer to the position.

Promotion Policies

Water utilities, along with most other organizations, accept the value of filling higher-level positions from within their organizations. However, in some cases, the type of individual needed to fill a particular position is not available within the utility, creating a need for recruitment from outside. These situations underscore the value of a well-written promotion policy. The maintenance manager will gain substantial benefits by working with counterparts in the human resources office to verify the terms of a promotion policy that satisfies the needs of the maintenance department. Maintenance staff must receive copies of the policy.

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Electrical/Mechanic Journeyman

GENERAL STATEMENT OF DUTIES: Performs journeyman-level electrical/mechanical (E/M) tasks in a wide variety of maintenance activities, does related work as required. DISTINGUISHING FEATURES OF THE CLASS: An electrical mechanic is responsible for performing assigned tasks in accordance with standard practices of the electrical/mechanical trade at a journeyman level, but is not as well versed in electrical theory and practices as the electrical/mechanical technician. Working conditions include inside and outside work in inclement weather, climbing ladders and scaffolding, and descending underground, as well as exposure to the hazards of high-voltage electrical shock. Work is performed independently, or for more difficult work, under the general supervision of a lead electrical mechanic or electrical/mechanical technician with inspection upon completion for quality of work.

EXAMPLES OF WORK: (illustrative only) Diagnoses and makes repairs on electric motors and other electrical equipment; inspects and tests various electrical/mechanical units; maintains various electrical and mechanical equipment in the buildings, plants, dam sites, and pumping stations; disassembles and repairs a wide variety of pumps, generators, heating and air conditioning units, telemetering devices, and other equipment; assists an electrical/mechanical technician in installing and repairing high-voltage electrical power supplies, transformers, motor controls, and related repair operations.

REQUIRED KNOWLEDGE, SKILLS, AND ABILITIES: Good knowledge of the practices, methods, tools, materials, and equipment of the electrical mechanic's trade; good knowledge of the occupational hazards of the trade and of necessary safety precautions; some knowledge of electronic and mechanical theory; ability to locate and correct defects in electrical and mechanical systems and equipment; ability to acquire a working knowledge of blueprints and schematics; ability to understand and follow oral and written instructions; good physical condition.

ACCEPTABLE EXPERIENCE AND TRAINING: Considerable experience in electrical/mechanical maintenance work at the level of electrical mechanic apprentice, or its equivalent, with completion of technical courses in basic electricity and blueprints and schematics or any equivalent combination of skills and training that provides the required knowledge, skills, and abilities.

ADDITIONAL REQUIREMENTS: Possession of a valid state driver's license

Figure 2-3 Example job description: Electrical/mechanical journeyman

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Disciplinary Policies and Safety Rules

Similarly, a utility must prepare a written policy detailing actions to be taken if an employee violates its rules and regulations with respect to conduct on the job, safety, and attendance. Again, a maintenance manager will be in a better position to resolve conflicts related to these areas if the utility's policies are clearly stated in writing. Because of the inherent danger associated with some maintenance tasks (e.g., electrical work), the manager may need to formulate additional safety rules for maintenance personnel. Certainly, all safety rules must be logical, and they must be strictly enforced.

Employee Evaluations

Most water utilities require that each employee undergo an annual evaluation of job performance. A conscientiously implemented evaluation program can be a valuable tool for informing an employee of supervisors' impressions of performance.

However, the annual evaluation is not an end in itself. The practice can even lead to problems if not properly applied. For instance, field personnel promoted to supervisory roles must be trained to work with and evaluate subordinates. Poorly conceived evaluations can cause serious morale problems and hamper the effectiveness of the entire maintenance system. Additionally, annual evaluations should not substitute for routine monitoring of an employee's performance. In this way, the maintenance manager can avoid confrontations with employees who are frustrated and unhappy with annual evaluations, because they were not told earlier about perceptions of unsatisfactory work. One approach to counteract this problem is to schedule quarterly or semiannual meetings with each employee to review strengths and problems. These informal meetings should address any problems and acknowledge any significant contributions the employee has made to the maintenance effort.

Maintenance by Operations Personnel

The role of each person on the maintenance staff must be clearly defined to avoid duplication of effort, and more importantly, to avoid overlooking necessary tasks. For similar reasons, the operations staff must understand its role with respect to the maintenance function.

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Role of the Water Plant Operator

The maintenance function of the equipment operator can range from very little work—strictly starting and stopping pumps and motors and recording operating data—to high levels of equipment maintenance. The water plant operator is always in the best position to inspect equipment on a daily basis. Because the operator sees the equipment often, changes become apparent through familiarity. For example, variations in pump performance may not be apparent to an electrical technician who performs monthly PM on a pumpset motor, but the operator may note the change. The operator can, by touch, note excess vibration or higher than normal temperatures in motors. A familiar ear listening for unexpected noises might detect problems in operating equipment. Daily presence helps one to see problems related to, for example, leaking fluids. The maintenance manager should work with the water plant superintendent to develop a checklist to guide plant operators in inspecting plant and pumping station equipment.

The role of the water plant operator in carrying out minor maintenance tasks must be determined at the senior management level in order to ensure consistent application of the decision to all sites. While some utilities do require operators to perform minor maintenance tasks such as changing the packing on water pumps or fan belts on compressor equipment, others limit the operators' functions to inspection activities. If the workload permits, the preference should be for operators to carry out some minor maintenance activities.

In summary, the role of water plant operators involves

- inspecting equipment daily,
- reporting malfunctions to the maintenance department,
- performing minor maintenance tasks (if directed by management), and
- understanding the criticality of the equipment they are handling.

Plant operators play an important role in maintaining reliable equipment performance. Therefore, facility operation managers should meet regularly with maintenance staff, particularly plant equipment maintenance personnel, to discuss issues and work together to resolve any problems. Regular meetings are one method of establishing good communications between operations and maintenance.

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Maintenance by Outside Contractors

Virtually all water utilities hire outside contractors to carry out some maintenance work. For example, a maintenance manager may contract with outside services to carry out building renovations or grounds maintenance. A pipeline maintenance group is likely to use contractors to reline water distribution lines. Equipment maintenance personnel may hire outside contractors for numerous specialized tasks such as performing work on high-voltage electrical equipment. Therefore, maintenance managers must prepare carefully considered rules and regulations for working with contractors. For example, the manager should require that multiple (at least three) bids are solicited, that a Request for Bids is advertised in local newspapers and, if the job is large enough, in national publications, that the contractors identify the firm's experience and that of the staff who will work on the project, that appropriate references are provided and, of course, that each contractor detail the cost to do the work. In addition, utility staff—particularly those from contracting and maintenance—must be available to ensure that the contractor follows the regulations during the bid process and as the work is being executed.

While contractors provide cost-effective service under the proper circumstances, failure to adequately prepare for dealing with contractors could result in incomplete work, unexpected costs, poor quality, and legal entanglements.

Advantages and Disadvantages of Working With Contractors

Maintenance managers can gain important advantages by using contractors. Some of the advantages in hiring contractors include:

- Contractors can help smooth out the peaks and valleys in the workload and enable the maintenance department to keep a constant workforce.
- Contractors can bring specialized skills or equipment to a job, particularly jobs that occur infrequently.
- Contractors may be able to perform the work at lower cost than utility personnel can. This situation is likely only if a number of qualified contractors are available to bid on the work and if the utility's workers lack skills in the particular type of work required.

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- Contractors are usually easier to terminate than full-time employees once they are no longer needed. (The contract document must take this possibility into account.)

Managers also need to understand the disadvantages of engaging contractors:

- Dedicated employees are more likely to show greater pride in work for their utility than are contract employees.
- The utility will need specialists to prepare effective documents for contract bidding and enforcement.
- The maintenance department will need to employ inspectors to monitor a contractor's work. Because experienced personnel are needed to perform this work, senior field people should be assigned this responsibility, which means these staff members may not be available to carry out the complex maintenance tasks they routinely handle.
- Costs may be higher than expected if few contractors are available to bid on the work.
- The utility will have less control of the schedule and worksite than it would have if maintenance department personnel were to perform the work, and the quality of the finished work may be lower than expected.

The maintenance manager must take time to assess these factors to determine if outside contractors offer the most efficient way to complete certain maintenance tasks. Of course, rational arguments must justify this decision.

Methods of Employing Contractors

Once it is decided that outside contractors would be appropriate for completing certain maintenance tasks, the next step is to structure the deal for the contractor's services. Three types of contracts are used.

Service contracts are generally negotiated for work involving preventive and corrective maintenance. The contractor agrees to perform scheduled PM tasks in exchange for a fixed price covering both labor and materials. If any problems are uncovered during PM, the contract requires the contractor to either submit a fixed price for completing the repair or carry out the work at a contractually fixed rate for labor and

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materials. The latter method, although more difficult to control, permits a faster response by the contractor to carry out the repair.

The second type of contract covers a period of time, typically one year, during which the contractor executes specific work orders for the utility at specified rates for labor and material. The work is nonrepetitive maintenance (not PM), and a price is submitted for each job. The utility has the option of accepting or rejecting the price. The utility can get work done fairly quickly without formal bidding procedures in this way, while retaining the option of using another contractor if competitive bidding might produce a better price. The contractor effectively becomes an extension of the maintenance workforce.

The third type of contract requires development of specifications and requests for proposals for a particular job. Contractors submit bids to complete the work for stated prices, and the technically qualified bidder that agrees to the lowest price is generally awarded the contract. This type of contract is often limited to large-scale repair or rehabilitation work.

To be successful, each type of contract must be developed under certain conditions:

- Competitive bidding
- Close coordination between the maintenance and purchasing departments
- Effective contract documents
- Close monitoring of performance by maintenance inspectors

A maintenance manager can often increase department efficiency by working with outside contractors. Time spent learning how to select and work with contractors will help to yield the maximum benefit from the relationship.

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CHAPTER 3

Planning a Maintenance Management System

A maintenance management system (MMS) is primarily a technique for organizing the operations of the maintenance department(s) within a utility to enable personnel to execute their responsibilities in a consistent, timely manner while maintaining high performance standards at minimum cost. To establish a system that fully realizes this definition, the maintenance manager must first develop a strategy for planning and implementing the MMS. The strategy should include

- Organizing a team to develop and install the system
- Carrying out a needs assessment
- Identifying the costs and benefits of implementing the system
- Establishing a timetable for implementing the components of the system

The process of developing an effective strategy requires an understanding of the elements that constitute an MMS.

Elements of an Effective MMS

Development of a new MMS or an extensive upgrade of an existing system is a major project. Careful planning is a key condition for success.

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Functional Responsibilities and Maintenance Management

Rather than develop the MMS from scratch, a maintenance manager usually begins with an existing maintenance program, modifying features and adding enhancements as needed. In addition, as seen in chapter 1, the particular structures and equipment found in a specific utility have substantially different maintenance requirements. Therefore, individual water utilities organize maintenance work in different ways. In particular, organization schemes vary for utilities of different sizes. For example, some rely heavily on outside contractors, while others tend to do more work by their own personnel.

Also, the functions of different groups within a maintenance department require different management techniques. Pipeline maintenance crews generally perform a lot of corrective maintenance (CM), whereas electrical/mechanical (E/M) crews should devote more time to preventive maintenance (PM). In addition, the work performed by pipeline maintenance crews is generally better suited for the development of time standards. Grounds maintenance crews often carry out seasonal work, so the manager of that group must plan off-season work with care to maximize staff utilization.

Development of an MMS should allow for different teams to carry out needs assessments for different maintenance sections. Equally important, different maintenance groups may be assessed at different times. Management can evaluate where the need for reviewing the maintenance system is most urgent and concentrate efforts on that basis. However, planning for any successful maintenance system must account for certain key elements.

Key Elements of a Maintenance System

Identification of the key elements of a particular maintenance system is a subjective decision, but a review of successful programs (including both manual and automated systems) does suggest a number of elements required for a successful system.

Equipment/Structure Inventory. All equipment and structures that may require maintenance work, either preventive or corrective, must be included in an exhaustive inventory. Even a small water system will encounter problems in setting up maintenance records if all equipment and structures have not been specifically identified as part of an

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inventory of water system components. In most cases, this evaluation includes assignment of identification numbers.

To facilitate distribution system maintenance work, all valves and fire hydrants should be identified with a suitable numbering system. Information on buried piping is necessary in order to facilitate repairs to broken water lines. The implementation of GIS/GPS programs to assist with identifying the location of distribution system components will help the utility automate the tracking of these components, making maintenance scheduling easier and simplifying system updating.

Equipment maintenance tasks rely on a numbering system to maintain equipment histories. An automated MMS manipulates these numbers to generate PM schedules and track work orders.

For building and grounds maintenance, a facility identification system guides maintenance personnel to the correct job locations and helps them to schedule building and room renovations such as periodic painting.

Work Orders. Work orders are essential requirements for any MMS. Layouts vary, but any work order must include space for the following:

- Equipment or structure affected and/or the location of the problem
- Work to be done (if known) or the nature of the problem
- Equipment specifications
- Special tools needed
- Work done
- Pertinent dates
- Labor hours and crew identification

If the person who initially reports the problem cannot immediately see the results of the maintenance action, the work order system should also include a means of reporting the status of the work to the originator. Equipment maintenance work often falls into this category, whereas the results of work done by pipeline maintenance crews (e.g., repair of a burst main) are frequently quite apparent. Manual and automated work order systems will be discussed further in the next chapter.

Preventive Maintenance. A consistent PM program is a key requirement for ensuring reliable equipment operation. The PM program should include building services equipment such as HVAC units, water pumping

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equipment, and valves for controlling the flow of water. Thus, the utility cannot limit the PM program to any single maintenance function. This important element of the maintenance system is considered in detail later in this chapter.

Work Planning and Scheduling. Maintenance managers need to be able to estimate the level of effort (LOE) required to complete both PM and corrective maintenance tasks during the planning period, for example, the next month or quarter. The LOE required to complete PM tasks for most equipment is relatively easy to calculate. The difficult task is to estimate the LOE to complete CM and emergency work. Past experience is one guide, particularly for scheduled CM work where the specific requirements in labor and material can be reasonably estimated. For the type of emergency work encountered most often in pipeline maintenance, the best approach is to have sufficient material on hand to accomplish virtually any repair and to have sufficient crews on duty and on standby to make at least essential repairs as quickly as possible.

Feedback and Control. This information loop is a frequently overlooked aspect of any maintenance program. The maintenance manager must be able to determine the status of all PM and CM work to ensure that PM is being completed as scheduled and that CM (particularly high-priority work) is done in a timely manner. It is futile to issue work orders if no mechanism for tracking them is built into either a manual or an automated system.

Accountability for Resources Expended. The importance of readily available, up-to-date information on resource usage is increasing. Data on utilization of labor and material help to justify additional personnel, increased supplies of spare parts or material, or labor-saving tools and equipment.

Maintenance History. A method for tracking the maintenance history of equipment and structures is a fundamental part of an effective maintenance program. This function keeps a record of all corrective maintenance tasks completed, and PM tasks are tracked for a period of one to three years, depending on the utility's PM cycle.

The need for a history of equipment and structures such as pipelines may be obvious, because it will provide vital information in such areas as equipment reliability and replacement. However, accurate

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records are also important, particularly for cost control, to track the work of building maintenance personnel such as painters and carpenters. The manager of the building group will find such data very useful during the preparation of the department's annual budget.

The elements listed in this section form the basis for a system that will provide efficient, reliable control of maintenance activities. The most important of these elements, with a critical role in consistent water processing and extensive links to other elements, is a consistent PM program.

Preventive Maintenance

For a water utility, the foundation of a successful maintenance program is preventive maintenance. Effective PM enables field technicians to limit time spent on corrective maintenance, resulting in a significant increase in productivity through effective planning. While this relationship is most easily verified for equipment maintenance activities, it is also true for pipeline maintenance work. For example, an article in AWWA's *Opflow* magazine related the positive experience of one utility when it embarked on a valve exercising program (Nayer et al. 2008). Regular maintenance of distribution system valves simplifies the work of pipeline repair crews, as does periodic updating of system maps. Certainly, quick identification of the location of valves during an emergency, for example, a water main break, will likely reduce the number of customers negatively affected as well as the amount of water lost.

For equipment maintenance, equipment reliability is substantially improved by the introduction of a PM program for treatment plant and pumping equipment. PM is characterized by consistent, timely completion of regular maintenance tasks, according to guidelines composed of three primary components: documented procedures, a clear schedule, and regular follow-up. Brady (2010) explained why regular maintenance is important in an *Opflow* article: "If properly operated and maintained, pumps can provide decades of efficient and reliable service." He also noted that pumps represent a significant portion of a utility's equipment investment and discussed major elements of an effective pump maintenance program.

Maintenance Procedures. The first activity in planning PM is to establish the tasks that must be performed on each piece of equipment. The usual sources of information include

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- equipment operations and maintenance manuals,
- other product information from equipment manufacturers, and
- experience of plant maintenance personnel.

Task specification must include the PM cycle. Normally, tasks are categorized as daily, weekly, monthly, quarterly, semiannual, or annual activities. Each PM task must be described in a detailed maintenance procedure (MP).

Documentation of procedures aids in training new employees, helping them to follow correct sequences and complete all required tasks, and ensures uniformity in the performance of PM tasks. Figures 3-1, 3-2, and 3-3 are checklists of typical maintenance procedures. These checklists identify specific PM tasks to be performed on the flexible coupling of a filtrate pump, on a motor control center, and on a slip-ring motor.

Note that the first of these procedures was developed for an automated system, whereas the other two are used within a manually operated system. The MP sheet for the automated system includes:

- A description of the maintenance task, the name of the equipment or structure, and its location
- The PM cycle and its estimated completion time
- All skills or trades needed, as well as tools and safety precautions
- Complete work instructions

The maintenance procedure sheet for a manual system can be simplified by excluding data on completion time, skills, and tools needed.

PM Schedule. Information from the procedure descriptions allows preparation of the PM schedule. Typically, the schedule is developed annually, guided by several considerations:

- The workload should be balanced.
- For especially expensive or critical equipment, running time, not lapsed time, should be used to schedule PM.
- Since labor may be limited, critical tasks and components are identified and fitted into the schedule first.
- The schedule should be monitored and revised if necessary, at least on an annual basis. Figure 3-4 gives an example of an annual PM schedule developed for a water filtration plant as part of a manually operated PM program.

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Preventive Maintenance Procedure

EQUIPMENT NAME — AVERAGE TIME _____ MINUTES

Flexible Coupling, Motor Filtrate Pump

PLANT AREA	LEVEL	LOCATION
Secondary	Ground	Dewatering

MAINTENANCE DESCRIPTION

Inspect coupling

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit, lock and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Safety tag
Adjustable wrench
Screwdriver
Hammer

PROCEDURE

Preliminary—De-energize unit, log and tag "out of service"
To inspect coupling:

1. Remove cover on coupling.
2. Slide coupling apart.
3. Remove rubber spider and inspect for wear, deterioration, and breaks.
4. Check both halves of coupling for wear and damage.
5. Replace rubber spider and slide coupling together.
6. Put cover back and bolt down.
7. Remove lock and safety tag and return to service.

Figure 3-1 Maintenance procedure for flexible coupling of a motor filtrate pump

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Preventive Maintenance Checklist

Work Request No. Interval: Annual

Equipment Name: Motor control centers Equipment Type: 51

Facility: Bldg/Room. Motor No.

OK	Not OK	
		1. De-energize all circuits before working in equipment.
		2. Clean interior by vacuuming.
		3. Replace badly worn contacts as quickly as possible.
		4. Do not sand silver cadmium contact points of line starters. In the event of wear, replace all contacts to avoid misalignment problems.
		5. Inspect all bolts, nuts, and screws for tightness.
		6. Inspect all wiring for signs of damage.
		7. Examine the insulation system for evidence of heating.
		8. Open all hinged panels; remove all bolted panels to thoroughly inspect all internal devices, and clean.
		9. Check instantaneous trip on breakers to verify that settings agree with specifications.
		10. Never lubricate any part of an electrical device.
		11. Change all indicating light bulbs.

DO NOT USE emery paper, sandpaper, or a file cloth to clean or dress up any portion of the electrical equipment.

Completed by: Date:

Crew No.: No. of Workers: No. of Hours:

Figure 3-2 Preventive maintenance checklist—motor control centers

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Preventive Maintenance Checklist

Work Request No. Interval: Semiannually

Equipment Name: Motor with slip-rings Equipment Type: 12

Facility: Bldg/Room. Motor No.

OK	Not OK	
		1. Clean motor thoroughly, blowing out dirt from windings.
		2. Inspect and tighten connections on motor and controls.
		3. Run motor and examine drive critically for smooth running.
		4. See that all covers and guards are in good order.
		5. Inspect brushes to confirm the following: a. Pig-tail shunts are properly attached to brushes and holders. b. Correct tension is maintained as brushes wear. c. Worn-out brushes are replaced before they reach their limit of travel and break contact with the slip-rings or cut out due to contact with the metal brush shunt clip. d. Newly installed brushes are fully seated and free in the brush holder. e. "Sanding-in" allows full contact with the slip-ring.
		6. Check for excessive brush movement, brush chattering, and brush chipping.

DO NOT USE emery cloth or emery paper to seat brushes.

Completed by: Date:

Crew No.: No. of Workers: No. of Hours:

Figure 3-3 Preventive maintenance checklist—motor with slip-rings

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