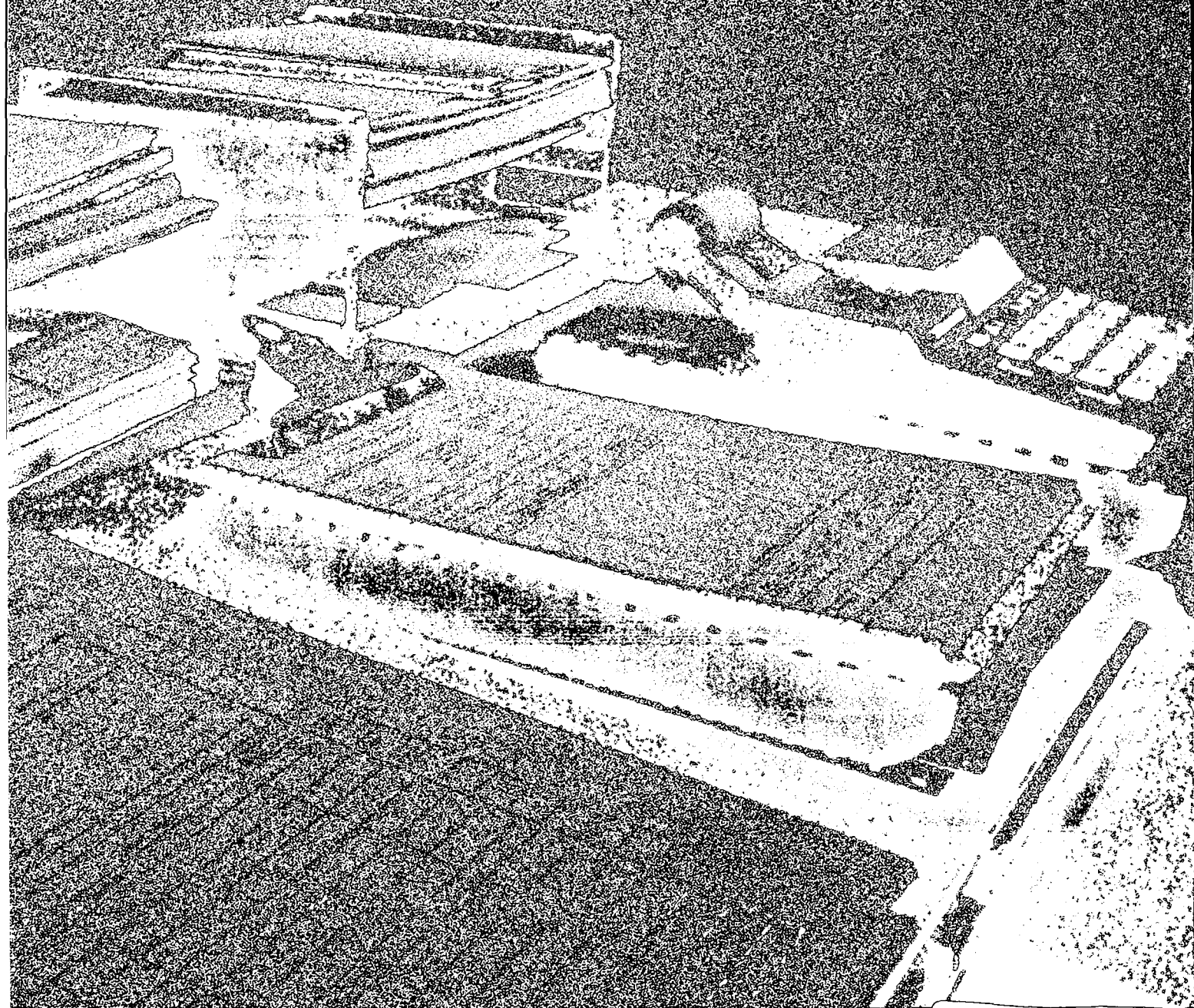


Maintenance Management

James K. Jordan



202.6-984A-8447

isn 8447, pag. 129,87

21.00
26.50

Maintenance Management

James K. Jordan

isn 8447
202.6 90MA



American Water Works Association

Copyright © 1990
American Water Works Association
6666 West Quincy Ave.
Denver, CO 80235

Printed in USA

ISBN 0-89867-526-X



Printed on recycled paper

Contents

Preface, v

Chapter 1 Introduction to Maintenance Management 1

- The Need for Maintenance, 1
- Role of the Maintenance Department, 2
- Maintenance Department Management, 2
- General Maintenance Functions, 4

Chapter 2 Maintenance Department Organization and Personnel 7

- Organization of the Utility, 7
- Effective Maintenance Organizations, 9
- Maintenance Personnel, 11
- Maintenance Personnel Policies, 13
- Operations Personnel and Maintenance, 15
- Using Outside Contractors for Maintenance Work, 16

Chapter 3 Planning a Maintenance Management System 18

- Elements of an Effective MMS, 18
- Planning the System, 25

Chapter 4 Information Management and System Monitoring 29

- Equipment and Structure Records, 29
- Work-Order Systems, 33
- Maintenance Work History, 39
- Management Reporting, 41
- Maintenance Management System Monitoring Techniques, 43
- Maintenance Management System Control, 44
- Performance Monitoring, 52
- References, 56

Chapter 5 Inventory Management 57

- General Concepts, 57
- Maintenance Requirements, 58
- Determining Quantities in Inventory, 59
- Inventory Information Systems, 60
- Inventory Accountability, 64
- Storeroom Design and Location, 65
- Automated Inventory Systems, 66
- Reference, 70

Chapter 6 Maintenance Costs and Budgets	71
The Cost of Maintenance, 71	
Controlling Maintenance Costs, 74	
Collecting Cost Data, 75	
Reporting to Management, 80	
Preparing a Budget, 81	
Estimating Maintenance Costs, 82	
Reference, 88	
Chapter 7 Training	89
Responsibility for Training, 89	
Assessing the Need for Training, 90	
Structuring Training Programs, 90	
Meeting Maintenance Training Requirements, 96	
Safety Training Programs, 98	
References, 99	
Appendix A Computerized Maintenance Management Programs	100
Bibliography, 103	
Index, 105	

Preface

Any project requires careful planning, design, implementation, and monitoring. The establishment of an effective maintenance program is no different. Many significant advances in maintenance management systems (MMSs) have been made in the past few years, including a number of packaged programs that make designing a good maintenance program a much easier task. Yet, the fundamental requirements for establishing an effective program remain the same. The individual responsible for establishing or improving a maintenance program must

- develop a scope of work with cost estimates;
- sell the merits of the project to senior management;
- carefully design the program to incorporate all necessary elements, including planning for future expansion;
- solicit the cooperation and recommendations of upper management, operations personnel, and maintenance field technicians;
- develop an implementation plan and schedule; and
- plan techniques for monitoring and reviewing the program after implementation.

The establishment or improvement of a maintenance program must be high on the priority list for any water utility. Not only are the benefits from an effective maintenance program well established, but the attitude of senior management for providing the support needed to implement or improve a maintenance program is generally favorable. In addition, an effective maintenance program will contribute to more effective operation of the water utility.

This manual was prepared to provide water utilities with guidelines for analyzing a maintenance management program. The manual systematically covers the primary components of effective maintenance management. Also, it describes ways to improve the operation of a utility's maintenance department.

* * *

The author wishes to acknowledge the assistance of his associates at the Local Development II/P Project in Cairo, Egypt, for reviewing this manual. Their comments were very useful in preparing the document.

Special thanks are given to the author's former colleagues, particularly those in the maintenance sections at the Washington Suburban Sanitary Commission (WSSC), Hyattsville, Md., who contributed much useful information for the manual and, most importantly, who have established a successful maintenance program for their organization.

1

Introduction to Maintenance Management

THE NEED FOR MAINTENANCE

When a piece of equipment is first placed in service, it usually operates near its maximum efficiency. A new automobile is assembled with new parts, and the engine operates smoothly with all adjustments being made according to the specifications of the vehicle's designers and manufacturers. The shock absorbers, springs, and tires produce the best ride that the vehicle is capable of delivering. This is also true of a water pump set and its auxiliary equipment.

Assuming proper design, construction, and installation, the amount of water pumped immediately after starting up the system is at or near the unit's design capacity. This is true whether the method for transmitting the water is a hand pump located in a village or farm or a 50-mgd centrifugal pump set providing water to a large community. It is also true that 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 must recognize this fact and develop plans to counteract the equipment wear.

Water utilities are the most capital intensive of all utilities. Consequently, many utilities have established a separate group—the maintenance department—to protect this investment. The maintenance department is a necessity if the utility is to effectively provide good water to the community it serves.



ROLE OF THE MAINTENANCE DEPARTMENT

The primary function of a water utility is to provide high-quality water to its customers at a reasonable cost. A key component to a utility's success or failure is the performance of its maintenance department. In general, the maintenance department provides support services to other departments within the utility. The department's responsibility is to keep utility equipment, vehicles, and structures in good operating condition. The services provided by maintenance range from routine tasks (such as replacing light bulbs) to critical tasks (such as repairing a piece of equipment necessary for water production). Whatever the task, a planned management approach is necessary.

Responsibilities

The specific responsibilities of the maintenance department include the following:

- equipment, vehicle, distribution system, and building repair—planning and executing repair of equipment and other 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 from developing;
- communications—developing methods to keep operations personnel, upper management, and other departments aware of maintenance activities;
- budget—preparing realistic budgets detailing maintenance manpower and material needs;
- inventory—ensuring that the parts and materials necessary to perform maintenance tasks are available and can be accounted for;
- manpower—developing techniques for monitoring the activities of maintenance personnel;
- training—providing opportunities for maintenance personnel, including both supervisory and field personnel, to improve their skills and perform effectively;
- safety—developing safety education programs for maintenance personnel and implementing techniques to improve the safety of the work place;
- contract management—preparing contract specifications and inspecting contractors' work to ensure compliance with contract requirements;
- construction—reviewing plans for new facilities and for the installation of new equipment; and
- records—maintaining up-to-date information on equipment and plant services, including files containing operations and maintenance (O&M) manuals and water system plans.

A utility's maintenance department is primarily responsible for ensuring the efficient and reliable delivery of water. Successfully fulfilling this responsibility requires that the maintenance department develop and implement a maintenance management program consistent with the needs of the water utility.

MAINTENANCE DEPARTMENT MANAGEMENT

The maintenance department's image as one where "seat-of-the-pants" management prevails is changing. The rising costs of equipment, spare parts, and supplies as well as the increasing complexity of contemporary water treatment processes have drawn

the attention of upper management to the maintenance department's operation. It is now recognized that if equipment is to function reliably and if costs are to be kept under control, the maintenance manager must be professionally skilled in both the technical and financial fields. The maintenance manager must be a good manager of people as well. Increasingly, water utility management is learning that while it is important for the head of maintenance to be technically competent, it is essential that he or she be an effective manager.

Advances in Maintenance Management

A number of significant advances have been made in maintenance management. The most important of these may be the use of microcomputers to schedule and track maintenance work. On one hand, these new tools have made it easier for the manager to gather information and make it readily available to appropriate individuals. Conversely, the many techniques available have made selection of the proper techniques more difficult.

The role of the maintenance technician (for example, an electrician) is also changing. He or she is required to maintain major, complex equipment. Also, the knowledge needed to troubleshoot and repair this equipment is much greater. This places greater emphasis on the importance of the first-line maintenance supervisor who must be able to effectively use the technician's skills.

Recently, the maintenance department has paid considerably more attention to the use of more complex information systems. The advent of packaged information systems (i.e., programs that are developed independently for use by a number of water utilities), along with increasing demands by upper management for timely, more accurate data on maintenance activities, has fostered this trend. The maintenance group has frequently found it necessary to add staff to monitor entries to the system, interpret output, and maintain the integrity of the data stored in the system.

A key responsibility of the maintenance manager is to determine what data should be gathered and how this task is to be accomplished.

Maintenance Management Information Systems

The term *maintenance management information system (MMIS)* is generally used to describe a program designed to schedule, issue, and track the department's maintenance tasks. The program can also be designed to provide information on other maintenance aspects, such as inventory and budget control. A MMIS may be either manual or computer assisted, and the maintenance department may use several different information systems to control its operation. Some programs operate entirely by manually processing information, while others use schedule boards and other aids to facilitate system operation. Automated systems can be programmed to use a mainframe computer or a microcomputer.

The development of numerous "canned" programs has brought computer-assisted information systems within the reach of most water utilities. A number of software packages designed to assist the maintenance section and a brief description of each are listed in appendix A. The significant developments that have taken place in information gathering, processing, and reporting justify the treatment of this component of maintenance operations as a separate chapter of this manual, that is, chapter 4.

Relationship Between Operations and Maintenance

Though the maintenance department interacts with virtually all other utility departments, the relationship between operations and maintenance is particularly close. Operations and maintenance (O&M) are frequently considered a single function. In fact, operations personnel frequently perform minor maintenance tasks as part of their normal duties. However, the two elements (operations and maintenance), though strongly dependent on each other, differ substantially in their objectives.

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

Maintenance is defined as a series of activities carried out 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. The different components of the water system require specialized maintenance programs that balance the use of available resources between reacting to problems after they occur and taking preventive measures. In view of this, maintenance managers must be aware of the different approaches to maintenance and how these impact the strategy used to maintain the water system's different components.

Maintenance Practices

The maintenance activities carried out by the maintenance department are divided into two categories—preventive and corrective. Preventive maintenance (PM) incorporates actions that are performed on a regular and scheduled basis to keep equipment or structures operating effectively and to minimize unforeseen failures. These actions consist of inspections and/or maintenance tasks. Corrective maintenance (CM) incorporates actions that are taken to either repair or restore equipment or structures to standard operating condition. These actions may result from problems discovered during PM or as a result of failure during operation. Actions are *scheduled* if they can be carried out as part of the normal work plan. They are *unscheduled* if immediate action is needed to correct a failure. Unscheduled maintenance is often called emergency maintenance.

A third type of maintenance, breakdown maintenance, differs from CM in that only a minimal number of or no PM tasks are performed. Actions are taken to either repair or restore equipment or structures to standard operating conditions only after the equipment or structure fails 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 manual.

Water System Maintenance Requirements

The maintenance department's mode of operation with respect to handling equipment, pipeline, and facility maintenance differs due to cost factors, the availability

of practical methods to assess maintenance needs, and the importance of the equipment or structure. In larger utilities, the maintenance organization is frequently organized into four different sections to recognize the different O&M requirements. These sections are

- electrical and mechanical (E/M) equipment maintenance,
- distribution system maintenance,
- building and grounds (B&G) maintenance, and
- vehicle maintenance.

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

E/M equipment. Electrical and mechanical equipment consists of all of the electrical, mechanical, and pneumatic equipment used to draw water from its source and deliver it from the discharge point(s) of the utility's treatment works. This includes booster pumping stations and water storage facilities. Depending on the size and complexity of the operation, maintenance may be required, for example, on raw and finished water pumps; chemical-feed equipment; flocculation, sedimentation, and filtration units; process instrumentation devices (such as flowmeters and other system telemetry); and transformers, motor control centers, and protective relays.

Since E/M equipment consists of a multitude of moving parts that are subject to wear (for example, bearings and contacts), it requires an effective PM program. Such a program will ensure reliable and economical operation of the utility's treatment plants and pumping stations. However, it is not cost effective to carry out PM on all E/M equipment, as some equipment will be operated until it fails. For example, unless a fractional horsepower motor is driving a critical piece of equipment, it is probably not cost effective to include it in the PM program. The motor will be replaced when it fails. Despite a good PM program, other equipment will fail on occasion simply because of a faulty component. Thus, provision for CM needs to be made in the work schedule. An effective PM program will include 70 to 80 percent of the E/M program's work.

Distribution system. The pipelines used to transmit water from the treatment works to the consumer are included in this category. Transmission and distribution mains and the lateral connections to the individual customer constitute the distribution network. Also included are the valves used to control the flow of water in the pipeline (such as those used to reduce system pressure or to isolate sections of the network) as well as consumer water meters and fire hydrants.

The maintenance of pipelines is primarily reactive. Maintenance crews must be available to respond to waterline breaks, valve leaks, and customers' complaints. These tasks constitute the bulk of the work of the system maintenance section—approximately 75 percent of this section's work is CM. However, the section can carry out some scheduled maintenance on a regular basis, including exercising main-line valves, testing fire hydrants, and controlling leaks in the system. Programs for cleaning and relining pipelines and evaluating and controlling the impact of corrosion on the distribution system may also be the responsibility of this group.

Building and grounds. Maintenance activities involving the utility's buildings and grounds include renovations requiring carpentry, painting, and masonry work; the planning and execution of building modifications; groundskeeping; and housekeeping. Little of the work carried out by this section is unscheduled CM.

Generally, only responses to safety or security issues fall outside of planned work. Responding to conditions caused by weather (for example, cleaning snow from sidewalks) may also be the responsibility of this group.

Maintenance of the utility's grounds is a regularly scheduled activity, depending only on seasonal conditions. It can be described (loosely) as PM. Facility housekeeping is handled in a similar manner.

Upgrading buildings for aesthetic purposes (for example, painting and floor replacement) is also scheduled work. However, the intervals between such activities in any particular area are measured in years, rather than in weeks or months.

The B&G department may also be responsible for relocating personnel within the utility as a result of changes in work assignments and facility modifications resulting from reorganization. This type of work should be planned, but the incidence of occurrence cannot usually be predicted more than weeks, or possibly months, in advance. Utilities commonly contract with outside firms to handle this work.

Vehicle maintenance. Servicing of automobiles, trucks, and specialized mobile equipment (for example, cranes and backhoes) is the responsibility of the vehicle maintenance section. Vehicle maintenance is a vital component of effective utility O&M; however, it requires a separate publication to adequately explain its role in the water utility. Therefore, this subject will not be covered in this manual.

Summary. The maintenance department needs to recognize that maintenance of structures and equipment requires a different organizational approach. Staffing, recordkeeping, budgeting, work monitoring, and other functions are impacted by differences in maintenance requirements among the E/M, distribution, and B&G sections. An analysis of the organizational requirements for a water utility's maintenance department is the first step in establishing an effective maintenance management system.

2

Maintenance Department Organization and Personnel

ORGANIZATION OF THE UTILITY ---

Before investigating the organization of maintenance personnel, it is important to understand the organization of a utility. The maintenance group does not stand alone in a water utility. A successful maintenance program requires that maintenance personnel interact with many, if not all, of the other departments within the utility.

Elements of a Maintenance Program

To appreciate the necessity of the interaction between maintenance personnel and other utility departments, it is important to review the key elements of an effective maintenance program and see how other groups within the utility relate to these elements. These key elements are

- institutional support—The utility's senior management must provide active support if an effective maintenance management program is to be implemented. This support extends beyond providing adequate funds for maintenance to active participation on the part of the management team. For example, senior management should read and react to management reports on maintenance activities and, on occasion, visit the maintenance work site.

Institutional support must come from all levels of management, including the utility's general management.

- system maintenance—To ensure effective maintenance of equipment and structures, responsibilities should be clearly defined, and maintenance personnel should have the necessary tools and skills to do their jobs correctly.
- spare parts and supplies—An effective inventory control system for spare parts and supplies is necessary for efficient maintenance. Since another department usually is responsible for this function, close coordination among purchasing, maintenance, and inventory management is important.
- logistics—Proper vehicles, materials, and structures must be procured for the maintenance organization and provided to maintenance personnel. Work areas equipped for PM and CM work should be provided.
- financing—Funds needed to support the maintenance program, particularly with respect to PM, are frequently the first to be cut by a utility anxious to reduce costs. While maintenance management must be cost conscious, significant funding cuts usually result in increased equipment downtime and, in the long run, a more costly maintenance operation.
- records—Up-to-date, accurate records need to be kept for all water utility maintenance operations. The system in use will determine the type and number of records and reports to be developed and kept.
- human resources and training—A continuing management and technical training program should be set up for maintenance personnel. This is essential to successful maintenance. The most important department resource is the personnel who are responsible for maintaining the utility's equipment and structures. If the maintenance personnel lack the knowledge and skills to plan and execute their duties, the other resources that are available to them will, at best, be poorly used; at worst, the improper use of these resources can result in serious interruptions in water processing and delivery.
- proper location of resources—It is equally important to organize and locate maintenance department personnel according to their function. For example, it makes sense to place some E/M personnel at the utility's plant sites, whereas the pipeline and valve maintenance group should be located closer to the center of the distribution system.

These key elements reveal how much the maintenance department must rely on other groups within the utility to be effective. Each department—purchasing, budgeting, information management, transport, etc.—plays a key role in a well-run maintenance department.

However, before a maintenance department can determine its need for these key elements, the following items must be addressed:

1. The role of the operations personnel in the maintenance function must be established.
2. The amount and type of work that will be given to private contractors need to be identified.

These issues will be addressed later in this chapter.

EFFECTIVE MAINTENANCE ORGANIZATIONS

At this stage, it is useful to examine the organization of one large water utility—the Washington Suburban Sanitary Commission (WSSC)*—and review the responsibilities of the utility's maintenance department personnel.

The WSSC—An Example

The WSSC, which will be used for example purposes throughout this manual, has combined its O&M functions at the department level, thereby emphasizing the close cooperation that must exist between these two groups. Because of the WSSC's size, its maintenance bureau is further divided as outlined in chapter 1 so that separate divisions have been organized to handle the maintenance of the distribution system (systems maintenance) and the maintenance of plant and office structures (facilities maintenance). Figure 2-1 is an organizational chart of these divisions.

The O&M department consists of one additional bureau—supply and resource control. This group is responsible for purchasing, doing inventory and warehousing, and maintaining vehicles, all of which are vital components of a successful maintenance management program.

The systems maintenance division has the most personnel of the three divisions within the maintenance bureau. Thus, WSSC management decided to establish a maintenance information system for this group first, and the maintenance management division was created to carry out this task. One of this group's principal tasks is to process and track the work requests for the systems maintenance division. This effort eventually resulted in the development and implementation of the MMIS, an automated monitoring system for the maintenance tasks carried out by the division.

The facilities maintenance division is responsible for the other maintenance functions covered in this manual. As shown in Figure 2-2, the division consists of two sections—E/M and B&G. This figure lists the types of equipment or systems maintained by each of the distinct groups that make up the E/M section. The field personnel classifications that are likely to be stationed at an E/M zone office are

- supervisor,
- E/M technician(s),
- electrical mechanics,
- E/M helpers,
- instrument technician(s), and
- data-entry clerk.

In general, an E/M crew is comprised of a technician and an electrical mechanic or helper. They are responsible for all E/M maintenance activities (PM and CM) for a certain section of the treatment plant, with one crew assigned to the water pumping stations within that zone. The instrument technicians handle all instrument maintenance for their assigned zone.

*The Washington Suburban Sanitary Commission, located near Washington, D.C., is a state-chartered agency that provides water and wastewater treatment services to approximately 1.5 million customers in Prince George and Montgomery Counties in Maryland.

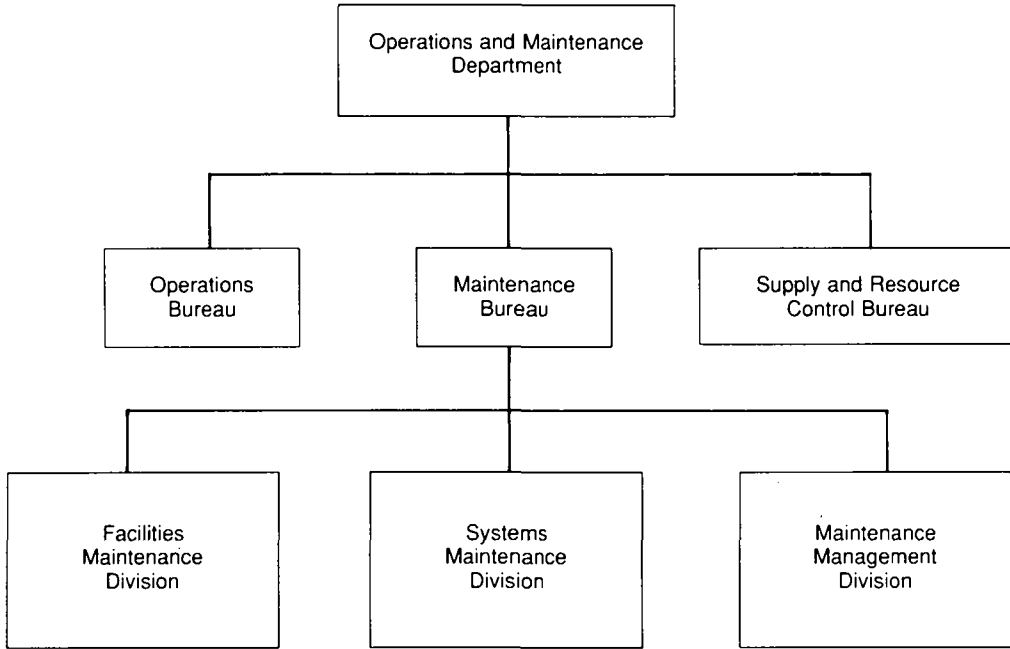


Figure 2-1 WSSC maintenance organization—department/bureau/division levels.

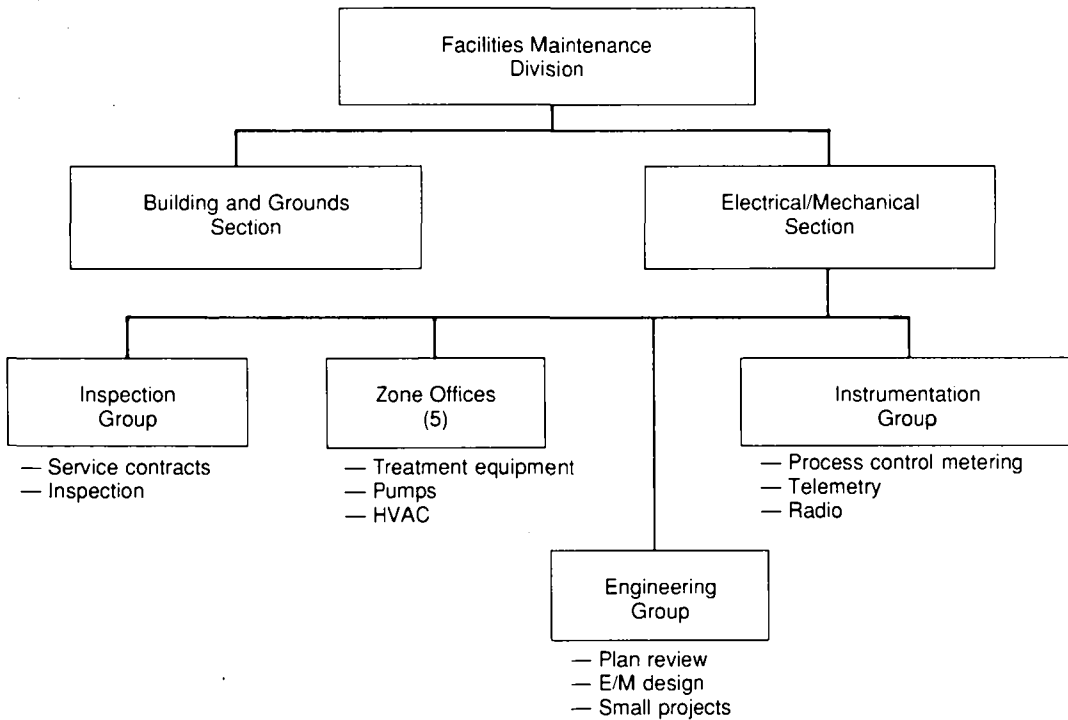


Figure 2-2 WSSC maintenance organization—division/section/zone levels.

Other Maintenance Organizations

The WSSC adopted an organization that works well for it. Because of its numerous treatment and pumping station facilities, the WSSC concluded that a centralized management structure for maintenance was appropriate. This approach is especially effective for carrying out those maintenance functions that do not occur regularly. One example is infrared scanning of electrical equipment.

However, other water utilities have organized their maintenance groups in equally successful ways. For example, in many water utilities, the distribution superintendent is responsible for all aspects of the distribution system, including maintenance. In others, particularly small-sized to medium-sized utilities, maintenance is a functional area within the operations section.

Two factors seem to determine how the maintenance organization is structured. The first factor is if management believes that the maintenance group, particularly those 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.

The second factor is the size of the utility. Water utilities that have a relatively small service area and that operate a single treatment plant will usually find it most cost effective and prudent to have the plant manager be in charge of all maintenance functions, including building, equipment, and distribution system maintenance.

MAINTENANCE PERSONNEL

Personnel with a variety of skills are needed to staff a water utility's maintenance department. 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 for all maintenance positions and are adequately rewarded for good performance.

Supervisory Staff

The maintenance department of a typical multiplant water utility will require several levels of management to operate effectively (Figure 2-2). These levels will range from the maintenance managers to regional maintenance supervisors and crew leaders. As seen with the WSSC organization, the highest level of management where all maintenance work is combined is in the O&M department.

Functional maintenance manager. The responsibility of these managers, for example, the E/M section head (Figure 2-2), is to maximize the use of personnel and physical resources by

- establishing effective PM 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, and
- informing senior management of group progress and problems.

Regional manager. While the regional or zone managers are not generally involved in specific maintenance tasks, they are expected to provide “hands-on” direction to the field crews assigned to the regional office. In addition, they

- prepare work schedules;
- assess their crews’ effectiveness;
- carry out maintenance programs;
- ensure that spare parts, materials, and transport are available;
- interact with other utility organizations, particularly with operations personnel; and
- ensure that safety programs are carried out.

Crew leaders. The crew leader’s role is to plan the work for his or her crew and, depending on the work procedures of the organization, participate in the work of his or her crew. For example, in crews with two or three subordinate workers, the crew leader is likely to be a working member. In larger crews, organizing the crew for maximum productivity is the crew leader’s primary responsibility, which leaves little time for actual physical work.

Field Staff

The field staff required to maintain the structures used by a water utility ranges from equipment operators to painters and electricians. The field staff’s primary responsibilities include

- professionally carrying out duties;
- preparing all required paper work;
- reporting any operational problems, regardless of whether they directly affect the unit;
- communicating regularly with the immediate supervisor; and
- following work rules.

Support Staff—Technical

Larger utilities will typically have an engineering staff as part of the maintenance group to carry out design and construction activities. In the area of equipment maintenance, the engineers should have knowledge in troubleshooting operational problems, reviewing design drawings for new construction (with emphasis on maintenance after the equipment is placed in service), and, in some cases, assuming responsibility for executing smaller projects as construction managers.

The maintenance manager must be able to justify the level of engineering support that the maintenance group needs and determine whether sufficient work exists to warrant full-time positions or if the work can be accomplished through other sources. For example, for smaller utilities and for work requiring specialized technical skills, it may be more cost effective to use a consulting firm to carry out engineering on a job-by-job basis than to employ a full-time technical person.

Support Staff—Nontechnical

Some nontechnical personnel represent new additions to maintenance. While maintenance organizations frequently employ stockroom clerks and work-order clerks, it is only recently that data-entry clerks have been regularly employed.

The introduction of automated information systems has placed new demands on the maintenance manager. The manager must now determine whether the advantages of having access to previously unavailable information outweigh the cost of purchasing equipment such as computers and employing personnel to operate this equipment. This issue will be considered later in the manual.

MAINTENANCE PERSONNEL POLICIES _____

Because many employees are needed to staff the maintenance department, employee rules and regulations are needed.

General Principles

Since maintenance personnel play a key role in making a maintenance management program successful, the maintenance manager should view the utility's personnel department as an important contact in the utility. Clear and comprehensive rules and regulations for employees are essential for effective people management. In general, employees need to understand

- for what they are responsible,
- how their performance will be judged,
- what are the opportunities for advancement in the utility, and
- the utility's rules of conduct.

Job Descriptions

Job descriptions need to be prepared for each member of the maintenance team, since they inform personnel of their duties and provide a basis for an employee's annual performance evaluation. Job descriptions, such as the one shown in Figure 2-3 for an electrical mechanic, also indicate what skills and experience an employee needs to be eligible for a promotion or a lateral transfer to another position.

Promotion Policies

Many water utilities recognize the value of filling higher-level positions from within the organization. However, in some cases, because the type of individual needed to fill a particular position may not be available from within the utility, someone must be recruited from outside. These situations call for a well-written promotion policy. The maintenance manager should work with his or her counterpart in the personnel office to ensure that an appropriate promotion policy is prepared for the maintenance department. Copies of the policy should be distributed to each member of the maintenance staff.

Disciplinary Policies and Safety Rules

It is equally important that the utility prepare a written policy detailing actions it will take if an employee violates its job conduct, safety, and attendance rules and regulations. The maintenance group manager will be better able to resolve conflicts in these areas if the utility's policies are clearly stated in writing. Because of the

Electrical Mechanic

General Statement of Duties:

Performs journeyman-level electrical/mechanical tasks in a variety of maintenance activities and does related work as required.

Distinguishing Features of the Class:

An electrical mechanic is responsible for doing 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 indoor work, outdoor work in inclement weather, climbing ladders and scaffolding, and descending underground, as well as exposure to the hazards of high-voltage electrical shock. While some work is done independently, more difficult work is supervised by a lead electrical mechanic or electrical/mechanical technician who inspects the electrical mechanic's work for quality when it is completed.

Examples of Work (illustrative only):

The electrical mechanic

- diagnoses problems and repairs electric motors and other electrical equipment;
- inspects and tests various electrical/mechanical units;
- maintains various electrical and mechanical equipment in the buildings, plants, dams, and pumping stations;
- disassembles and repairs a variety of pumps, generators, heating and air conditioning, telemetering, and other equipment; and
- 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:

The electrical mechanic must be

- knowledgeable of the practices, methods, tools, materials, and equipment of the electrical mechanic's trade;
- knowledgeable of the occupational hazards of the trade and of necessary safety precautions;
- familiar with electronic and mechanical theory;
- able to locate and correct defects in electrical and mechanical systems and equipment;
- able to acquire a working knowledge of blueprints and schematics;
- able to understand and follow oral and written instructions; and
- in good physical condition.

Acceptable Experience and Training:

The candidate must have 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:

The electrical mechanic must possess a valid Maryland State driver's license and be able to secure a WSSC driver's license.

Figure 2-3 Example job description—electrical mechanic.

inherent danger associated with some maintenance tasks (for example, electrical work), it may be necessary to formulate additional safety rules for maintenance personnel. All safety rules must be logical and should be strictly enforced.

Employee Evaluations

Most water utilities require that each employee be annually evaluated for his or her previous 12-month job performance. Such evaluations can be invaluable in informing employees how they are viewed by their supervisors.

However, the annual evaluation is not an end in itself and can lead to problems if not properly used. For instance, field personnel who are promoted to supervisory roles must be trained how to evaluate their subordinates. Poorly conceived evaluations can cause serious morale problems and hamper the effectiveness of the maintenance system.

Additionally, annual evaluations should not be a substitute for continuous monitoring of each employee's performance. By promptly informing employees of any performance problems, the maintenance manager can avoid confrontations with employees who are frustrated or unhappy because they were not told that their work was unsatisfactory. One approach to counteract this problem is to schedule quarterly or semiannual informal meetings with each employee to review his or her progress. These informal meetings should address any performance problems and acknowledge any significant contributions the employee has made to the maintenance effort.

OPERATIONS PERSONNEL AND MAINTENANCE _____

Just as the role of each person on the maintenance staff needs to be clearly defined, the operations staff must understand its role with respect to the maintenance function.

Role of the Water Plant Operator

The water plant operator is responsible for

- inspecting water processing equipment daily. Because the operator sees the equipment often, he or she can sense changes in, for example, pump performance that may not be apparent to an electrical technician who performs monthly PM on a pump-set motor. The operator can, by touch, note excess vibration or higher-than-normal temperatures in motors. He or she also can listen for strange noises or look for unexpected leaking in operating equipment. Together, the maintenance manager and the water plant superintendent should develop a checklist for plant operators so that they can properly inspect plant and pump station equipment.
- reporting malfunctions, in writing, to the maintenance department.
- performing minor maintenance tasks, as defined and directed by senior management. While some utilities require operators to perform minor maintenance, such as changing the packing on water pumps or fan belts on compressor equipment, others limit the operator to inspecting equipment as described above. If the work load permits, operators should do some minor maintenance.

Plant operators play an important role in ensuring that equipment performs reliably. Therefore, the manager of pipeline and, particularly, plant equipment

maintenance should meet regularly with the operations managers to discuss issues and resolve problems.

USING OUTSIDE CONTRACTORS FOR MAINTENANCE WORK

Virtually all water utilities use outside contractors to carry out some maintenance work. For example, the B&G group may contract to carry out building renovations and/or grounds maintenance, while the pipeline maintenance group is likely to use contractors to reline water distribution lines. Equipment maintenance personnel also may use outside contractors for numerous tasks, such as performing high-voltage work on electrical distribution equipment.

Therefore, it is essential that maintenance managers prepare rules and regulations for working with contractors. While using contractors properly is cost effective, failure to prepare adequately to deal with contractors could result in incomplete work, unexpected costs, poor workmanship, and, possibly, legal problems.

Advantages and Disadvantages to Using Contractors

The following are advantages to using contractors:

- Using contractors for maintenance can help to smooth out the “peaks and valleys” in the work load and enable the maintenance department to maintain a constant work force.
- Outside contractors can perform infrequent maintenance tasks requiring specialized skills or equipment.
- The cost may be less if contractors rather than utility personnel perform the work. This is likely if a number of qualified contractors are available to bid on the work, and the utility does not have workers with the proper skills to do the particular type of work required.
- When they are no longer needed, contractors may be easier to terminate than full-time employees (if the contract document addresses this possibility).

However, even if the contracted work goes smoothly, there are disadvantages to using outside contractors for maintenance work.

- Dedicated utility employees are likely to take greater pride than contract employees in a job well done.
- The utility will need to employ contract specialists to prepare effective documents for contract bidding and enforcement.
- The maintenance department will need to employ inspectors to monitor contractors’ work. Experienced senior field personnel may serve in this capacity. However, if so assigned, they will not be available to do the more complex maintenance tasks of which they are capable.
- The contract cost may be high if few contractors are available to bid on the work.
- The control of the work may be less since the contractor’s personnel are not directly supervised by the maintenance department personnel, and the quality of the finished work may be less than expected.

The maintenance manager must assess these advantages and disadvantages to determine if using outside contractors is the most cost-effective way to complete certain maintenance tasks.

Methods of Employing Contractors

After deciding to use outside contractors to do certain maintenance tasks, the next step is to decide how to use the contractors' services. Three types of contracts can be considered.

Service contracts are generally used for work involving both PM and CM. Under this contract, the contractor is required to perform scheduled PM tasks under a fixed price covering both labor and materials. If any problems are uncovered during PM, the contract requires the contractor either to submit a fixed price for completing the repair or to carry out the work at a contractually fixed rate for labor and materials. The latter method, though more difficult to control, permits faster response by the contractor to carry out the repair.

The second type of contract is issued after competitive bidding on a time basis, generally one year, within which the contractor must execute specific work orders for the utility at contractual rates for labor and material. The work is nonrepetitive (not PM), and a price is submitted for each job. The utility has the option of accepting or rejecting the price. The advantages to the utility are that it can get work done fairly quickly without formal bidding procedures and that it has the option of using another contractor (through competitive bidding) if it believes that the price is too high. The contractor becomes an extension of the maintenance work force.

The third type of contract requires that specifications and requests for proposal (RFP) be developed for a particular job. Contractors will submit bids to complete the work. The lowest bidder who is technically qualified is then awarded the contract. This type of contract is generally limited to larger repairs or rehabilitation work.

To be successful, each type of contract must be combined with

- competitive bidding,
- close coordination between the maintenance and purchasing departments,
- effective contract documents, and
- close monitoring by maintenance inspectors.

Because the maintenance manager often can make his or her department more efficient by using outside contractors, it is imperative that he or she learn how to select and work with contractors.

3

Planning a Maintenance Management System

A maintenance management system (MMS) is used to organize the operations of the maintenance department(s) within the utility. Such organization enables maintenance personnel to execute their responsibilities consistently and efficiently while maintaining high-performance standards at a minimum cost. To meet this goal, the maintenance manager must first develop a strategy for planning and implementing the MMS. The strategy should include

- organizing the team that will be responsible for developing and installing the MMS,
- assessing the need for the MMS,
- identifying the costs and benefits of implementing the MMS, and
- establishing a timetable for implementing the MMS.

Developing an effective strategy requires an understanding of what constitutes an MMS.

ELEMENTS OF AN EFFECTIVE MMS

All maintenance management systems should be planned to include certain features, for instance, work orders. However, the designers of such systems need to recognize that the MMS for a particular water utility and its different maintenance operations, such as equipment maintenance, must be tailored to satisfy the specific requirements of that utility.

Functional Responsibilities and Maintenance Management

Rather than develop the MMS from scratch, the maintenance manager usually builds the MMS from the existing maintenance program, modifying features and adding enhancements as needed. Because a utility's different structures and

equipment require substantially different maintenance, the following points should be considered when developing the MMS:

1. Water utilities have different organizations for maintenance as well as different sizes of maintenance departments. For example, while some utilities rely on outside contractors, others tend to be more self-sufficient.

2. The functions of the different maintenance groups require different approaches to maintenance management. The pipeline maintenance crews generally perform more CM than the E/M crews, who devote more time to PM. In addition, the work done by the pipeline maintenance crews is generally better suited for the development of time standards.* Because grounds maintenance crews often do seasonal work, their manager must carefully plan off-season work to maximize the crews' work time.

Thus, maintenance management should form different teams to assess the MMS needs for different maintenance sections and recognize that different maintenance groups may be assessed at different times. Management can evaluate where the need to review the maintenance system is most urgent and concentrate its efforts on that maintenance function.

Key Elements of a Maintenance System

Identifying the key elements of a maintenance system is subjective. However, a review of successful programs (manual and automated) reveals various elements that must be included in a successful system. These are as follows:

Equipment/structure inventory. All equipment and structures that may require maintenance work, either preventive or corrective, must be included in the inventory. It is difficult, even for small water systems, to effectively set up maintenance records if all equipment and structures have not been inventoried as part of the water system components. In most cases, assigning an identification number to each component is also necessary.

For pipeline maintenance, valves, such as those used for isolating stretches of the distribution system, should be numbered to expedite repair of broken waterlines.

For equipment maintenance, a numbering system is essential for developing equipment histories and, for automated MMS, to generate PM schedules and track work orders.

For B&G maintenance, an identification system for buildings will help guide maintenance personnel to the correct job location. This identification system also helps in scheduling future building and room renovations (such as periodic painting).

Work orders. The work order is essential for maintenance management. The work order must include space for

- equipment description and/or location of the problem,
- work to be done (if known) or nature of problem (that is, symptoms),
- work done,
- equipment specifications,
- special tools needed,
- pertinent dates, and
- work hours and crew identification.

*See chapter 4 for information about time standards.

Quite often, an individual who reports a maintenance problem has no way of knowing if maintenance is actually being done. For example, the results of maintenance on a piece of equipment may not be as apparent as the results of a pipeline repair. For this reason, the work-order system should include a means of following up on the status of the work to whoever reported the problem.

Manual and automated work-order systems will be discussed further in the next chapter.

Preventive maintenance. The **only** way to ensure reliable equipment operation is through a consistent PM program, which should cover water pumping equipment, valves for controlling water flow, and building services equipment such as heating, ventilation, and air conditioning (HVAC) units.

For a water utility, PM is the foundation for a successful maintenance program. Effective PM will enable field technicians to spend less time on CM, resulting in a significant increase in productivity. While this is especially true for equipment maintenance, it is also true for pipeline maintenance. Regular maintenance of distribution system valves, as well as periodic updating of system maps, makes the work of pipeline repair crews significantly more effective and productive.

Equipment maintenance crews will find that equipment reliability will be substantially improved with the introduction of a PM program for treatment plant and pumping equipment.

Preventive maintenance involves consistent, prompt completion of regular maintenance tasks. It is comprised of

- maintenance procedures—This involves determining the PM tasks for each piece of equipment based on equipment O&M manuals, experience of plant maintenance personnel, and equipment manufacturers.

Normally, the tasks are categorized as daily, weekly, monthly, quarterly, semi-annually, or annually. Each PM task will require a detailed maintenance procedure (MP). Maintenance procedures detail the correct sequence and method of doing PM on a particular piece of equipment and can be a valuable tool in ensuring uniformity and training new employees to do PM. Figures 3-1, 3-2, and 3-3 display typical MPs for performing PM on the flexible coupling of a motor filtrate pump, on motor control centers, and on slip-ring motors.

Note that the first of these MPs was developed for an automated system, while the latter two are for manually operated systems. 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; skill or trade needed; tools and safety precautions; and complete work instructions. Some of this information, while important, is excluded from the PM data sheet for the manual system in order to simplify the form.

- scheduling—Information from the MP sheets is used to complete the PM schedule, which is typically prepared annually. The PM schedule should balance the work load and should identify critical equipment for PM first, especially if the number of available workers is limited. Additionally, in scheduling critical or more expensive equipment, running time rather than lapsed time should be used.

The schedule should be annually monitored and revised if necessary. Figure 3-4 illustrates a PM schedule developed for a water filtration plant as part of a manually operated PM program.

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, lock, and tag "out of service"		
To inspect coupling:		
<ol style="list-style-type: none"> 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, etc. 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—flexible coupling, motor filtrate pump.

- monitoring—Methods must be developed to ensure that PM tasks are being completed as required and to measure program effectiveness. Methods for tracking both PM and CM are provided in chapter 4.

Feedback and control. This is a frequently overlooked aspect of the maintenance program. The maintenance manager must be able to determine the status of PM/CM work to ensure that PM is being completed as scheduled and that CM is being done promptly. It is futile to issue work orders if they cannot be tracked.

Accountability for resources expended. Readily available, up-to-date data on the use of manpower and materials are needed to justify additional personnel, a greater supply of spare parts or materials, or labor-saving tools and equipment.

Maintenance history. Recording the maintenance history of equipment and structures is a fundamental part of effective maintenance programs. All CM tasks completed and all PM tasks completed for a period of one to three years (depending on PM cycle) should be included.

Preventive Maintenance Checklist		
Work Request No.: _____	Interval: Annually	
Equipment Name: Motor control centers	Equipment Type: 51	
Facility: _____	Bldg./Room: _____	
OK	Not OK	
_____	_____	1. De-energize all circuits before working on equipment.
_____	_____	2. Clean interior by vacuuming.
_____	_____	3. Replace badly worn or pitted contacts as soon as possible.
_____	_____	4. Do not sand silver cadmium contact points of linestarters. 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 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.

A history for equipment and structures such as pipelines should provide vital information about equipment reliability and replacement. However, it is also important, particularly from a cost-control standpoint, to keep accurate records of the work of building maintenance personnel (such as painters and carpenters). Building group managers will find these data very useful when preparing the annual budget.

The elements just listed form the basis for a MMS, which provides efficient, reliable control of maintenance.

Maintenance System Enhancements

A maintenance system that already includes the key elements detailed in this chapter can be enhanced by the following:

- inventory control systems—A basic maintenance system need not include an inventory control system. For example, PM and CM tasks can be performed on a motor control without detailed data on its components, but a parts warehouse cannot be set up without knowledge of the breakers, relays, and protective devices that make up the unit. However, if the maintenance group maintains

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.
_____	_____	4. See that all covers and guards are in good order.
_____	_____	5. Inspect brushes:
_____	_____	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. When a new brush is installed, be sure it is fully seated and free in the brush holder.
_____	_____	e. "Sanding-in" is always necessary to ensure 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.

its own spare parts and material inventory, the effort needed to prepare the equipment history files should be expanded to include the collection of information on the equipment. This will require many more work-hours and may delay the implementation of the maintenance system. (Inventory management will be considered further in chapter 5.)

- a purchasing system—The maintenance system can be designed to interface with the inventory and work-order systems to generate purchase orders. If the utility does not use centralized purchasing, a purchasing system should be considered when developing the maintenance program. If the utility has a separate purchasing department, the maintenance manager should communicate the needs of the maintenance section to the appropriate purchasing personnel.

The maintenance manager must anticipate the purchasing needs of his or her department to fulfill maintenance needs efficiently and should not expect purchasing agents to know which parts are easily accessible and which are difficult to obtain. Proper communication is the key to having the right parts at the right time.

Preventive Maintenance Schedule

Potomac Water Filtration Plant

Month/Task	Interval
January	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Brushless Motors, Group B	Monthly
Brushless Motors, Group C	Quarterly
Slip-Ring Motors	Quarterly
Rectifiers	Quarterly
Kingsbury Bearing Cooling Water System	Quarterly
Transfer Switches (Motor Control Center-1)	Quarterly
Motor Control Center A	Semiannually
February	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Slip-Ring Motors	Monthly
Rectifiers	Monthly
Brushless Motors, Group B	Monthly
Brushless Motors, Group D	Semiannually
Motor Control Center B	Semiannually
5V Switchgear	Semiannually
March	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Brushless Motors, Group B	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Slip-Ring Motors	Monthly
Rectifiers	Monthly
Traveling Screens	Semiannually
April	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Brushless Motors, Group B	Monthly
Brushless Motors, Group C	Quarterly
Slip-Ring Motors	Quarterly
Rectifiers	Quarterly
Kingsbury Bearing Cooling Water System	Quarterly
Transfer Switches (Motor Control Center-1)	Quarterly

Figure 3-4 Preventive maintenance schedule—Potomac Water Filtration Plant.

- performance and productivity reporting—Many organizations have incorporated performance and productivity information into their MMS. The MMS developed by the WSSC for its distribution system maintenance crews gathers such data, and the WSSC has obtained useful information on the use of pipeline maintenance personnel through data gathered by its MMS.

However, obtaining this information does require establishing standard work data, such as time standards and job procedures, which can be costly and time-consuming. This is particularly true for E/M work and, thus, equipment maintenance work in general. In addition, a computer is needed to process data. Therefore, it may be prudent to use performance and productivity reporting only in the later phases of the maintenance program and then only after completing a careful cost-benefit analysis. Chapter 6 contains more information on this subject.

- management reports—Some management reports, such as for system control, are essential to a successful maintenance program. However, once a data base is established, additional reports can be prepared by and for the maintenance manager. This is particularly true if the recordkeeping part of the maintenance program is automated. It is likely that the manager will insist on supplementary reports as experience with the system grows. For example, the performance of crews can be compared if appropriate data are gathered and analyzed.

PLANNING THE SYSTEM

After determining that changes are needed to make the maintenance system operate more effectively, the maintenance group manager must convince senior management that the effort and funds needed to implement the modifications are justified.

Gaining Management Approval

While one of the maintenance manager's primary responsibilities is to provide for reliable equipment operation, this goal cannot be achieved without a well-planned maintenance program. However, it is difficult to place a monetary value on improved reliability. Thus, while upper management will acknowledge the importance of dependable equipment operations, this factor alone may be inadequate to justify the expenditures necessary to establish or modify a maintenance program. The maintenance manager may argue many ways of how an effective maintenance management program can contribute to smoother operation of the entire water utility. The following are some of the most important justifications for establishing a MMS:

Safety. An effective maintenance program is the first step to employee safety. If breakdown maintenance is the normal mode of operation for equipment, field crews are frequently forced to work under pressure to return equipment to service as soon as possible. Employee safety may be compromised in this situation. While an effective maintenance program will not completely eliminate emergency equipment repairs, it will reduce their frequency, and a safer work environment will result.

This same principle holds true for pipeline maintenance crews, despite the high percentage of emergency repairs. The work of these crews is difficult in any case. However, if valves are inoperable or impossible to locate, their work becomes substantially more time-consuming and, because of pressures to complete repairs quickly, more hazardous.

Employee morale. The field mechanics' morale will deteriorate if they are constantly responding to emergencies rather than completing their work in an orderly manner. A maintenance supervisor once pointed out how frustrating it is for an equipment crew to begin a job and lay out the tools and spare parts needed, only to be called to an emergency situation elsewhere. It is likely that the group manager will eventually lose the respect of the field mechanics if steps are not taken to control the number of emergency jobs.

Plant operations. Without a MMS, larger maintenance organizations will find it difficult to gather the data necessary to control operations. Senior management recognizes the need for accurate data, and only a good MMS will ensure that this information is collected.

Other reasons for a MMS. Planned maintenance will also result in reduced breakdowns, decreased equipment downtime, increased equipment life, and reduced personnel needs (overtime).

The results from establishing an effective MMS may not be measurable for several years. In fact, the maintenance costs involved in establishing the MMS are likely to be high until the benefits outlined above begin to have an impact. However, the benefits are clear, and they can help convince management to take a fresh look at the maintenance operation.

However, it is possible to estimate the savings in labor costs realized through increased productivity resulting from the maintenance program. A conservative estimate of this increase is 5 percent, based on the experience of two of the E/M zone offices of the WSSC. Reductions in the number of employees of 6 to 8 percent were realized despite the addition of approximately 5,000 PM work orders per year within three years of the start of the maintenance management program.

The experience of other organizations has been similar. Savings can also be expected in overtime, materials usage, and use of outside contractors.

Finally, the advent of powerful microcomputers and canned maintenance management system software has resulted in dramatic cost reductions for implementing an effective program. While the cost of installing an automated system to support the maintenance group may have been inordinately expensive for many water utilities 15 years ago, the hardware and software can now be purchased for much less.

An effective maintenance program is within the reach of virtually every maintenance group. The maintenance manager can now present sound reasons for undertaking the effort.

Forming a Planning Team

After senior management approves funding for the project, the next step is to determine how to plan and implement the program. A planning team must be formed to propose modifications for the maintenance department.

This team needs to have technical and financial capabilities with input from other departments, including purchasing, personnel, and data processing. In addition, the team's makeup will depend on which maintenance components need to be addressed. For example, if the team will study the maintenance needs for filtration plant and pumping stations, one member should be an equipment maintenance specialist. A civil engineer with experience in distribution system valves is a good candidate for investigating the requirements for pipeline maintenance.

A proposed list of team members to examine the needs for an equipment system includes

- a financial analyst—This position could be filled by the utility's financial department, the maintenance department, or an outside consultant. This individual would be responsible for investigating implementation costs and carrying out cost-benefit analyses if required.
- a maintenance engineer—This individual should be from the maintenance department and must understand maintenance operations. He or she would be responsible for developing the technical needs of the department with respect to maintenance and would coordinate activities with other departments. This person is a good candidate for team leader.
- a senior maintenance technician—One of the experienced field personnel (either a line supervisor or crew leader) should be on the team to represent the field personnel's viewpoint regarding the practicality of any proposed change. For example, additional paper work requirements may elicit negative reactions from technicians unless they are explained and justified.
- an operations representative—Since operations personnel may carry out minor actions as well as report maintenance problems, an operations representative should be on the team to help with the development of distribution and plant equipment maintenance systems. This way, any disagreement on responsibility can be resolved before the system is installed.

The team proposed above represents one scenario for planning the maintenance system. However, such a team may not be necessary for a small water utility or if only modest changes are being considered. Whether they are large or small, modifications must be carefully planned according to how the maintenance department operates.

Implementation Steps

The planning team's first task is to determine the steps needed to implement the maintenance system. The following steps should be part of any program, no matter what its magnitude:

1. Assess needs.
2. Design the maintenance system so that current procedures are integrated with proposed changes.
3. Establish an implementation schedule.
4. Determine the training needs.
5. Test proposed changes on a small scale if necessary.
6. Implement the system.
7. Evaluate the new system's effectiveness.

These steps will help the team organize and set up standards by which to measure progress.

Needs Assessment

The team should begin the assessment process by agreeing on what kind of program presently exists, listing the strengths and weaknesses of the current program, and deciding what kind of system is required to satisfy the maintenance function needs. For example, is the work-order system adequate, does it record appropriate information, and does it permit easy follow-up for monitoring purposes?

The team should also identify the organization's characteristics, including

- plant size,
- workers and skill levels available,

- complexity of plant operation,
- variety and number of equipment,
- available budget for development and implementation, and
- number of sites.

The planning team also should evaluate the maintenance needs for each of the following factors. One approach is to prepare a list of issues that need to be resolved for each factor. The following is an example list:

- institutional support—How will senior management be involved in the program?
- system maintenance—Are responsibilities for maintenance tasks well defined?
- spare parts and materials—Is the supply of spares adequate? Is coordination among maintenance, purchasing, and warehousing satisfactory?
- logistics—Are the number and type of vehicles available for maintenance sufficient to support any program changes?
- finance—What level of funding is available to support changes in maintenance operations?
- records—What records are needed, and can they be obtained through current data collection techniques?
- human resources and training—Are existing training programs adequate? Is manpower available to support modifications in current operations?

Only after completing this study can the team begin to define what changes must be made to improve the maintenance operation.

After reaching a consensus on potential solutions to identified problems, the team may find it necessary (because of funding limitations) to prioritize proposed modifications to the maintenance system and to propose an implementation schedule that is phased in over several years.

Certainly, one of the major issues facing the team will be whether to use computers and where their use to facilitate operations is justified.

Automated and Manual Maintenance Information Systems

A small- to medium-sized water utility operating a single treatment facility can realistically expect to achieve a satisfactory level of maintenance with a manual information system. However, a maintenance group responsible for large or multiple facilities may require an automated system to gather and report the information necessary to control the maintenance effort. For example, substantial clerical effort would be needed to provide data on PM versus CM work-hours used or on the cost of maintenance. Yet, today's maintenance managers cannot manage without these data. Computers enable managers to receive frequent updates on their operation, which enables early identification and correction of potential problems before they become more serious. Relatively inexpensive microcomputers and off-the-shelf software have made automation a reasonable alternative for water utilities of all sizes.

After initially determining where computers could fit into the maintenance operation, the planning team should "shop" available software to determine if a package exists to satisfy its requirements. Examples of automation appear throughout this manual, particularly in the chapters dealing with information processing.

4

Information Management and System Monitoring

Accurate, timely information is essential for effective maintenance management. Consequently, one of the first steps that the planning team should take is to assess the accuracy and completeness of the data that the utility has on file for its equipment, pipelines, and buildings.

EQUIPMENT AND STRUCTURE RECORDS _____

The most essential information that needs to be recorded relates to the equipment used to process and treat water and to the pipelines and valves that make up the distribution network. Recording such information serves two purposes—one is to maintain data on hardware (equipment and structures) specifications, and the other is to keep a written history of maintenance activities. If the planning team determines that the necessary data are not available or are incomplete with respect to specifications, the first task in implementing the maintenance program is to gather the data.

Water System Inventory

A maintenance department cannot operate without information on the hardware that it is required to maintain. Therefore, the maintenance manager should begin to gather the necessary data (if they do not exist) even if senior management has not yet approved proposed modifications to the maintenance program or if a planning

team has not yet been formed. To help him or her with this often lengthy process, the maintenance manager should enlist the help of in-house staff who can record data as they work or during slack periods. This could save money as well as take advantage of the knowledge and experience of field personnel. Before beginning this task, however, the manager needs to decide what hardware should be inventoried first, what data need to be recorded, and, finally, how the information is to be filed.

Equipment inventory. Equipment that is critical to the water treatment and delivery process should be inventoried first. Of primary importance is such equipment that is not supported by standby capability. Data collected should include

- manufacturer and local supplier,
- dates of purchase and installation,
- model name and number,
- serial number,
- location, and
- specifications.

This information is recorded on an appropriate data sheet (such as the one shown in Figure 4-1 for electric motors). The data sheet is then stored in the equipment data file.

Distribution system inventory. Many water utilities use maps to record inventory data on the distribution system. These maps show the location of pipelines and water valves based on a grid system. For example, the WSSC uses a map book distributed by a local firm to identify a particular location within the distribution network. For each distribution section, a map details pipeline size and approximate location as well as the location of valves with respect to nearby landmarks. Field crews can use these books to locate valves and isolate sections of the distribution system if, for example, repairs are needed because of a water main break. Figure 4-2 shows an example of the “page and grid” book.

Water meters. Water meters require special consideration because they are important to the revenues of the utility and their PM cycle is measured in years, rather than in weeks or months. Particularly in larger utilities, a separate group within the maintenance department is frequently responsible for maintaining water meters. However, the maintenance system for the meters is similar to that used for other water utility equipment.

Fire hydrants. Because fire hydrants are an integral part of the service provided by the water utility, they must be included as part of the inventory. Data need to be collected on location, manufacturer, size, and date placed in service. A gridded map system can be used to chart their location, or, because the hydrants are aboveground, intersecting roads can be used to indicate their approximate location.

Equipment Files

Equipment data should be filed in equipment history files that include O&M manuals, history of CM activities, and PM requirements. Similar records should be kept for valves, meters, and fire hydrants. For pipelines, a history of CM work is the primary file entry. This information will help identify sections of the distribution system that are particularly prone to breaks and should be considered for replacement.

Equipment Data Sheet

Electric Motors

<p>Identification</p> <p>Name: _____</p> <p>I.D. No.: _____</p> <p>Model Name: _____</p> <p>Model No.: _____</p> <p>Serial No.: _____</p>	<p>Location</p> <p>Zone: _____</p> <p>Site: _____</p> <p>Process: _____</p> <p>Installation Date: _____</p>
<p>Specifications</p> <p>Motor Type: _____</p> <p>Horsepower: _____</p> <p>Volts: _____ Amps: _____</p> <p>Phases: _____ RPM: _____</p> <p>Power Source:</p> <p style="padding-left: 20px;">Utility: _____</p> <p style="padding-left: 20px;">Feeder No.: _____</p> <p>Driven Unit: _____</p> <p>I.D. No.: _____</p>	<p>Acquisition</p> <p>Date Purchased: _____</p> <p>P.O./Contract No.: _____</p> <p>Manufacturer: _____</p> <p>Local Suppliers:</p> <p>_____</p> <p>_____</p> <p>_____</p>
<p>Other Information</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>	

Figure 4-1 Equipment data sheet—electric motors.

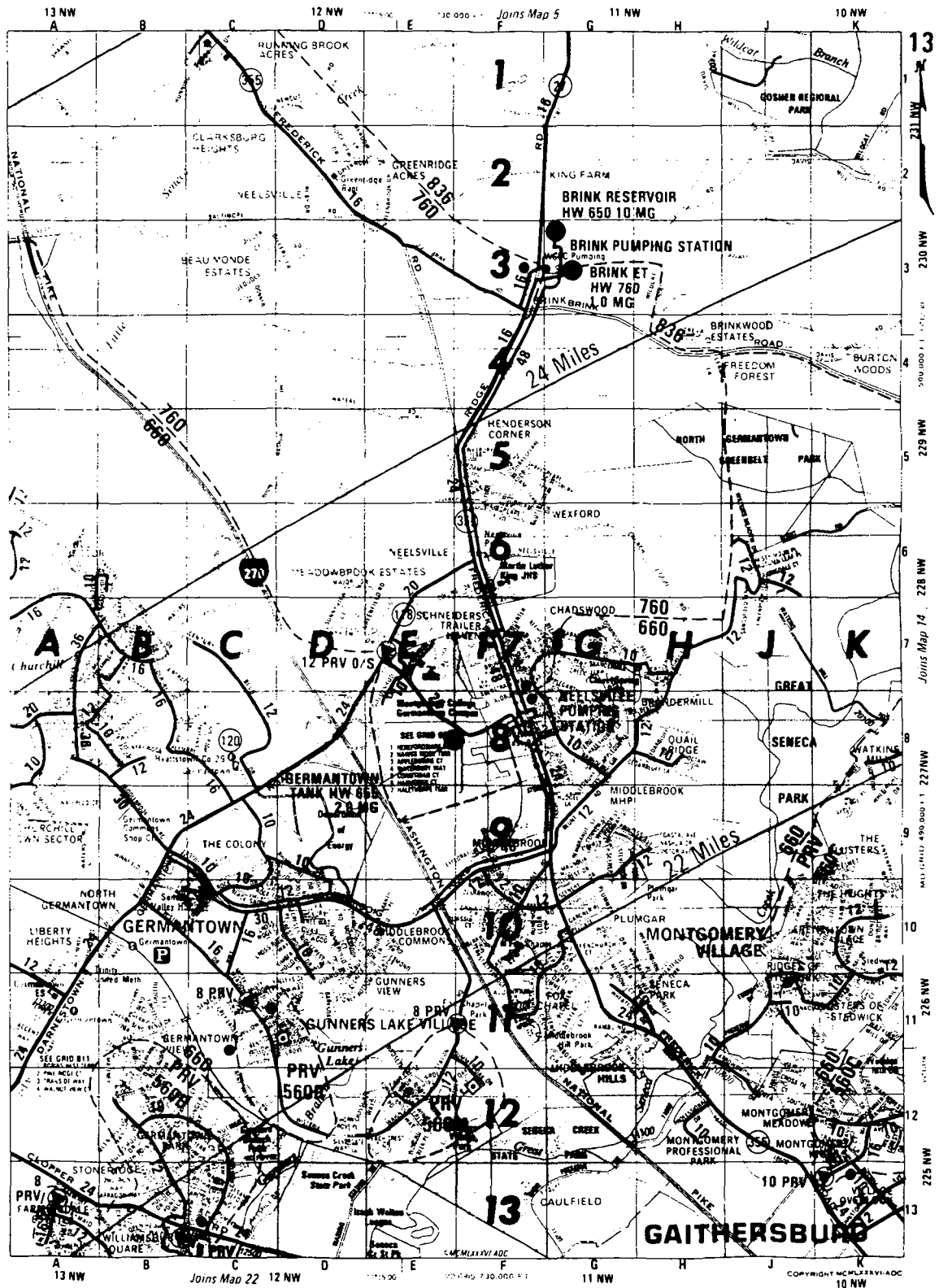


Figure 4-2 Page/grid map.

Equipment Identification Number

Each piece of equipment should be assigned an identification number to tie it to the information about its maintenance functions stored in the equipment record file. Because the identification number significantly impacts the development of management reports and the ability to access data for other purposes (for example, parts inventory), the planning team should establish a numbering scheme suitable for its utility. For instance, to identify E/M, the team could choose to number each piece of equipment sequentially as it is inventoried or to categorize equipment based on location, process type, and particular unit. Though easy to implement, the sequential numbering technique is not likely to satisfy the needs of maintenance management, especially if the utility uses an automated information system.

The following example illustrates the identification number of the electric motor driving finished water pump no. 2 for a utility with a number of plant and pumping station sites:

001—13—03—2

For this numbering scheme,

- the first three digits identify site location of equipment,
- the second two digits identify equipment type,
- the third two digits identify process type, and
- the last digit identifies a specific piece of equipment.

The number of digits used for each category could be expanded or contracted depending on the size of the utility's operations. Smaller utilities with one plant site would be able to use fewer digits. The planning team should begin with a system that is suitable for use with an automated MMS, even if initial plans call for a manual MMS.

WORK-ORDER SYSTEMS

One of the prime requisites for an effective maintenance management program is a work-order system covering all work done by maintenance department personnel. For example, tracking PM work is virtually impossible without work orders. In addition, work orders provide the data required to build the history segment of the equipment file. Each of the software programs listed in the appendix includes work orders among its features.

Each of the maintenance functions described in chapter 1 has different requirements for a work-order system. For example, the majority of requests for distribution system maintenance originate from customers or the general public by telephone. In addition, action taken to respond to each call is generally apparent to the originator of the complaint (for example, the repair of a leaking valve or flushing of a fire hydrant to clear cloudy water).

On the other hand, reports of problems to the equipment maintenance group generally originate from within the utility itself. For equipment repair work, the action taken by maintenance crews is sometimes not apparent. Thus, the work-order system should incorporate a means of reporting back to the department or individual who reported the problem.

Work-order systems are also needed for B&G maintenance activities. Since requests for service usually originate from within the utility, the work-order requirements parallel those for equipment maintenance, with one exception. Because the B&G group is normally responsible for maintaining grounds, if this work is not done promptly, the public is likely to complain. Thus, the B&G work-order system should be designed to address this.

Work-order systems must be tailored to effectively support particular maintenance activities. Descriptions of different types of manual and automated work-order systems are provided below.

Manual Work-Order Systems

Manual work-order systems are feasible for all sizes and types of water utilities. The advantages of nonautomated systems are

- they can be developed in-house,
- they can be implemented quickly,
- they are relatively inexpensive to develop, and
- they can be designed for conversion to automated systems when appropriate.

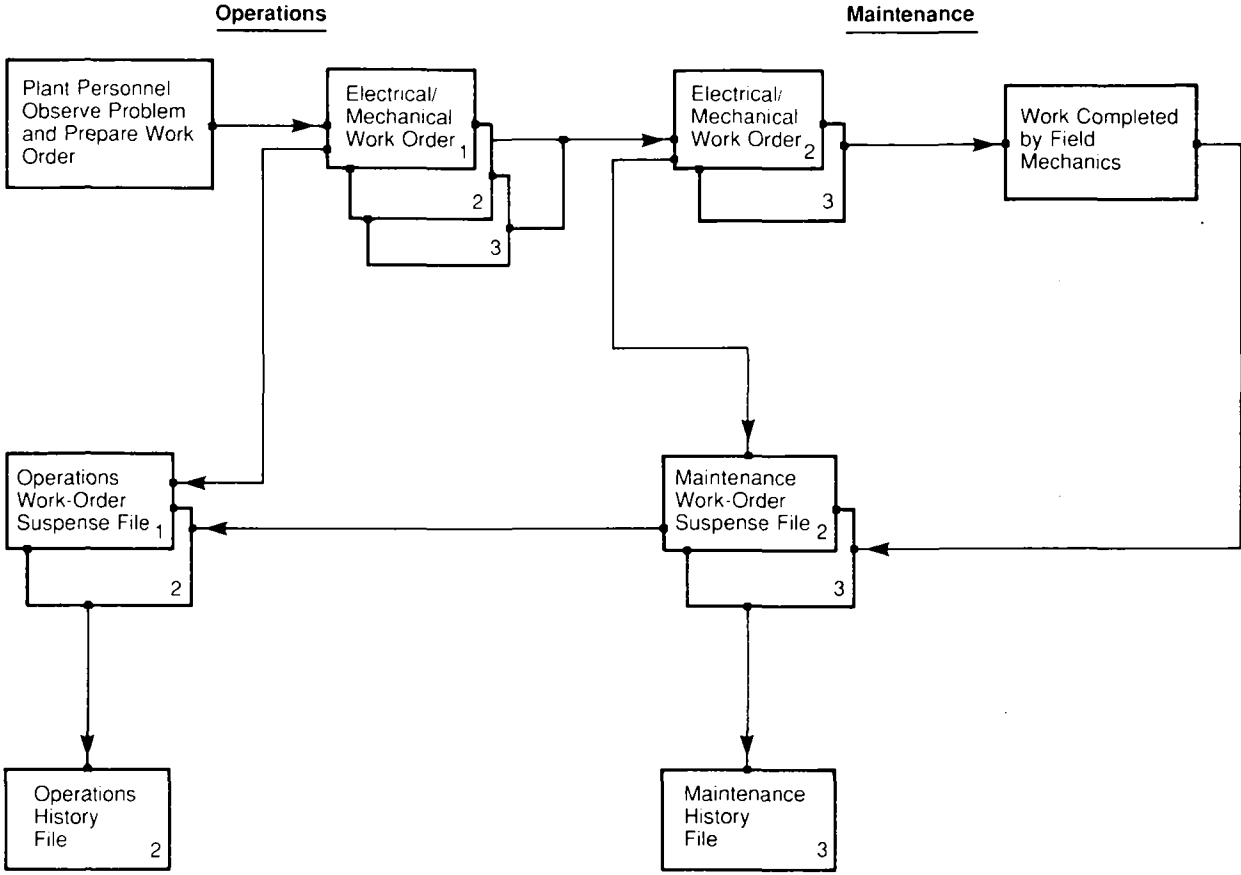
Their disadvantages, particularly for large systems, are

- the impracticality of covering all equipment in a PM program,
- the limited number of management reports that can be prepared using this type of system, and
- the difficulty in effectively using the information in the history segment of the equipment file.

The first step in developing the work-order system is determining how to monitor information from the time a maintenance problem or need is identified until all related tasks on the work order are completed. For example, how will operations personnel complete equipment maintenance work? Can PM and CM work be covered by the same form? Will the work-order system be capable of tracking work? Figure 4-3 shows a flow chart of the manual work-order system used by one water utility for its equipment maintenance activities.

The flow chart displayed in Figure 4-3 is for nonemergency CM work. However, the same work order can be modified to handle emergency and PM work. Using the work-order form shown in Figures 4-4 and 4-5, PM work can be handled by discarding the first copy of the three-part form. Also, emergency work can be handled by issuing field mechanics a field work order using the same work request number as shown in the upper right-hand corner of the work order (Figure 4-4). Information from the field work order is entered on the work order itself when it is received from operations personnel. This approach enables operations to receive the same information feedback as they do with nonemergency work.

To track work orders, each work request is assigned a work-order number, and this number is entered into the work-order logbook. Figure 4-3 shows an excerpt from the logbook. When work is completed, the work order is closed out in the logbook. Reviewing the logbook regularly will enable management to pinpoint maintenance tasks, both CM and PM, that are not being promptly completed. However, because such review will consume much clerical time, especially in a large utility, using computers to manage the work-order system should always be considered.



NOTE: Operations can discard copy 1 since copy 2 shows work done plus the data on the top part of copy 1.

Electrical/Mechanical Work-Order Log							
Work-Order Number	Date Received	Priority	Work Req. Number	Work Description	Location	Work Hours	Date Finished

Figure 4-3 Corrective maintenance work-order flow and work-order logbook.

Equipment Maintenance Work Order			
INSTRUCTIONS: 1. Fill out only unshaded areas. 2. Keep first copy. 3. For emergency work, give copies 2 and 3 directly to E/M field supervisor. For lower priorities, send copies 2 and 3 to E/M office.			
	Equipment Name	Location (facility name and building)	32440
Equipment I.D. Code	Work Required		Priority
Indication of Trouble		When Problem Was Discovered Starting ____ During Oper. ____ Stopping ____ During PM ____	
Special Instructions			Time Problem Observed ____ AM ____ PM
Reported By	Phone No.	Date of Report	
ELECTRICAL/MECHANICAL WORK REQUEST			Copy 1—ORIGINATOR

Figure 4-4 Equipment maintenance work order—copy 1.

Automated Work-Order Systems

Numerous automated systems have been developed to replace manual work-order systems. For example, a recent issue of the *Journal of the American Institute of Plant Engineers* (1987) compared nearly 100 maintenance management software packages, listing each one's features. Many of these systems can be adapted for water utility use. Certainly, one of the most important functions of the planning team will be to decide if an automated system is justified. Also, the team must determine what part of the maintenance information system should be automated.

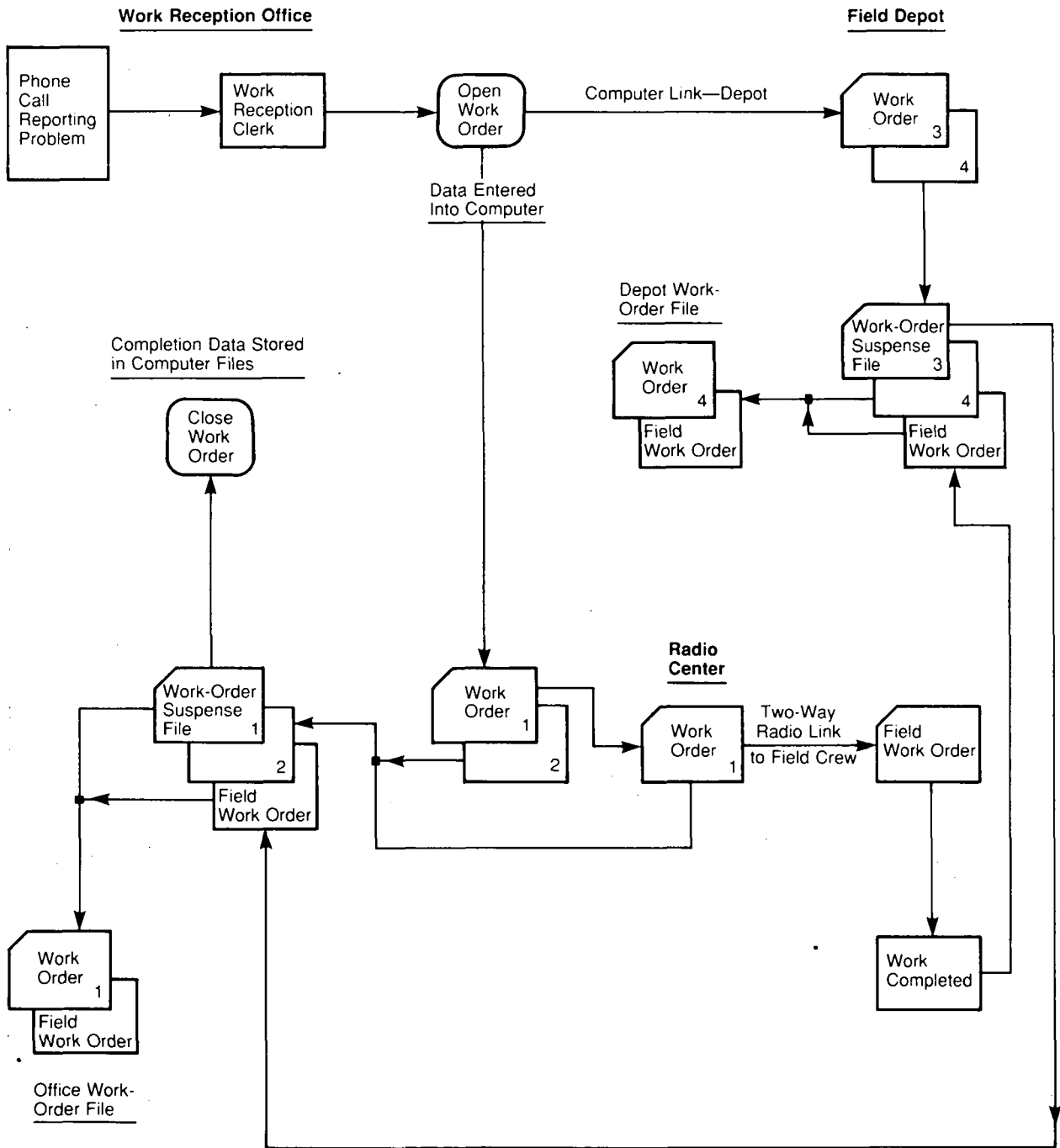
As with a manual system, an automated work-order system must accommodate the different work-order needs of a maintenance group. Figure 4-6 shows the evolution and flow of an automated work order for a maintenance section responsible for the distribution system. This work-order system originally used the computer only to record data on work-order activity. Then, it used the computer to print work orders at the central office. The current system permits work orders to be printed in the appropriate depot.

The next step for this system was to establish the capability to enter data to the work-order file and to close out the work order from the depot.

When the utility decided to maintain all customer files in one central area, the field work order was delivered by internal mail to the reception office. One reason for this decision was the need for the utility's legal department to have easy access to customer files containing maintenance information. Another reason was that work orders prepared and signed by field personnel may be needed to defend against lawsuits involving, for example, alleged negligence by the utility.

Equipment Maintenance Work Order						
Reported By	Phone No.	Date of Report	Source Code	Account No.	Issued To:	Total Hrs. Used
Date Work Req. Rec'd.	Is Additional Work Req.? Yes _____ If yes, see No _____ work order.		Has Work Been Delayed? Yes _____ If yes, why? No _____		Est. Start Date	
Cause of Problem						
Work Performed						
						Date Repair Was Completed
ELECTRICAL/MECHANICAL WORK REQUEST				copy 2—SUSPENSE		
Reported By	Phone No.	Date of Report	Source Code	Account No.	Issued To:	Total Hrs. Used
Date	Crew No.	Work Done			No. of Workers	No. of Hours
Completed By		Date Comp.	Additional Work Required			
NOTE: List all parts or materials ordered on the back of this form.						copy 3—MECHANIC

Figure 4-5 Equipment maintenance work order—copies 2 and 3 (bottom sections).



NOTES: 1. Copy 2 is not needed after copy 1 returns from radio center and is discarded.
 2. Field work order is used for emergency work only. Copy 4 replaces it for nonemergency work.

Figure 4-6 Work-order flow—distribution system maintenance (emergency work).

Figure 4-7 displays the work order printed after the work-order clerk enters the required information into a computer. The work-order form is menu driven for easy use. By prompting the clerk to enter the needed data, it ensures that all entries are made, particularly if a telephone call from outside the utility reported the problem. Various codes are used to identify the nature of the problem, its location, and the type of crew needed to investigate it.

All the information needed to produce the work order in this automated system could have been generated manually. However, the ability of the automated system to handle an increasing number of work orders without adding staff, plus the need to manage a large amount of data, influenced this utility to implement an automated work-order system.

MAINTENANCE WORK HISTORY ---

Criteria for Retaining/Discarding Work Orders

Since any maintenance group will generate quite a large number of work orders, the planning team needs to consider what information should be retained in the maintenance history file. While the simplest method is to keep all work orders, this is not a good long-term strategy. The individual files will be more difficult to use because of their bulk, and, sooner or later, the files will have to be purged of information that is no longer useful.

A better strategy is to establish criteria for retaining or disposing of completed work orders. Since the type of work done by the three maintenance sections discussed in this manual differs significantly, their needs for work-order records will be reviewed separately.

Distribution system. This group's work falls into the following three categories:

- responses to customer complaints, for example, cloudy water;
- preventive maintenance on distribution equipment, for example, valves and fire hydrants; and
- corrective maintenance on the network that is not related to a specific customer, for example, broken main-line pipes.

As a general rule, work orders related to customer complaints should be kept indefinitely, while those generated for PM work may be discarded after two to three cycles of the PM schedule are completed. For example, if the main-line valves are scheduled to be exercised yearly, then PM work orders for this work may be discarded after two years.

The hard copies detailing customer service should be retained in the active history file for several years or until a particular problem is resolved (for example, renewing water service in response to a complaint concerning a water leak). Work orders should then be transferred to and stored in the utility's archives. In addition, if the utility's record system is automated, data on maintenance activities for a particular customer can be stored on a computer file for easy reference by service representatives. Figure 4-8 shows the output from the maintenance service file.

For network CM, work orders should probably be retained for at least five to seven years after incidents occur or until the section of pipeline is replaced. For legal reasons, the utility's legal department should be consulted before disposal criteria are established.

Customer Work-Order History				
12/20/88				
Account: 60237721 00 0				
WORK- ORDER NO.	WORK DESCRIPTION	STATUS	DATE RECEIVED	DATE COMPLETED
8799629	REPAIR BROKEN MAIN	F	12/03/88	12/04/88
7707292	REPLACE METER—NR	F	10/19/87	11/24/87
6676126	SOD R/W	F	09/16/86	10/29/86
5577051	REPLACE METER—NR	F	09/30/85	12/02/85
3839289	REPLACE METER—NR INSIDE	F	11/01/83	11/22/83
3808516	REPLACE METER—NR INSIDE	F	09/01/83	10/11/83
3253812	CLR. SEW. MAIN—SER. IN MH	F	04/21/83	04/21/83
2482107	INSPECT LEAKING HYDRANT	F	10/05/82	10/06/83
8678351	INSTALL METER NEW	F	12/25/78	12/19/78
8339475	INSTALL CURB BOX	F	09/20/78	09/27/78

Figure 4-8 Data printed from history file.

Equipment. Since the majority of the work done by the equipment group will be PM (if the maintenance system is operating effectively), regularly purging the history files of older work orders is important. This is done to keep the size of the equipment file at a reasonable level. The same rules should apply for plant, pumping station, and distribution system equipment.

For CM work orders, the best approach is to retain for two to three years those work orders resulting from normal wear while keeping indefinitely those relating to unexpected wear. For example, if a manufacturing defect is suspected, work orders on the piece of equipment in question must be kept until the issue is resolved.

Once a piece of equipment is replaced, work orders for it can be discarded (unless legal questions remain). However, for future reference, it is prudent to retain the equipment file with perhaps a summary of the performance of the equipment noted. Such information may be useful for maintenance work on similar equipment or for the purchase of future equipment.

Building and grounds. Building and grounds maintenance records are kept primarily to schedule work so that the integrity and aesthetics of the utility's properties are properly maintained. Such records may help support or deny requests for renovations from other departments. The section manager also may use them to prepare contracts for grounds maintenance by establishing schedules for services (for example, grass cutting or fertilizing).

Corrective maintenance work orders can be kept for several years unless legal questions arise. For example, if injuries result from a hazard in a building, the maintenance group's response time to the problem is likely to be important.

The planning team should review with the utility's legal staff any criteria it establishes for retaining or discarding work orders. The team also should ensure that these rules satisfy the needs of the maintenance group as well as those of other departments.

MANAGEMENT REPORTING

Management at all levels of the utility must be kept informed of maintenance activities. Regular reports should be made to management to ensure that maintenance work is being carried out as required, to keep management informed of

particular problems, to keep maintenance high on the list of management priorities, and to encourage senior management to demonstrate interest in maintenance activities by intervening in selected maintenance actions. Management reports are also used to track maintenance costs.

Types of Management Reports

The types of management reports needed depend on the maintenance function involved, the level of management that will receive the report, and the type of maintenance system installed. An automated system will enhance the maintenance manager's ability to gather and analyze data. Typical reports include

- number of CM actions taken for the month;
- number of CM work orders originated during the month;
- number of PM actions taken for the month;
- backlog of PM and CM work orders;
- work orders started, but not completed, by priority;
- maintenance costs for various categories;
- manpower utilization;
- manpower hours used for the month;
- various types of exception reports; and
- spare part availability.

For example, Figure 4-9 is an excerpt from a report listing all CM work orders not completed during the previous month in WSSC's Parkway equipment maintenance zone.

While reports contribute to the effective management of the maintenance section, each one costs money to produce. Therefore, the planning team and the

ZONE/PLANT: 211		Plant Maintenance Management System			RUN DATE: 10/27/88	
ZONE NAME: PARKWAY		Part 1—Corrective Maintenance			RUN TIME: 17:55	
Not Completed By 10/27/88						
WORK- ORDER NO.	EQUIPMENT I.D. NAME AND LOCATION INFO.	PRIORITY	DATE REQ.	REQUEST	CORRECTIVE WORK REQ.	MALF. NO.
003265	33-01110302 FINISHED WATER PUMP 2	A03	10/13/88	REMOVE, WORN	REPLACE VALVE	001552
003270	22-01111803 LIME SLAKER # 1, MIXER # 3 MOTOR	A03	10/15/88	CHECK, NOISY	REPLACE MOTOR	001564
003274	45-01121602 HEAD HOUSE UNIT SUBSTATION	A03	10/15/88	INSTALL	TEST ALARM	001568
003280	28-01134401 CLARIFIER DRIVE 1A MOTOR	A03 A03	10/16/88 10/18/88	REMOVE, INOPERATIVE	REPLACE MOTOR	001588

Figure 4-9 Part 1—corrective maintenance not completed by specific date.

maintenance manager should review each report carefully to ensure that the expense is justified.

The planning team should determine the information needs of the different levels of management. The maintenance section itself will need a list of all work orders generated and completed during the month, plus cost and monitoring data. Upper management will need only a listing of the total number of work orders started, data on the backlog of CM and PM work, and information on expenditures. Senior management will also be interested in employee productivity and utilization if the MMS is designed to provide such data. Generally, management at all levels is interested in trends, that is, changes from the status quo. The information system should address the following questions at a minimum:

- Is the number of PM and CM work orders carried out increasing or decreasing?
- Is the backlog of work remaining constant?
- Is the ratio of PM to CM work changing?
- Are costs related to maintenance rising? If so, why?
- Are top-priority jobs being completed promptly?
- Are customer complaints increasing? If so, in what areas?

The flow of information is not a one-way street. Feedback from management is vital for the success of the maintenance program. Unfortunately, however, senior management often lacks the time to review each and every report. A common solution is to have maintenance management forward exception reports to upper management. Exception reports detail deviations from normal performance and include a description of the reasons for the changes. For example, it makes little sense to transmit detailed data on CM work orders to upper management. However, management will want to know if and why the number of CM jobs is steadily increasing. Thus, management can respond to maintenance management on specific issues without having to waste time reading detailed reports.

MAINTENANCE MANAGEMENT SYSTEM MONITORING TECHNIQUES

Monitoring MMS performance serves four functions: (1) to ensure that work is carried out in a timely manner, (2) to ensure that no work is unaccounted for, (3) to provide the data needed to track maintenance costs, and (4) to provide a means of assessing maintenance group performance.

Monitoring reports themselves fall into two categories: reports to track the work itself and, particularly for automated MMSs, reports to check the entry and processing of data within the information system. As noted before, manual systems have limited monitoring capabilities because of the time it takes to process data. However, system control is still needed, and techniques have been developed to monitor such systems.

Work-Order Priority

The work done by the different maintenance sections is not of equal importance. Some work must be done immediately, while less urgent work can be delayed for weeks or even months. Between these extremes are jobs that are not of an emergency nature but which cannot be delayed for extended periods. Since the

monitoring system must be able to differentiate among these jobs to ensure appropriate response times by the maintenance crew, a work-order priority system needs to be established. By assigning jobs a priority number, maintenance management can track work to make sure that the highest-priority situations are being addressed expeditiously. The equipment maintenance section of the WSSC established the following priority system for its work:

Priority	Description
1	Work must be done within 3 days. All emergency work is in this category.
3	Work must be done within 7 days.
4	Work must be done within 30 days.
5	Handle as available manpower permits.
7	Cannot start.

This numbering scheme was developed for a manual system, and it was felt that additional categories could not be easily analyzed with a manual MMS. However, gaps between priorities 1 and 3 and priorities 5 and 7 were made to allow for greater differentiation when the MMS was automated. The no. 1 priority may be misleading since emergency work is always started as soon as possible. Generally, the no. 7 priorities are used when work cannot begin because needed spare parts or supplies are unavailable.

While the work priorities established by a utility may vary from the WSSC's scheme, the maintenance group must establish some system. Tracking all levels of work is vital. While addressing the no. 1 priority is most critical, it is also important not to build up a large backlog in the other categories. Work that is of lower priority today may become emergency work tomorrow; thus, the reason for the increasing backlog must be quickly resolved.

MAINTENANCE MANAGEMENT SYSTEM CONTROL

Both manual and automated maintenance management systems need to have mechanisms or controls to maintain the integrity of system data. Since the automated system eases data processing, the method of control used will normally be more comprehensive, permitting greater control over maintenance work than is feasible with manual data control techniques.

Manual Systems

The primary tools for monitoring manual systems are the work order and the log-book. Each maintenance manager needs to establish monitoring reports for his or her section within the section's clerical limitations. The examples of typical monitoring reports cited here are designed to satisfy the four purposes of a monitoring system described earlier in this chapter. The most important of these reports is likely to be that which ensures that all work is accounted for.

The form illustrated in Figure 4-10, which combines raw data on work orders written during the month, is an example of this type of report. This form lists all no. 1 priority jobs that were started but not completed, as well as all no. 3 priority

Work-Order Summary

Maintenance Depot _____ Month _____

	PM	CM
Number of work orders outstanding from last month.	_____	_____
Number of work orders started this month.	_____	_____
From E/M.	_____	_____
From operations.	_____	_____
Number of work orders originating this month but not completed.	_____	_____

Incomplete Work Orders

Work-Order Number	Date Opened	Reason for Delay	Expected Completion Date
Number 1 priority work orders not completed this month.			
Number 3 priority work orders not completed from previous months.			

Figure 4-10 Work-order summary.

work that remains undone from previous periods. The work-order summary report such as the one in Figure 4-10 is a combined listing of work accomplished during the period as well as a monitoring document for the highest-priority CM work orders. If time and staff permits, similar reports can be prepared for other CM work.

The portion of the work-order summary report that deals with specific uncompleted jobs is an example of an exception report. This type of report, which reports data only on work outside of normal completion standards, is particularly valuable for manual MMSs because it can be prepared easily by scanning the work-order logbook. For the example shown in Figure 4-3, neither of the work orders entered into the logbook would have been listed in the summary report since they were completed in a timely manner.

Since PM is critical to a successful maintenance program, special reports should be developed to monitor PM. Figure 4-11 shows a report developed by the WSSC to track the PM work orders covering the E/M equipment at the Potomac Water Treatment Plant (WTP). This report is essentially an exception report, and its main purpose is to alert the maintenance manager of any PM work orders that are not promptly completed.

Cost reports are considerably more difficult to develop and prepare for manual systems. Even for small water systems with relatively few work orders, the effort to assemble and analyze the data on maintenance utility costs may be extensive. Figure 4-12 shows one such report (Wyatt 1988). While this report does not analyze individual jobs, it does measure the cost of maintenance from month to month. Another alternative or supplementary report could detail costs for only top-priority jobs, since these are ones for which costs are likely to be less under control. Management may be able to determine better methods for responding to such work.

Preventive Maintenance Work-Order Summary	
ZONE: _____	MONTH: _____
Number of preventive maintenance work orders outstanding from last month.	_____
Number of preventive maintenance work orders originated this month.	_____
Number of preventive maintenance work orders originated this month but not completed.	_____
Equipment types for which preventive maintenance was scheduled but not completed.	
1. _____	
2. _____	
3. _____	
4. _____	
5. _____	
6. _____	

Figure 4-11 Preventive maintenance work-order summary.

The report shown in Figure 4-11 could be expanded to incorporate these additional data.

Assessing the productivity of all field staff also can be time-consuming and difficult to track with a manual MMS. One method that the maintenance manager can use to overcome these limitations is to take a random sample of PM and CM work orders and then draw on experience to assess whether the time spent doing the work seems reasonable. If the time spent seems excessive, the maintenance manager can ask the crew why the work took so long.

One practical quantitative approach is to determine the ratio of work-hours actually spent on work orders to total work-hours recorded on time sheets for a given period. This ratio can be compared on a month-to-month basis.

Graphic techniques such as those shown in Figures 4-13 and 4-14 are quite useful for displaying and reviewing this type of data. Figure 4-13 shows PM work orders left incomplete over time. The number of open work orders is worthy of attention only if it increases with time, indicating that the PM-work is behind schedule and that PM resources may be inadequate.

Figure 4-14 graphically monitors the effectiveness of PM by tracking hours spent on CM activities over time. Without a good maintenance program, a ratio of three to one (CM to PM) for equipment maintenance is likely, while the reverse of this ratio can be reasonably expected as the maintenance management program matures. By starting such a CM work-hour graph when the PM effort begins, a maintenance program's progress can be continuously charted.

However, the ratios cited above for equipment maintenance do not apply to distribution system or B&G maintenance. The most reliable measure for these functions is probably the ratio of work-hours spent on work orders to total available work-hours. In addition, since much of the distribution system activities may be done using overtime, the ratio of overtime hours to total work-hours spent on work orders can help assess if the number of field crews is adequate to manage the work load.

The maintenance manager must determine how much staff time can be devoted to gathering and analyzing data and which monitoring techniques will provide the best return for the time investment made. If the maintenance section is currently using a manual MMS, the maintenance manager also should evaluate the possibilities for automating the information system.

Automated Systems

Computers have created numerous opportunities for the maintenance manager to gather and manipulate information to review his or her operation in ways never before possible. Thus, every maintenance manager should consider the practicality of using an automated MMS for the utility. However, implementing an automated system is neither simple nor inexpensive despite the availability of easy-to-use hardware and software.

Once the planning team has determined which parts of the maintenance program to computerize, it must survey software packages and identify which ones can fulfill the section's requirements. This planning process includes analyzing the various packages' capabilities to deliver management reports—especially those addressing the need for system control. The package ultimately selected must be equipped to deliver the two types of monitoring reports already discussed in this chapter: reports that track actual maintenance work done as well as those that check the entry and processing of data by the information system to ensure that quality data are maintained.

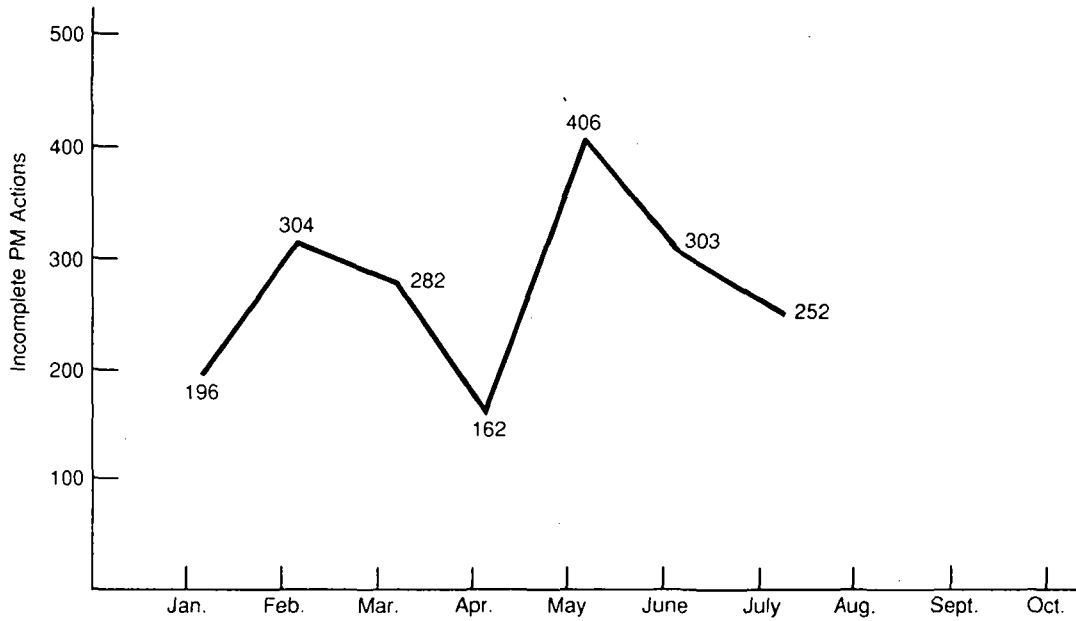


Figure 4-13 Graph—number of incomplete preventive maintenance actions versus time.

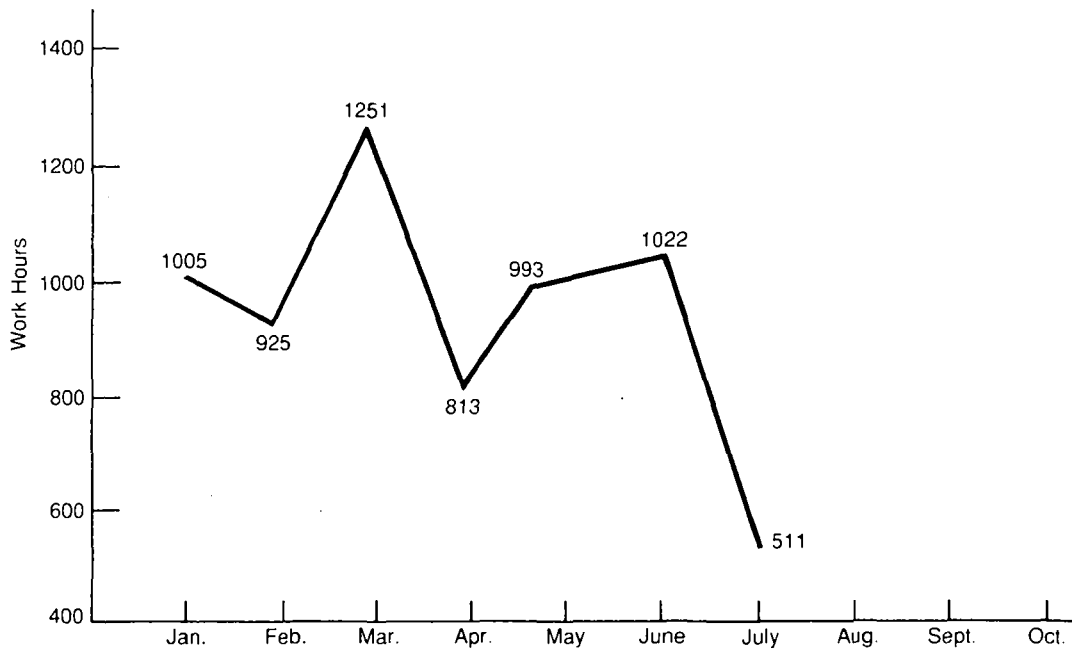


Figure 4-14 Graph—corrective maintenance work-hours.

Data maintenance. Because the output of any information system is only as good as the data entered, ongoing data maintenance is the key to the success of any automated MMS. The integrity of the information in the computer file is contingent on control of the work order from the time the work is generated, through field processing, to the processing of the completed work order. System control is mandatory at each of these stages.

For example, if the maintenance group processes 10,000 work orders per year and the error rate is 10 percent of total work-hours reported, the accuracy of the management reports generated by the MMS may be compromised. One water utility found that even though the flow of data for its distribution system MMS was straightforward, the error rate was still unacceptably high. This utility took several approaches to resolving its problems with maintaining data integrity.

The first approach focused on improving how work orders are generated, especially those resulting from customer complaints. A work order is generated when a customer service representative gathers information from a caller. Several problems can occur at this stage. The representative may not receive enough information or may incorrectly identify the work required. Either of these problems can result in the wrong type of work crew being sent to the job. This, in turn, can distort the data generated on crew productivity. To assist the representative, a work-order questionnaire was developed (Figure 4-15).

This questionnaire helps system control in several ways. Because its systemic layout organizes the information obtained from the caller, the right crew can be dispatched to the job with a better understanding of the caller's problem. Most important, these questionnaires led to the development of standardized work descriptions with work description codes. This information was entered directly into the computer.

Next, the utility had to revamp how work-order information was fed into the computer. Initially, work-order information was entered nightly into the computer file using a seven-digit work-order number taken from the second copy of the work order. In many cases, however, because of a clerical or data-entry error, the work data and their correct number did not appear in the maintenance master file. Because the computer lacked a way to cross-reference the work-order number when the data processing section updated the work-order files, it could not distinguish if a work-order number was valid. Subsequently, some work orders were rejected. Even though a computer report had been developed to list errors, it was difficult to back-track when the correct number for a rejected work order was unknown.

To solve this problem, the utility changed to on-line entry. The clerks enter the work-order information directly into a computer terminal as soon as the complaint is received. The computer checks the work-order number immediately. If it is incorrect, the terminal transmits an error message to the clerk. This process also eliminates the problem of entering incorrect data into the computer.

Problems encountered in the field processing stage of the work-order system also had to be addressed. After a work order is prepared, it is dispatched by radio to a crew if it is an emergency, or it is sent to the appropriate depot if it is a routine job. At this point, work orders could become lost in the depot; the crew chief either may fail to submit a field work order to close the work or may enter incorrect data on the work order, causing it to be rejected by the computer; or the crew chief may fail to submit his or her activity report, including work-hours, crew numbers, and work-order number; or may incorrectly fill out the report.

Field processing errors result in lost production time, cause work orders to remain on the open file for an indefinite period, and create incorrect management

Water Leak Questionnaire

I. Problems Covered by This Questionnaire

1. Water mains and valves
2. Water services and inside plumbing
3. Water meters
4. Fire hydrants

II. Information Required From Owner/Occupant

- | | |
|--|---------------|
| 1. General Location | Go to Section |
| A. Inside building | 2-A |
| B. Outside building | 2-B |
| C. Off property—more specific location | 2-C |
| 2. Specific Location | Go to Section |
| A. 1. Inside pipe | III-1 |
| 2. Inside meter | III-2 |
| B. 1. Outside building—on property | III-1 |
| 2. Outside meter (8-in. or 12-in. cover) | III-3 |
| 3. Curb box (4-in. cover) | III-4 |
| C. 1. Near curb | III-4 |
| 2. Fire hydrant | III-5 |
| 3. In street | III-6 |

III. Action to Be Taken

1. If leak is from inside plumbing (not including meter) or on property, advise occupant that she or he is responsible for repairs. Do not prepare work order. If in doubt as to whether leak is on or off property, see III-4.
2. Advise occupant that WSSC will investigate and repair if necessary. Before preparing work order, determine if leak is causing substantial or very little property damage.
 - A. If substantial damage, prepare "Repair Inside Meter Leak" work order, code 400.
 - B. If little or no damage, prepare "Repair Inside Meter Leak" work order, code 401.
3. Advise occupant that WSSC will dispatch personnel to investigate problem. NOTE: It is acceptable to ask customer to walk outside and see if water is coming up from meter housing (8-in. or 12-in. cover). This may avoid identifying the problem as a service leak. Prepare "Repair Outside Meter Leak" work order, code 403.
4. For both off-property service leaks and curb box leaks, the same type work order is written, depending on severity of the leak. In either case, determine if leak is causing substantial or very little damage.
 - A. If substantial damage, prepare "Inspect for Service Leak" work order, code 216.
 - B. If little or no damage, prepare "Inspect for Service Leak" work order, code 217.
5. Determine severity of leak.
 - A. If fire hydrant blowing, prepare "Repair Blown Fire Hydrant" work order, code 225.
 - B. If small leak, prepare "Inspect Leaking Hydrant" work order, code 226.
6. If caller reports water in street, it may be a broken main or valve leak. The severity of the problem is determined by questioning the caller to determine which of the five work descriptions listed below best describes the situation.
 - A. If obvious broken main with high volume of water causing damage, prepare "Repair Broken Main" work order, code 211.
 - B. If suspected broken main with moderate flow of water causing no immediate damage, prepare "Inspect for Broken Main" work order, code 202.
 - C. If light flow causing no damage, prepare "Inspect for Broken Main" work order, code 203.
 - D. If standing water or continuous wet area is reported, prepare "Inspect for Possible Leak" work order, code 204.
 - E. If caller states water is coming up through valve box or cover, prepare "Inspect for Valve Leak" work order, code 209.

Figure 4-15 Work-order questionnaire for water leaks.

reports. To resolve these problems, the utility combined manual checks, computer checks by the terminal, and system control reports.

Though several manual techniques were implemented to reduce the error rate, including daily cross-checking of activity reports, the problems with data persisted. Thus, maintenance management introduced three reports specifically designed to address the problem of system error.

- The first of these reports, called the "Golden Oldie" report, helps identify errors by listing the three oldest work orders by crew type for each depot. To update the file of routine work orders, the depot scheduler needs only to review his or her depot's list of about 30 jobs instead of the entire file of several thousand open work orders. A column in the Golden Oldie report indicates the number of times a work order has appeared in the report. Figure 4-16 shows a sample of this report.
- Also displayed in Figure 4-16 is an excerpt from the second of these control reports, the "01 Priority" report, designed to pinpoint work orders for emergency jobs that have been started but which, according to the computer file, have not been completed. Since emergency work (no. 1 priority work) is normally completed within 2 days, this report lists, by depot, all emergency work over 14 days old. This report also alerts the depot scheduler of unfinished work exceeding 14 days' duration and helps him or her track finished work for which a completed work order has not yet been submitted.
- The last of the three control reports, the "Started-But-Not-Completed" report, accomplishes the same goal for routine work as the previously described report does for emergency work. It was found that most routine work orders listed as open, with time reported against them at least 15 days before the report date, should be closed. The Started-But-Not-Completed report identifies work orders in this category. Maintenance department personnel should then investigate the actual status of this work.

Other changes were also made to this MMS to limit the number of errors as information flowed through the system. Since the system's inception, the management reporting system has frequently been modified.

Smaller water utilities' maintenance information systems may not need the extensive controls required by the system described above. However, the MMS team designing a system for a smaller utility still needs to keep the system as flexible as possible and to plan for system control in the initial design. The entire system also should be periodically analyzed to determine its effectiveness and to take advantage of new techniques.

PERFORMANCE MONITORING ---

Scheduling Work on the Computer

To use the computer to schedule maintenance work, particularly PM, the maintenance manager must be able to estimate the amount of time needed to perform various tasks and tabulate the number of work-hours available in each skill category. While the latter information is relatively easy to obtain, the former can be complicated.

Once a method for scheduling work has been established and tested, a way to track personnel as well as section performance should be developed to enable the maintenance manager to analyze the productivity of the field crews.

"Golden Oldie" Report													
													PAGE 2
													03/09/88
SECT.	DEPOT	CREW TYPE DESCRIPTION	WORK ORDER	CREW SIZE	CREW TYPE	PRI. CODE	PAGE/GRID	ADDRESS	JOB TYPE	ISSUE DATE	STND. HRS.	WEEKS ON REPORT	
43	02	MAIN LINE	7198799	01	03	01	08/G07	2000 BLK. HAMILTON ST.	2A05	87/05/10	0.5	04	
43	02	SERVICE	7338791	03	09	04	08/G10	4208 32ND ST.	3B04	87/08/16	4.0	01	
43	02	FIRE HYDRANT	8051237	03	04	01	08/J09	4500 41ST AVE.	2A06	88/01/06	3.0	01	
43	02	METER	8051773	01	10	04	19/K02	3922 TRITON CT.	4A01	88/03/06	1.0	01	

01 Priority Report													
													03/09/88
SECT.	DEPOT	CREW TYPE DESCRIPTION	WORK ORDER	CREW LEADER NO.	CREW TYPE	PAGE/GRID	ADDRESS	ISSUE DATE	WEEKS ON REPORT				
43	01	MAIN LINE	8064127	1467	03	13/L09	2100 BLK. LAUREL AVE.	02/10/88	02				
43	01	SERVICE	8156023	2168	09	08/G10	660 33RD ST.	02/15/88	01				
43	01	MAIN LINE	8276619	1832	02	07/J01	3300 BLK. NICKY CT.	02/22/88	01				
43	02	METER	8031246	3306	10	04/G11	2764 COLLEGE AVE.	02/22/88	01				

Figure 4-16 System control reports—"Goldie Oldie" and "01 priority."

Work Measurement

Productivity is the ratio of the time a crew reports against work orders to the total work time available. Performance is the ratio of the time it takes to do a job to a time standard. This latter time, which is the time it should normally take to do a particular job, is the key to a successful performance monitoring program since time standards are critical for measuring performance. Utilization is the product of the two ratios and provides a single number against which to measure the progress of the maintenance effort over time using, for example, graphical techniques.

Several methods have been used to develop standard times:

- Time studies are on-site measurements of how long it takes to do specific tasks. The analyst records the productive and nonproductive time of each crew member, breaking the time down to discrete tasks.
- Predetermined time values are established in advance for all manual operations. The standard time for any task (for example, excavating a ditch to repair a broken water main) is derived by adding together the amount of time it takes to do each of the operations needed to complete the entire task.
- Work sampling involves taking a random sample of the field crews' work to establish standard times.
- Past records draw on the experience of maintenance supervisors to develop a history of estimated times for the field crews' various tasks.

The descriptions of the different techniques that can be used to establish time standards are deliberately sketchy. If the maintenance manager decides to investigate performance monitoring by using these methods, he or she is likely to need the services of a specialist in the field of work measurement to set up an effective program.

If the time standards are determined with care, the resulting management reports will accurately indicate the performance of the utility's field crews. However, because developing these time standards is time-consuming and costly, maintenance managers might consider other alternatives. For instance, one approach is to gauge the performance of individual field crews by using the past experience of maintenance managers and supervisors who can estimate the time it should take to complete certain tasks. If the utility deploys four or more crews for similar distribution system maintenance work, another approach is to compare the amount of time it takes each crew to complete the same work. If one crew regularly takes significantly more time than the other crews, the supervisor should determine why. Additional training may be needed, or the crew leader might lack effective leadership skills.

Performance Monitoring of Maintenance Work

The different maintenance functions differ with respect to the development of time standards.

Distribution system. Since the work of this maintenance group does not require a significant amount of troubleshooting, time standards can be developed for the majority of its work. Standard times should be established first for those tasks that occur most frequently, such as repairing broken water mains and valve leaks and replacing fire hydrants. Management reports on the performance of these tasks should be developed to ensure that management gains experience in analyzing the data generated. The program then should be expanded to include the balance of the distribution system work.

Performance Report				
Program Name: Water Main/Service Maintenance			Section: Eastern Zone Maintenance	
	Current Month	Year-to-Date Monthly Average	Fiscal Year to Date	Budget Reference
Expenditures				
Salaries	\$34,400.83	\$27,692.03	\$110,768.12	\$ 465,300
Wages	67,606.66	54,502.09	218,008.36	690,700
Material	7,431.23	4,876.59	19,506.36	183,000
Total	\$109,438.72	\$87,070.71	\$348,282.84	\$1,339,000
Work-Hours				
Actual Productive Hours	3,711	3,274	13,098	
Actual Nonproductive Hours Allocated	3,757	2,795	11,181	
Equivalent Annual Work-Years	52.7	43.2	43.2	51
Percentage of Emergency Hours	64.0	44.1	44.1	
Percentage of Preventive Maintenance	17.6	13.4	13.4	
Percentage of Corrective Maintenance	26.0	55.9	55.9	
Completed Work				
Work-Order Count	361	327	1,309	3,693
Standard/Estimated Hours	2,091	1,371	5,485	16,020
Total Work-Hours	4,809	3,200	12,802	
Percentage of Performance	53.0	51.0	51.0	
Backlog				
	Same Time Last Year			
Work-Order Count	81	82		
Standard Hours	740	1,897		
Weeks	2.2	5.7		
Average (days)	268	130		
Date of Oldest Work Order	08/17/87	05/01/86		

Figure 4-17 Performance—program report for October 1988.

Building and grounds. Time standards can be developed for the majority of the work carried out by this group, which is a good candidate for performance monitoring.

Equipment maintenance. Since 70 to 80 percent of the work performed by equipment maintenance crews will be preventive if the maintenance program is effective, time standards can readily be established for much of this work. It may be difficult, however, to establish standards for CM work since a significant amount of problem analysis may be required to identify the problem. One approach the manager of this group could take is to develop time standards for PM work and rely on field supervisors to review CM work-hours in assessing whether the time reported for a particular task seems reasonable.

Purposes of Performance Monitoring

The effort required to measure crew performance with or without developing time standards is quite large. Therefore, the manager must ensure that the payback will be worth the effort. Performance monitoring serves three purposes:

1. It identifies crews that are not performing as well as other crews.
2. It provides a basis for analyzing how tasks are done and determining if procedures can be improved.
3. It provides management with data to support requests for additional personnel or other resources.

The WSSC demonstrates the uses of performance reporting. The WSSC used time studies to develop time standards for work done by its distribution system maintenance crews and developed a series of management reports to capture the data. Figure 4-17 shows an example of such a report. By analyzing information gathered on field crew performance, the WSSC was able to reduce the size of main-line maintenance crews from four to three workers and to introduce one-person crews to inspect reported problems before sending a full crew (as was the past practice). Subsequent analysis revealed that these inspectors could resolve approximately 70 percent of the jobs they undertook. In cases where a full crew was actually needed, the inspector could frequently inform the crew what work was required. An important factor in the success of this program was the use of the work-order questionnaire previously discussed (see Figure 4-15).

References

1. "Maintenance Management Software Comparison." *The Journal of the American Institute of Plant Engineers. Facilities Management, Operations & Engineering*, Sept./Oct. 1987 (pp. 27-49).
2. WYATT, A. *Guidelines for Maintenance Management in Water and Sanitation Utilities in Developing Countries*. Prepared for the US Agency for International Development under the Water and Sanitation of Health Project, Activity 421. Roslyn, Va. (July 1988).

5

Inventory Management

Since a reliable water supply is a fundamental requirement for a community, the maintenance section must pay special attention to its inventory of spare parts and supplies. The implications of not having a quality water source because of a lack of a replacement part are great. For example, if the maintenance manager operates a water pumping station without a backup pump set because one unit is out of service due to the lack of a spare part, senior management might question his or her capability. On the other hand, if several backup units are in place at the pumping station, the maintenance manager must guard against overstocking spare parts for these backup units. The point is that the utility's maintenance manager needs to strike a balance between stocking the right type and amount of spare parts to do repairs and controlling the cost of maintaining an extensive inventory.

GENERAL CONCEPTS

The purpose of this chapter is to review the basic concepts of inventory management and how they apply to a water utility. An effective inventory system will ensure that the parts, materials, and tools necessary to minimize downtime and service interruptions for the utility's equipment and structures are readily available and that the cost of maintaining these supplies is as low as possible. Since numerous books and reports are available on specific methods of setting up and operating inventory systems, this chapter will present only guidelines and examples for planning or revising the inventory system. The operation itself will dictate which kind of system should be implemented.

The utility's maintenance manager must first fully understand the existing system for obtaining spare parts and supplies. The maintenance manager needs to address the following questions:

- Who is responsible for purchasing and storing supplies?
- What is the procedure used by the different maintenance functions to obtain parts and materials?
- What problems are associated with ordering supplies?

- Should the maintenance sections have their own storerooms?
- Should the inventory system be centralized, decentralized, or incorporate a combination of the two?
- Is an automated system justified?

The answers depend on the size of the utility and its service area. For large utilities with several sites spread over a wide geographical area, multiple storerooms may be justified despite the additional cost of maintaining them. For smaller water utilities, a single storeroom located in the treatment plant may be adequate.

Since the principles involved in establishing an efficient inventory system apply to any water utility, regardless of size, this chapter discusses the requirements for a large utility.

MAINTENANCE REQUIREMENTS

To install an inventory system that will serve all maintenance functions, the maintenance manager needs to differentiate between equipment downtime and service interruptions. In particular, these differences will affect the method and cost of maintaining an adequate stock of spare parts and supplies.

Equipment Maintenance

When maintaining equipment, minimizing downtime does not mean having enough supplies on hand to restore every piece of equipment to immediate service. Such an approach is too costly. However, the equipment maintenance group does need to assess each operating system according to the following factors:

- availability of standby equipment—If having backup gear, such as raw water pumps, means that one unit can be out of service without threatening water delivery until repairs are completed and if spare parts can be obtained easily, then it is not necessary to stock expensive spares.
- criticality of equipment to primary water plant operations—While a roof exhaust fan may remain out of service for an extended period without affecting water production, this is not true of most plant and pumping station equipment. Operations and maintenance personnel need to agree how long a piece of equipment can be out of service before plant operations are seriously hampered.
- frequency of part use—If a piece of equipment frequently needs the same part replaced or if the part is used on many pieces of equipment, it is probably cost effective to stock a few parts to avoid delaying the completion of work orders.

The factors above relate more to CM than to PM work. Since PM is done regularly with known requirements for parts and supplies, the inventory system should be designed to ensure that the requisite parts and supplies are always available when needed.

Distribution System

For the manager of the distribution system maintenance section, reducing service interruption time is vital. Thus, the necessary parts and supplies to restore service to customers must be available when the need arises. Even though many utilities

have looped networks, some customers will be without water throughout the time it takes to repair a break in the distribution system. Service-line breaks will cause similar problems though the number of customers impacted is smaller. In addition, since many main waterlines are in roadways, the utility will receive unwanted publicity if it is slow to repair those system failures that inconvenience the general public.

Water meters and fire hydrants are special cases for the distribution system maintenance section. Obviously, fire hydrants should be operational all of the time. Since they are aboveground and susceptible to damage from vehicles as well as to malfunction because of part failure, spare units must be available when needed. Although water meters probably will not cause major damage if they fail, maintaining an adequate supply of replacement parts is still important from a revenue standpoint.

Building and Grounds

What inventory is needed to support this group depends on the activity required. While failing to stock paint and groundskeeping supplies will not affect water delivery, B&G work schedules may be disrupted if these items are not available when required. Thus, the B&G manager should maintain a minimum inventory of materials and supplies. Items relating to safety and security need to be available when needed. They are as important to the utility as those supplies required for the reliable delivery of water.

DETERMINING QUANTITIES IN INVENTORY _____

Deciding the quantities needed to properly and effectively maintain the utility's equipment and structures is a time-consuming and sometimes difficult task. It requires evaluating basic maintenance requirements, assessing the use of equipment and structures, and knowing the availability of spare parts and supplies.

As already discussed, it is neither necessary nor desirable to stock all supplies or spare parts used for maintenance. The actual quantities stocked will be influenced by:

- long lead times—How long will it take to receive an order?
- obsolete equipment—If the equipment is no longer made but still in service, overstocking the spares or materials used to maintain it may be desirable.
- local availability—It may be cost effective to let a local vendor stock the item, especially if the part is costly and several local vendors normally keep it in stock.
- stockroom space—How much space is available for storage? Can the size of the stockroom be increased?
- use of contractors—If contractors are to make repairs, will they supply the parts and supplies?
- equipment or structure life—If a piece of equipment or structure is scheduled for removal or abandonment, more attention needs to be placed on the inventory of parts and materials used to maintain it. This is, of course, obvious. The important point is that this type of assessment must be built into the inventory procedures.

Inventory cost is the final item that needs to be addressed when establishing quantities. Because many water utilities are operated by a local government agency and are nonprofit, maintenance managers may tend to stock as many spare parts or supplies as possible to avoid delays in maintenance work. However, this is an incorrect premise. Not only will this result in an unmanageable stockroom, but it also may adversely impact water rates. This, in turn, will result in a negative reaction from senior management.

How are quantities established then? The following four-step approach is recommended:

1. Based on criticality, number of pieces in service, and rate of usage, determine the minimum number of units that should be readily available. Manufacturers' data sheets will help, but experience is probably the best guide.

2. Determine how long it will take to obtain the item after placing an order. For example, is the part available locally?

3. Based on cost and space considerations, determine how many parts should be ordered to replenish stock. Among the cost factors are cost of keeping inventory, manpower, availability of quantity discounts, cost to place an order, and value of the item.

4. Ascertain if other factors such as obsolescence or scheduled abandonment of equipment or systems will impact the quantities kept in inventory.

INVENTORY INFORMATION SYSTEMS ---

An effective and efficient inventory system depends on a smooth flow of information through the system and the storeroom(s).

Purchase Requisition

Preparing a purchase requisition (PR) is the first step to obtaining spare parts or supplies. While not part of the internal paper work used for an inventory system, this document is key to properly identifying the item needed for maintenance. In most large water utilities, the purchasing group is in a separate department from maintenance, and cooperation between the two sections is very important. For example, in the WSSC, the same department manages the purchasing and warehousing functions. Upon receiving the requisition, the purchasing section will prepare the purchase order (PO) after determining the supplier for the items.

Purchase requisitions will generally originate from two sources depending on how the utility is organized. In some utilities, the maintenance section stores all the spare parts and supplies it uses. In other utilities, a centralized warehouse controlled by the inventory section will store commonly used supplies and materials, and maintenance will handle only spare parts peculiar to certain pieces of equipment. The only real requirements are that the items in inventory are available when needed and that system control mechanisms are in place.

In both situations described above, the maintenance section is responsible for preparing PRs, and it can assist the purchasing agent by preparing them carefully. In particular, the item identification should be as detailed as possible, and potential sources of the item should be given. The maintenance manager should also ensure that maintenance personnel specify a realistic date needed for the item. Figure 5-1 is an example of a PR.

Requisition to WSSC Purchasing Office						PR No. 881762		
The Purchasing Office shall obtain competitive bids to fill these needs. Requests for different processing must be fully explained (attach sheet).						Page ____ of ____ Pages		
Check One <input type="checkbox"/> To be delivered <input type="checkbox"/> To be picked up <input type="checkbox"/> Service or repair				If for Equipment (Subsidiaries 71, 72, 73, 74, 75, or 77), Check One: <input type="checkbox"/> Replacement item <input type="checkbox"/> Additional item		Purchasing Office Use Only		
						IFB No.		
						Open Date		
Account No.			Job No. (if any)			Buyer		
Requested By (authorized signature)					Date	P.O. No.		
Section Name			Section No.	Phone No.		Deliver		
Approved By (authorized signature)			Date	Estimated Cost \$		Ship to		
Item No.	WSSC Stock No.	Description <small>Complete and accurate specifications should be given for each item listed. Failure to do so will cause delay. Double space between items. A separate requisition must be made out for each type of material listed.</small>			Unit	Quantity	These columns for use of Purchasing Office	
							Unit Price	Amount
Do Not Write Below This Line. For Continuation, Use Plain Paper.								
Disposition								
<input type="checkbox"/> Phone Bid <input type="checkbox"/> Informal <input type="checkbox"/> Formal <input type="checkbox"/> Pickup <input type="checkbox"/> Del. Request <input type="checkbox"/> Confirming Order								
Delivery Ticket No.		Invoice No.	Quoted By (name)		Terms	F.O.B.		
						<input type="checkbox"/> Origin <input type="checkbox"/> Dest.		
Vendor Name								
Vendor Address								

Figure 5-1 Purchase requisition.

NOTE: The maintenance section should assume responsibility for preparing PRs for spare parts that require special instructions or are part of a complex E/M system. A clerk in the maintenance section needs to be assigned to track PRs to ensure that items are actually ordered and received. Using a tickler file based on an expected delivery date is a reliable technique for accomplishing this.

Documentation

Within the inventory section, three basic documents are used to control the flow of materials from the supplier to the maintenance section that ordered them.

Receiving order form. When receiving an order, the receiving clerk normally checks that the number of cartons, truckloads, or containers actually delivered matches the shipper's bill of lading. The next step is to prepare the receiving ticket and match it against the vendor's list of items shipped. Figure 5-2 shows an example of a receiving ticket. This form may also be used to authorize payment to the vendor.

The receiving record is used to open or add to the parts/materials history file, which is also called the master file or inventory ledger. Similar to the equipment history file described in chapter 4, Equipment Files, the parts/materials file contains data that are used to track the source and usage of a spare part and to reorder items as the minimum stock level is reached. The file should contain

- warehouse stock number;
- name and description of the part or material;

Receiving Ticket					
					Date: _____
Vendor: _____					
Shipper: _____					
P.O. No.: _____					
Item	Qty.	Unit	Description	Total	Stock No.
Received By: _____					

Figure 5-2 Receiving ticket.

- part number, manufacturer, and suppliers for spare parts;
- generic descriptions and suppliers for materials;
- storage location;
- where the part or material is used (if for a specialized purpose);
- reorder point; and
- reorder quantity.

The parts file will also trace the movement of the part from receiving to maintenance staff use. Figure 5-3 is an example of a parts history file. A similar file is set up for materials. The items received are either placed in the warehouse or storeroom operated by the inventory section (if stock items), or the maintenance section that requested the order is notified to pick up the item if a special order is involved. In the latter case, the maintenance section receiving the parts should maintain its own parts data file.

The maintenance sections should advise the inventory section if they expect the need for a particular part to increase or decrease. This will help the inventory

Parts History File								
Description: _____								
Stock No.: _____								
Original Source:								
Mfg.: _____								
Part No.: _____								
Host Equipment: _____								
Suppliers: _____								

Reorder Point: _____				Reorder Quantity: _____				
Location: _____								
Received:				Issued To:				
Date	P.O. No.	Qty.	Cost/Unit	Date	Req. No.	Qty.	Sect.	Balance

Figure 5-3 Parts history file.

section to adjust the time and quantity to reorder and hopefully will avoid stock shortages or oversupplies. Additionally, conflicts between the sections will be avoided, and better relations will be fostered between the maintenance and warehousing sections.

Materials requisition form. This form is used to issue parts and supplies to requesting sections. A form such as the one shown in Figure 5-4 is used to track materials usage and to ensure that the receiving section is properly charged for the items received.

Credit slip. This form is used by maintenance sections to return unused items to stock for credit.

INVENTORY ACCOUNTABILITY

In a perfect situation, all goods that flow into the warehouse or stockroom can be accounted for either as stock on hand or as delivered to the section using them. However, stock can be lost. Therefore, it is important that the inventory system use mechanisms to check the amount of stock that can be accounted for versus stock that is actually present or has been used.

In a large utility, thousands of transactions will take place to ensure that the spare parts and supplies needed by maintenance are available. It is likely that errors in recording additions or subtractions to inventory will result in apparent losses or gains of certain items. In addition, stealing is often a problem. For this reason (and, possibly, to satisfy legal requirements), both the inventory system and

Stores Requisition					
Date Issued: _____		Section No.: _____			
Depot: _____		Account No.: _____			
Work-Order No.: _____		or Stock No.: _____			
Item	Stock No.	Qty.	Description	Cost Each	Total
Received By: _____		Empl. No.: _____		Date: _____	
Issued By: _____		Recorded By: _____			

Figure 5-4 Stores requisition.

the maintenance sections (if the latter keep a storeroom) need to periodically check the stock in the warehouse.

To assess the accuracy of the history files, it is necessary to differentiate between general and specialized stock. General stock consists of inexpensive items, such as wire nuts, light bulbs, small pipe fittings, and some paint supplies, that are used regularly by field personnel. Precisely accounting for these items is not cost effective. It is better to spread their cost over the various user sections or jobs. Specialized stock consists of costly and/or infrequently used parts or supplies that could result in service interruptions if unavailable or in unusable stock if no longer needed (for instance, the equipment has been taken out of service).

To compare the number of items in stock versus the number recorded on file, a combination of two methods seems to work well for most inventory systems. The first involves randomly checking 5 to 10 percent of the stock at three-month intervals. For general stock items, the number in stock is estimated and then compared with the number given in the parts or materials history file to determine if the amounts approximate each other. For specialized stock items, a 100 percent check is made of physical inventory and compared with the history file. If any notable discrepancies are observed, the section manager needs to evaluate the control and security procedures used for the stockroom.

The second method requires a complete inventory of all stock, usually on an annual basis, using the same counting techniques as described above for the partial sample.

NOTE: This may require the storeroom to be shut down for one or more days, and all personnel who may be affected by the closing should be notified in advance.

STOREROOM DESIGN AND LOCATION _____

Larger water utilities may use centralized warehouses as well as regional storerooms to save travel time. The regional storeroom concept can be carried further by having individual maintenance sections maintain their own small "satellite" storerooms at convenient locations. For distribution maintenance activities, the storeroom should be located at major depots; for equipment maintenance sections, spare parts and supplies could be stored at plant sites. One advantage to the decentralized approach is that the regional storeroom may be operated using inexpensive manual techniques and still maintain proper control over stock movement.

Although the decentralized operation is logistically sound, it does have drawbacks. For instance, every storeroom must be carefully designed if proper controls are to be maintained. (Figure 5-5 lists guidelines for setting up a proper storeroom.) In addition to physically preparing the storeroom, the maintenance manager who deems it cost effective to set up satellite storerooms needs to account for the manpower required to operate the inventory system for each storeroom. Decentralized storage might also result in duplication of spare parts and supplies at the different locations, thus adding to inventory costs.

The maintenance manager must balance the advantages and disadvantages of regional storerooms and decide what is best for his or her operation.

AUTOMATED INVENTORY SYSTEMS _____

For a large utility, an automated system is a necessity for the inventory system used to control the central warehouse.

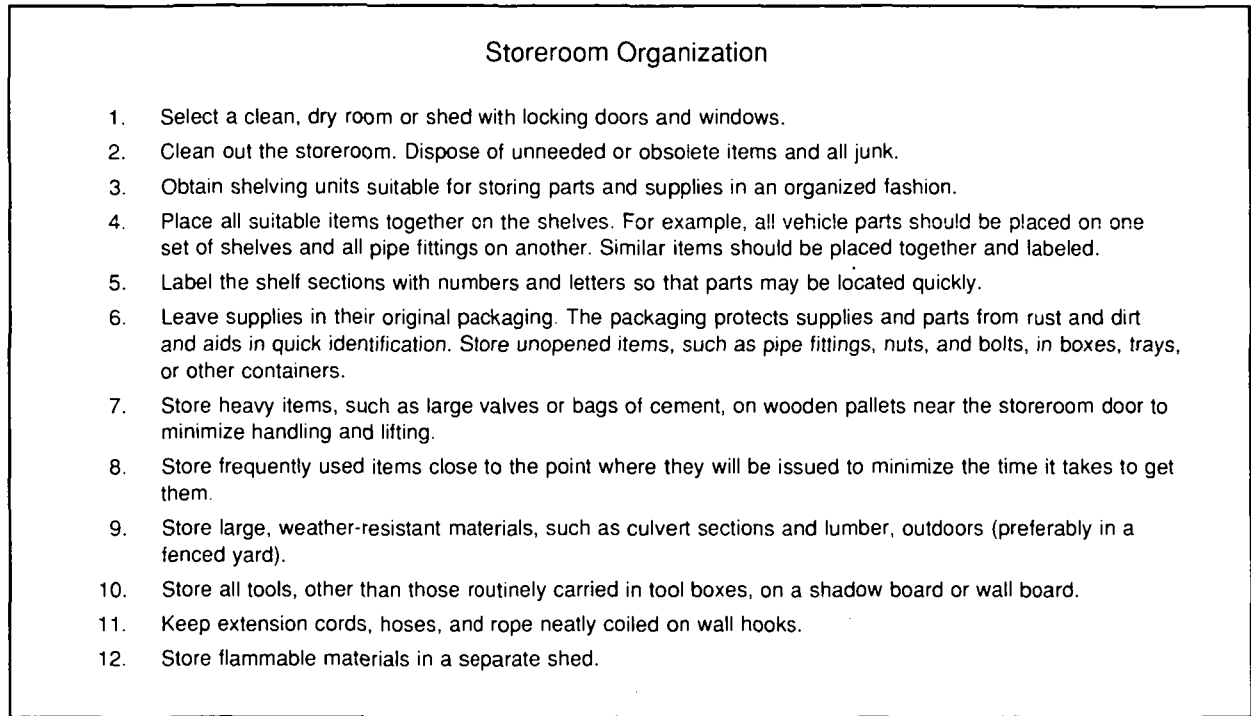


Figure 5-5 Organizing a storeroom.

Computer software has been designed to duplicate many of the documents and procedures described as part of a manual inventory system. Such software is most useful for

- recording the spare parts and supplies for incoming shipments,
- maintaining records of the quantities of stock in the warehouse,
- flagging items that have reached the reorder point,
- tracking the value of the items in inventory,
- recording disbursements and printing stores requisitions,
- monitoring parts and supplies to detect unusually high or low use of items in inventory, and
- maintaining the parts/materials history files.

In general, computers can produce and track most of the paper work needed to operate and control an inventory system. The following figures are examples of outputs from the automated inventory control system implemented by the WSSC for its main and auxiliary warehouses.

Figure 5-6 shows a report of the spare parts and supplies kept in the warehouses. The warehousing and purchasing sections can use these data to replenish inventory. The maintenance sections can also use the report to identify potential suppliers or gather cost information.

Figure 5-7 shows a report that identifies items that need to be reordered. The usage information can be used to revise the reorder point if the need for a particular item increases or decreases.

Figure 5-8, which shows a report on essential spare parts and supplies, lists items that need to be given first priority by the warehousing and purchasing departments.

Unit Price Purchase Data 12/09/88

STOCK NO.	ITEM DESCRIPTION	REQ. DATE	REQ. NO.	P.O. NO.	P.O. DATE	VENDOR NO.	VENDOR NAME	UNIT ISSUE	LAST PURCH. PRICE	DATE OF LAST RECEIPT	CLASS
1021-0600-2	ADAPTOR, COPPER PIPE TO LEAD PIPE, STRAIGHT, 3/4" DIA.	06/05/87	PR94230	P59217	06/23/87	03367	G&L FABRICATORS, INC.	EA	\$5.180	03/18/87	D
1021-1000-0	ADAPTOR, COPPER PIPE TO LEAD PIPE, STRAIGHT, 1" DIA.	08/27/87	PR96138	P60821	09/01/87	02162	MUELLER CO.	EA	\$13.850	09/10/87	D
1022-1600-9	ADAPTOR, M.J. BELL TO PRESTRESSED CYLINDER PIPE BELL, 16" DIA.	06/06/88	PR06078	P67571	09/19/88	02416	PRICE BROTHERS CO.	EA	\$1062.450	02/10/87	A
1023-0800-4	ADAPTOR, MECHANICAL JOINT TO BELL FLANGE, 8" DIA.	01/27/87	PR89331	P02880	12/05/83	02708	TYLER PIPE IND., INC.	EA	\$52.000	12/09/83	A
1023-1200-6	ADAPTOR, MECHANICAL JOINT TO BELL FLANGE, 12" DIA.							EA			A
1024-9010-9	ADAPTOR, MANHOLE, D-LOK, O-RING SPIGOT, 1" HEIGHT	03/31/87	PR90835	P57088	04/17/87	01141	ATLANTIC PRECAST CONCRETE	EA	\$150.000	04/13/87	B
1038-0304-5	BEND, MECHANICAL JOINT, 1/4" BEND, 3" DIA.	09/14/88	PR05756	P70027	10/26/88		TYLER PIPE IND., INC.	EA	\$30.000	10/17/88	Y

Figure 5-6 Report—purchasing and price information—spare parts.

Stock Reorder Notification														
Warehouse 6000 Anacostia														
STOCK NO.	UI	LEAD TIME	QTY. ON HAND	QTY. DUE	RE-ORDER POINT	SAFETY STOCK	MONTHLY AVG.	JAN MAR	QUARTERLY USAGE			PACK PRICE	MCC CLASS	
									APR JUN	JUL SEP	OCT DEC			
11067-1400-9	EA							6	3	20	4	1	S3	
COUPLING, COPPER/GALVANIZED FEMALE, 1-1/2" DIA.														
6000	ANACOSTIA	75	6	0	8	3	2.7					11.90	Y	
6025	LYTTONSVILLE		4			1	0.5							
6050	GAITHERSBURG		8			1	0.0							
6075	TEMPLE HILLS		5			0	0.0							
11253-0808-0	EA							3	2	3	5	1	S3	
WYE, MECHANICAL JOINT, 8" x 8" DIAS.														
6000	ANACOSTIA	45	0	3	3	2	1.0					140.00	Y	
6025	LYTTONSVILLE		0			0	0.0							
6050	GAITHERSBURG		0			0	0.0							
6075	TEMPLE HILLS		0			0	0.0							
74240-9052-0	EA							121	76	76	91	10	S3	
PROTECTIVE HELMET (HARD HAT), SLOTTED, ORANGE														
6000	ANACOSTIA	120	164	0	165	45	30.3					8.85	W	
6025	LYTTONSVILLE		9			18	7.2							
6050	GAITHERSBURG		15			18	6.7							
6075	TEMPLE HILLS		8			18	5.3							
05381-0300-3	EA							67	75	63	15	1	S4	
GASKET, PLAIN, MECHANICAL JOINT, 3" DIA.														
6000	ANACOSTIA	30	15	50	18	8	18.3					.90	C	
6025	LYTTONSVILLE		5			5	4.1							
6050	GAITHERSBURG		32			5	4.9							
6075	TEMPLE HILLS		9			3	2.0							

NOTES: The warehousing section of this utility maintains four warehouses. The Anacostia site is the main warehouse, and all shipments are received there. Thus, data on lead time, quantity due, and reorder point are kept for this location only. Spare parts and supplies for the other warehouses are delivered from the Anacostia warehouse.

Figure 5-7 Stock reorder report.

Critical Item/Stock-Out Report												
STOCK NO.	DESCRIPTION	BUYER NO.	REQ. DATE	REQ. NO.	P.O. NO.	P.O. DATE	BAL. DUE	LEAD TIME	MTHLY. ISSUE	AVG. MTH. USAGE	ON HAND	SAFETY STOCK
								VENDOR NO.	VENDOR NAME			
4742-0800-6	GLAND, RETAINER, 8" DIA.	0032	08/29/88	PR07937	P69716	10/19/88	115	45	4	35.0	50	53
			6000	ANACOSTIA				03451	0	0.9	4	0
			6025	LYTTONSVILLE					0	2.7	7	7
			6050	GAITHERSBURG					11	0.3	5	1
			6075	TEMPLE HILLS							66	61
4750-1000-5	PIPE, COPPER, 1" DIA.	0032	08/30/88	PR07940	P70111	10/24/88	9000	30	996	28505.5	6938	14253
			6000	ANACOSTIA				003367	0	89.1	175	273
			6025	LYTTONSVILLE					60	131.4	142	75
			6050	GAITHERSBURG					0	100.0	240	155
			6075	TEMPLE HILLS							7495	14756
4834-0400-0	VALVE, TAPPING, MECHANICAL JOINT, 4" DIA.	0099	11/04/88	PR09148		07/18/88	15	45				
		0030	05/13/88	PR06052	P67088			NO VENDOR NAME AVAILABLE				
			6000	ANACOSTIA				02932	3	4.4	2	6
			6025	LYTTONSVILLE					0	0.0	0	0
			6050	GAITHERSBURG					0	0.0	0	0
			6075	TEMPLE HILLS					0	0.0	0	0
4834-0800-0	VALVE, TAPPING, MECHANICAL JOINT, 8" DIA.	0030	07/25/88	PR07768	P68877	09/21/88	51	45				
			6000	ANACOSTIA				*** STOCK OUT ***				
			6025	LYTTONSVILLE				03423	4	13.7	0	20
			6050	GAITHERSBURG					0	0.0	0	0
			6075	TEMPLE HILLS					0	0.0	0	0
									0	0.0	0	0
											0	20

Figure 5-8 Status report on essential items.

Each of these reports is designed to collect general data and/or to alert management of potential problems. Once basic data have been gathered, other reports, such as those that identify items that are no longer used, can be programmed. Maintenance groups can effectively use the data generated to set up their own storeroom information systems, whether they be manual or automated. Although creating the data base is time-consuming for large warehouses, the need for it is clear. The guidelines presented here should help ease the way in establishing an effective inventory control system.

Reference

1. *Basic Management Principles for Small Water Systems*. AWWA, Denver, Colo. (1982).

6

Maintenance Costs and Budgets

One of the maintenance manager's most important responsibilities is to ensure that the utility's equipment and structures are reliably maintained at the lowest possible cost. In addition, the most effective managers are able to defend and sell to senior management legitimate budget requests and innovative programs that will require initial funding. Each of these tasks requires in-depth knowledge of the costs that are incurred to operate a maintenance department.

THE COST OF MAINTENANCE

Senior water utility management frequently views maintenance as a major cost center and carefully reviews it when the annual maintenance budget is submitted. The maintenance manager needs to thoroughly understand the costs incurred by his or her organization and must receive cost data in a concise, well-organized manner. The maintenance manager must be able to present cost information as well as budget requests to senior management concisely and intelligently.

Types of Maintenance Costs

Maintenance expenses comprise four primary categories:

1. Capital investments—This includes new and replacement equipment and structures. Some utilities categorize only tools and maintenance equipment as capital investments for maintenance, while others include treatment and pumping equipment (for example, water pumps and large motors) as maintenance expenses.
2. Maintenance actions—The cost of PM and CM activities, including labor and spare parts, is included in this category.
3. Utilities—This includes water, sewer, gas, power, and communications.

4. **Miscellaneous**—This includes service contracts, dismantling of equipment, and special studies. The effort needed to develop or modify a MMS would be included in this category.

The maintenance sections should carefully record expense information for each of these different categories to fulfill two needs: the accounting group needs the data to maintain proper accounting records to determine, for example, appropriate rate structures, and the maintenance manager needs data to prepare the budget and to control costs by comparing actual costs to estimated ones.

Accounting for Maintenance Costs

Many water utilities satisfy, at least partially, the needs of both the maintenance and accounting groups by classifying maintenance cost data into the following groupings:

Labor. This is the time spent by field personnel carrying out their duties. Usually, this is further divided into salaried and hourly personnel.

Equipment. Major pieces of equipment are generally included in this category and are capitalized and depreciated over their service life.

Spare parts/supplies. Items that are normally kept in the inventory or maintenance section storerooms are in this cost group. Small pieces of equipment, such as fractional horsepower motors, may also be considered in this class.

Services. This embraces the efforts of outside contractors or consultants and may include labor and materials.

Overhead. This category includes costs, such as the salaries of management personnel and the nonproductive time of field personnel, that cannot be assigned to specific jobs. Normally, maintenance and general utility overhead are segregated and analyzed separately. Maintenance overhead includes expense items specific to maintenance such as the cost of operating workshops and providing safety gear. The costs of operating departments such as finance and personnel, which provide services to all sections of the utility, are examples of general utility overhead. These costs are shared by all departments. Maintenance managers are expected to control at least a portion of their sections' overhead; however, they will probably have minimal influence on the utility's overall overhead.

With this type of accounting system, cost information is gathered for selected utility operations. For example, the cost elements listed above may be reported to the maintenance manager for filtration plant or well sites, impoundments, pumping stations, storage facilities, and the distribution system.

For each type of operation, costs are reported to the maintenance manager as direct or indirect. Direct costs can be charged against specific jobs, while indirect costs are the overhead costs described above. The indirect costs should be further broken down by individual section and general utility. This will enable the section manager to exercise control over the overhead costs specific to his or her group. For example, the cost of operating a maintenance storeroom would be recorded as an indirect maintenance cost, while the cost of running the main storeroom serving all departments would be reported as a general utility indirect charge.

Rather than report overhead costs to section managers, other utilities, particularly those in the public sector, establish expense categories for all cost elements. For example, power costs may be budgeted by the maintenance section. Figure 6-1 shows the monthly cost summary for a utility that uses this technique for reporting costs. Each office is assigned a section number. Costs are reported to the manager by expense element (for example, materials used) and broken down further

Monthly Section Report—June 19xx

	Current Month Charges	Fiscal To Date Charges	Fiscal Budget	Available Budget Balance
037 Distribution System Maintenance Office				
002 Salaries				
01601 Main Distribution System	\$ 4,345	\$ 68,029		
06437 Distribution Maintenance Office		1,265		
06465 Distribution Maintenance Administration	8,390	134,276		
06471 I/I Evaluation Office		21		
06760 Billed Work Charges—'X' Job Nos.		379		
06930 Educational and Training Time	1,665	5,143		
06939 Administrative Leave With Pay	28-	292		
06941 Vacation Pay	1,522	25,104		
06942 Sick Leave—Personal Illness	178	4,988		
06943 Holiday Pay	1,287	16,520		
06949 Sick Leave—Other	2,790	3,826		
07112 Water Supply Const.—Direct Charges	4,155	8,633		
	<hr/>	<hr/>	<hr/>	<hr/>
	\$24,304	\$268,476	\$271,133	\$2,657
003 Materials				
01601 Main Distribution System		\$ 490		
06437 Distribution Maintenance Office	\$ 5	146		
06760 Billed Work Charges—'X' Job Nos.	9,516	17,512		
	<hr/>	<hr/>	<hr/>	<hr/>
	\$9,521	\$18,148	\$21,200	\$3,052
008 Services By Others				
01601 Main Distribution System		\$326,453		
01603 House Connection Maintenance	\$ 45-			
06437 Distribution Maintenance Office	1,320	29,630		
06465 Distribution Maintenance Administration		806		
06760 Billed Work Charges—'X' Job Nos.	14,589	200,994		
07112 Water Supply Construction— Direct Charges	2,274	9,423		
	<hr/>	<hr/>	<hr/>	<hr/>
	\$18,138	\$567,306	\$553,500	\$13,806-
010 Contract Work				
07112 Water Supply Construction— Direct Charges	\$1,451,219	\$5,230,620		
	<hr/>	<hr/>	<hr/>	<hr/>
	\$1,451,219	\$5,230,620	\$5,380,000	\$149,380
014 Office Supplies, Services, and Expenses				
06436 Maintenance Bureau Office		\$ 196		
06437 Distribution Maintenance Office	\$266	1,610		
06454 Main-Line Section		78		
06465 Distribution Maintenance Administration		265		
	<hr/>	<hr/>	<hr/>	<hr/>
	\$266	\$2,149	\$2,500	\$351

Figure 6-1 Monthly expense report.

by account number. Account numbers are assigned to capture cost data for general information such as vacation or sick leave expenses.

Specific identifiers such as location, activity, or transaction codes can be used to gather data for specific utility operations. For instance, cost data on labor charges incurred by the maintenance section to service a particular pumping station could be determined by assigning a location code to that station.

Either of these approaches may satisfy the requirements of the accounting group and senior management for cost information. However, neither is likely to completely fulfill the requirements of the maintenance manager for the data on expenditures needed to monitor section operations. However, categorizing expenses using either of the techniques described above provides information needed by both the accounting and maintenance groups. Also, these techniques may make it possible to use a common data base. Maintenance management should be able to use the data gathered for the accounting system but may need to expand or modify the reports produced from the system in order to make the best use of the data for maintenance purposes.

Since the water utility will use an established system for gathering and reporting cost information to satisfy the accounting section's needs, the maintenance manager will need to understand this system. The maintenance manager also must ascertain in conjunction with other maintenance control techniques if additional cost data are required and how to collect and report these data to monitor maintenance costs. Certainly, the maintenance manager should plan to use the data already gathered for accounting purposes. He or she should build on this base of information and develop methods for maintenance cost control.

CONTROLLING MAINTENANCE COSTS ---

The maintenance manager can investigate two approaches toward controlling and, possibly reducing, the cost of maintaining the utility's property.

The first is to ensure that only required maintenance is done on equipment and structures. Water utilities have a special responsibility to deliver a safe and quality product to their customers at a minimum cost. This presents a dilemma: while undermaintaining equipment and structures for cost savings is a particularly poor policy for water utilities because of possible adverse health impacts, overmaintaining equipment is also out of the question because of the high costs involved. Thus, the utility must assess the importance of each component of the water processing and delivery system and evaluate the reliability of each system. Drawing on this information, previous experience, and manufacturers' recommendations, the maintenance manager can then strike a happy medium in system maintenance. The second approach is to make certain that each maintenance section's available resources, including personnel, equipment, and supplies, are used as efficiently and productively as possible.

With or without performance monitors such as time standards for maintenance tasks, cost data are an important source of information for the maintenance manager. There are three reasons for this:

1. Detailed cost data are needed to prepare the section's annual budget.
2. Performance reporting of field personnel accounts for neither expenditures relating to spare parts and supplies used for maintenance nor for the use of other section personnel such as the engineering and support staff.
3. Cost data will help to identify high-cost maintenance activities that may benefit from intense analysis, particularly those for which standard times are difficult to develop.

To satisfy the reporting requirements of the section with respect to cost data, the maintenance manager may need to develop new documents or modify existing ones. The next step is to determine how to gather cost data.

COLLECTING COST DATA

Determining what type of cost data the maintenance section should gather for internal analysis requires deciding how management will use those data. In turn, these decisions will help determine how to collect the information. For example, if the distribution of expenses by site is needed, then maintenance work orders should provide a place to record an account number (refer to Figure 4-5). The cost of utilities, equipment, and other expenses also will be charged against the appropriate account number. The techniques used to collect and report data will vary for the different cost categories.

Labor Costs

In most cases, the time sheet is the basic document for capturing data on labor costs. These costs can be recorded with an account number and a job number. In the example shown in Figure 6-2, the account number is used as described in the Accounting for Maintenance Costs section (that is, gathering data for general information), while the job number can be used to capture labor costs for particular types of activities done by the utility. For example, if the developer of a new housing subdivision uses utility personnel to perform specialized work and the utility policy requires the developer to pay for this work, the job number is used to gather all the costs associated with this work into one account. It should be noted, however, that since the work may be done by personnel from different sections of the utility, this accounting device will not gather cost data for individual maintenance work orders.

In general, because so many maintenance actions are done, it is impossible to use the job number to record detailed maintenance costs. Although, the time sheet is useful for gathering and reporting labor costs for both the accounting and maintenance sections, it is inadequate if the manager seeks information on the total cost of individual work orders. More data are required to determine the costs by specific job, category of work, skill, or some other classification. In these cases, it is more logical to use a work order or a job ticket, both of which may be designed to provide all hours recorded against particular maintenance jobs. For the work-order example cited in chapter 4, total crew hours are recorded, and the cost of labor can be estimated by averaging the cost per hour according to the skill level of each technician. If the number of work orders is relatively small, a cost can be estimated for each work order completed during the reporting period.

The manual approach for collecting these data is practical only for small water systems. To analyze cost data, larger water utilities should consider automating data collection. An automated maintenance information system can generate a number of useful reports, the form of which depends on the maintenance manager's needs and the time and money available to develop them. Figure 6-3 shows a useful report that gives labor and cost information on specific jobs. Programs can be developed to use these data to generate exception reports.

Figure 6-4 shows another useful report that lists nonproductive times for field crews. This report summarizes such data by depot. Note that management decided to record travel time as a nonproductive activity although crews take time to travel to the work site. By taking this approach, however, management can analyze if travel hours reported could be reduced by assigning crews to different depots.

Plant Maintenance Management System							
Monthly Corrective Maintenance Summary Run Date: 09/30/88							
September 1988							
Job Number Equip. Area/I.D.	Equipment Name Location	Apparent Cause Of Malfunction	Completion Date	Hours:		Costs:	
				Regular	Overtime	Labor	Parts Contract
003522	Raw Pump No. 3 Motor	Overload	09/14/88	8.00		\$166	
01-04023203	Raw Water Pumping Station	Overheated		0.00		0	0
		Equipment Malfunction:	Overload Relay Overheated				
		Corrective Action Taken:	Remove Replace Overload Relay				
003535	No. 2 Pump Motor	Bearing	09/15/88	10.50		\$190	
33-04034202	Hillcrest WPS	Worn		8.00		\$135	0
		Equipment Malfunction:	Outboard Bearing Worn				
		Corrective Action Taken:	Remove Replace Bearing				
003539	No. 3 Motor Control Center	Phase Balance Relay	09/18/88	6.00		\$120	
01-12043303	Finished Water Bldg.	Out Of Adjustment		0		0	0
		Equipment Malfunction:	Relay Out of Calibration				
		Corrective Action Taken:	Adjust Relay Calibration				

Figure 6-3 Monthly corrective maintenance summary.

Additionally, by excluding nonproductive hours from cost reports on individual jobs, management can determine the actual labor costs for specific jobs and identify the costs that seem to be excessively high.

Equipment Costs

The cost of equipment is easily determined from either the purchase order or the supplier's invoice. Equipment costs must be charged against the job in which the equipment will be used. To do so, the work-order number is frequently used. The account number is used to ensure that the correct account and department are charged.

Spare Parts and Supplies Costs

The costs of spare parts and supplies used to do maintenance are more difficult to allocate than equipment costs. For instance, it is not practical to individually charge

Distribution System Maintenance Nonproductive Time Summary Report—July 1988								
Current Month Shift 1								
Nonproductive Activity	Anacostia		Lyttonsville		Gaithersburg		Temple Hills	
	No. of Hours	% of All Hrs.	No. of Hours	% of All Hrs.	No. of Hours	% of All Hrs.	No. of Hours	% of All Hrs.
Depot	980	9.9	937	9.8	557	5.6	602	6.7
Travel	1,223	12.3	1,027	10.8	1,521	15.2	1,365	15.3
Truck/Equipment Breakdown	139	1.4	140	1.5	187	1.9	146	1.6
Instruction Delay	80	.8	63	.7	47	.5	134	1.5
Material Delay	177	1.8	71	.7	66	.7	52	.6
Equipment Delay	82	.8	39	.4	65	.6	24	.3
Tool Delay	0	0	0	0	19	.2	10	.1
Inclement Weather Delay	117	1.2	73	.8	175	1.7	66	.7
Customer/Miss-Utility Delay	13	.1	65	.7	92	.9	43	.5
Meetings	133	1.3	141	1.5	122	1.2	195	2.2
Injury	0	0	43	.5	0	0	0	0
Emergency Standby	43	.4	6	.1	2	0	11	.1
Inventory	273	2.7	151	1.6	206	2.1	243	2.7
Cleaning Yard/Equipment	490	4.9	7	.1	116	1.2	175	2.0
Warehouse Delay	43	.4	69	.7	37	.4	140	1.6
Contractor Delay	11	.1	24	.2	61	.6	35	.4
Transport Material/Equipment	498	5.0	633	6.6	633	6.3	790	8.8
Temp. Patch Maintenance	201	2.0	299	3.1	310	3.1	101	1.1
Safety Meeting	3	0	68	.7	57	.6	197	2.2
Formal Training	1,035	10.4	1,000	10.5	847	8.5	758	8.5
Total	5,541	55.5	4,856	51.0	5,120	51.3	5,087	56.9

Figure 6-4 Nonproductive time report summary.

for low-cost supplies such as nuts and bolts. Typically, low-cost supplies are accounted for as section overhead, and their cost is spread out over all maintenance work that uses them. More expensive items are charged against a job either as they are withdrawn from stock or after the job is completed. Although it is probably easier to record the actual cost of items and charge it to the proper job number when the items are taken from the storeroom, it is more practical to account for the cost of spare parts after the job is completed. That way, only those items actually used are charged against the job. Figure 6-5 shows a work order in which the estimated cost of spare parts is added after the technician records the parts actually used to complete the work order.

Costs for Outside Services

Maintenance sections frequently employ consultants and service contractors to do work involving special knowledge or equipment. Examples include the redesign of an HVAC system by a consulting engineering firm or the maintenance of elevators under a service contract. The cost of these activities is easily recorded from invoices and charged to an account designated for outside services.

Each incident of contract work should be recorded separately, keeping the cost of any parts used independent from labor costs, especially if the parts constitute

Corrective Maintenance Work Order

Date Printed _____ Bldg. Name _____ Job Number _____
 Date Requested _____ Priority _____
 Requested By _____ Malfunc. No. _____
 Equip. Name & No. _____ Plant Area _____
 Part or Model No. _____ Bldg. No. _____
 Serial No. _____ Level _____
 Instruction Book/File No. _____ CI No. _____
 Skill Code _____

Electric Motor Data:
 HP _____ Frame No. _____ Volts _____ Amps _____
 Pump Packing _____
 General Info. _____

Indication of Trouble _____ When Discovered _____
 Apparent Cause _____
 Effect _____
 Corrective Work Required:

Sketch Required? _____ Estimated Cost _____ Estimated Time _____
 Remarks _____

Card Code 01 (1-2)	Trans. Code RA (3-4)	Job No. (5-10)	Type Job (36-37)	Equip. I.D. (38-50)	
Parts Used:					Office Use Only Estimated Cost (30-35)
Part No. (11)	Description (12-23)	Contractor Req'd.? (24)	Quantity Used (25-27)	Unit of Measure (28-29)	
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Card Code 01 _____ Trans. Code CC _____ Job No. _____ Equip. I.D. _____
 (1-2) (3-4) (5-10) (11-23)

What was found wrong? _____ How was it fixed? _____

Outside Contractor Req'd.? Yes No Date Out of Service _____ Date Job Completed _____
 Contractor Cost _____ Requested By _____

 Mechanic I.D. No. Maint. Foreman

Figure 6-5 Corrective maintenance work order—equipment maintenance work.

additions to a basic service contract. This can be achieved by recording the location codes established for the cost accounting system, plus the dates the work was started, on the invoice when the invoice for a specific task is processed.

Overhead Costs

The accounting section normally is responsible for establishing both utility-wide and section-specific overhead rates. The maintenance manager then must ensure that the overhead rates for his or her section are consistently used wherever they apply. One example involves the cost of engineering services rendered by maintenance. Some water utilities charge this work to the department for which the work was done, while others absorb the cost of engineering as maintenance section overhead. Another way to keep track of overhead costs is to assign a work order for such tasks and gather cost data just like for any other maintenance activity. The method used depends on the utility's practices. The maintenance manager needs to be aware of how overhead is applied to assess if these costs are reasonable.

Energy Costs

For many water utilities, energy (particularly electric) used to operate their plants and pumping stations is a significant cost item in their budgets. Energy costs are frequently captured under one account because it is easier to detect significant variations in energy costs if one unit of the utility is responsible for monitoring them. The maintenance section is the logical choice since maintenance technicians are likely to follow up on any unusual charges from other utilities. The energy invoices are the source for cost data, which should be gathered by site using location codes.

REPORTING TO MANAGEMENT

Once the maintenance section has decided how to gather cost data, the next step is to determine how to report this information.

Management Cost Reports

Reports to management on the costs incurred by the maintenance department fall into two categories. The first type of report uses raw data to detail costs for individual jobs as well as costs by site. It also may include other reports used by the maintenance manager to track his or her section's costs during a specific period. Included in this classification are budget variance reports, which show actual versus budgeted expenses (see Figure 6-1). The second type of management cost report is the exception report, which relates information on costs that may be different from those expected. This type of report is produced only if costs exceed previously established limits.

Manual Cost Information Systems

Since most water utilities have automated accounting systems, the maintenance manager will generally receive computer-generated cost data reports from the data processing section (see Figure 6-1). These data are usually classified by expense type and department/section.

Even without an automated MMS, the maintenance manager will still be able to use graphics or other techniques to track costs over time. For example, labor costs, power costs, spare parts costs, and other costs could be plotted or recorded

monthly. A six-month average could be used to gauge costs for each category, and maintenance personnel would investigate any significant departures from the average. Any substantial deviations from the expected average would be included in an exception report for the maintenance section manager.

Unfortunately, manual reporting is practically limited by the magnitude of the effort and cost required to develop useful cost reports. With manual reporting systems, it is not cost effective to analyze individual work orders except for those in which the costs are quite high. In these cases, it is important to determine whether the costs of these jobs are within standard limits established by the manager. If not, these jobs would be reported to the maintenance manager on an exception report. Since the maintenance sections of large water utilities complete many work orders annually, these utilities should realize that using computers to gather and report cost information relating to maintenance may be a necessity if work-order cost data are to be managed properly.

Automated Cost Information Systems

Automated information systems enable the maintenance manager to gather and report cost data accurately and quickly. For example, the report shown in Figure 6-6 provides cost data on 680 work orders, breaking the information down into in-house PM and CM as well as contractor costs. Both labor and spare parts costs are given. In addition, other reports can be developed from this maintenance information system's data base.

PREPARING A BUDGET

The historic cost data gathered from the accounting and maintenance sections form the basis for developing the annual maintenance budget. In addition, actions proposed or undertaken by other departments may impact the maintenance budget.

For example, the engineering and operations departments may be planning or may have already implemented changes that will impact maintenance costs and operations. Senior management may be planning a major reorganization involving

Zone/Plant: Zone Name:		Plant Maintenance Management System Work Accomplished Summary May 1988		
		Preventive Maintenance	Corrective Maintenance	Totals
Number of Actions Completed		588	92	680
Regular Hours		1,948.25	972.90	2,921.15
Overtime Hours		0.00	20.00	20.00
Total Hours		1,948.25	992.90	2,941.15
Labor Costs		\$19,363.93	\$9,857.36	\$29,221.29
Parts Costs Estimated		400.93	17,954.62	18,355.55
Outside Contractor Costs		0.00	6,903.00	6,903.00
Total Costs		\$19,764.86	\$34,714.98	\$54,479.84

Figure 6-6 Work accomplished summary report.

substantial building modifications. Thus, the maintenance sections need to stay in contact with all other utility departments if they are to prepare realistic budgets for the next fiscal year.

Preparing the maintenance budget can be a straightforward process if the section manager plans adequately, gathers all necessary information, and allows sufficient time to prepare a well-documented, defensible case for the funds requested. A plan that employs these factors is as follows:

1. Prepare a schedule of the activities (items 2 to 7 below) needed to meet the budget deadline.
2. Collect data from the accounting section and maintenance records on the previous year's expenditures.
3. Identify extraordinary expenses from the previous budget and assess if these items will be repeated. If not, reduce the appropriate line items in the previous budget by the amounts expended on these items.
4. List major work activities or costly capital investments by the maintenance section itself that will be scheduled for the coming year. Estimate their cost. Such requests will need to be justified. The implementation of a new or modified MMS is likely to fall in this category.
5. Meet with other sections that typically impact the maintenance budget to determine if these groups are planning activities or changes that will affect maintenance expenses for labor, supplies, service contracts, and utilities during the coming year.

If meetings are not possible, ask the other sections to fill out forms assessing their requirements for specialized items that are included in the maintenance budget. The form shown in Figure 6-7 illustrates this method of obtaining information for budget purposes.

6. Incorporate inflation and overhead factors (as appropriate) as well as proposed increases in earnings for section personnel. Senior management will normally dictate the figures to be used for these expense categories.

7. Prepare a draft of the budget for review by the immediate supervisor before preparing the final draft for senior management's review.

The budget package that will ultimately be submitted to senior management for final review will include a summary sheet (see Figure 6-8) and detailed documentation in the form of attachments (see Figure 6-9).

The maintenance manager should allocate sufficient time from his or her schedule to thoroughly prepare the section's budget. It is easier to justify requests for additional resources when the budget is submitted than to request supplementary funds during the year. While much of the information needed to complete the budget is from historical data, maintenance costs for a new system or site will often need to be estimated.

ESTIMATING MAINTENANCE COSTS

Among the primary responsibilities of the maintenance section are to review specifications and plans for new systems, buildings, pumping stations, extensions to the network, and equipment and to estimate the funds needed to maintain the new system.

If the new system duplicates an existing one, the maintenance costs are relatively easy to estimate, except for the cost of unscheduled maintenance. However, even in this case, past experience will provide reasonably reliable figures to use. The maintenance department also must determine if it can justify requesting additional personnel to maintain even a modest addition to the utility's system. For example, if

Fiscal Year 1990
Radio Equipment Request Form

This Section to Be Completed By Requesting Section:

Section Number: _____ Section Name: _____

Total Number of Radios Requested: _____

Number to Be Installed in New Vehicles: _____

The above radios are required for the following reasons:

Number of Radios to Be Installed in Existing Vehicles: _____

The above radios are required for the following reasons:

Please reassign the following radios to another section as they are no longer needed:

Other Radio-Type Equipment, Pagers, Walkie-Talkies, Etc., Requested:

The above equipment is requested for the following reasons:

Section Head Requesting: _____ Date: _____

Division Head Approval: _____ Date: _____

Bureau Head Approval: _____ Date: _____

This section to be completed by Facilities Maintenance Division

Estimated Cost of Radios: \$ _____

Facilities Maintenance Division Recommendation:

Approved _____ Disapproved _____ By: _____

Date: _____

NOTE: Submit this form to the Facilities Maintenance Division by September 23, 1988, for inclusion in the budget.

Figure 6-7 Radio equipment request form.

Facilities Maintenance Division
Electrical/Mechanical Section #46

Sub. #	Items	FY '87 Actual	FY '88 Actual	FY '89 Budget	FY '90 Budget Request	FY '90 Proposed Budget
	Grand Total	\$ 6,078,547	8,261,747	10,589,400	11,683,600	
	Total Salaries and Wages	\$ 848,729	1,191,185	1,649,600	1,921,500	
	Total All Others	\$ 5,229,818	7,070,562	8,939,800	9,762,100	
	Salaries and Wages					
01	Regular Time	\$ 818,972	1,120,278	1,609,700	1,877,500	
	Overtime	\$ 29,757	70,907	39,900	44,000	
02	Total	\$ 848,729	1,191,185	1,649,600	1,921,500	
	Authorized Positions	# 53	60	89	97	
03	Materials	\$ 521,096	1,299,441	745,700	751,500	
05	Heat, Light, and Power	4,328,353	5,163,195	7,512,600	8,405,000	
07	Rental	36,737	53,779	39,500	46,000	
08	Services Rendered by Others	257,218	401,194	498,000	435,000	
10	Contract Work	—	—	25,000	—	
14	Office Supplies, Services, and Expenses	982	3,699	1,000	1,200	
18	Mileage	378	102	—	—	
38	Oils, Lubricants, and Other Petroleum Distillates	200	186	300	200	
42	Telephone and Telegraph	71,651	88,568	91,600	95,000	
49	Supper Money	130	199	100	200	
68	Refunds and Adjustments	476	651	—	—	
74	Radios and Radio Equipment	3,242	50,781	9,000	16,000	
77	Shop Tools, Laboratory, and Miscellaneous Equipment	9,355	8,767	17,000	12,000	

NOTE: This form is adapted from a sample form used by the WSSC.

Figure 6-8 Fiscal-year budget estimates.

Fiscal Year 1990 Proposed Programs
Explanation and Justification

Facilities Maintenance Division Electrical/Mechanical Section No. 46

PROGRAM ANALYSIS

POTOMAC ZONE—POSITIONS—The 19 currently authorized positions are divided into 6 crews. Each of the crews performs both preventive and corrective maintenance at various facilities in the zone. Of the 19 positions, the 5 electrical/mechanical positions complete the 2400 to 3000 work orders generated each year. It is estimated that one person can complete approximately 500 work orders per year. For fiscal year 1990, one additional electrical mechanic is requested to prevent a backlog in work orders. Work orders for fiscal year 1989, while budgeted at 2400, are estimated to total 3000. It is estimated that 3000 work orders will also be completed in fiscal year 1990.

In addition to the position necessary to continue current service levels, one additional instrument/electrical position is requested to perform the preventive and corrective maintenance associated with the three water stations that will become operational in fiscal year 1990.

ALL OTHER—The "All Other" items request for this program is \$267,000; \$113,000 for materials, \$27,000 for rentals, \$125,000 for services by others, and \$2000 for shop tools. Of the materials requested, \$40,000 is required to replace a hydraulically operated discharge at the Potomac plant, and \$20,000 is for the three new pumping stations opening in the zone. The remainder of the materials requested is for routine items that must be replaced on a regular basis. In fiscal years '86 and '87, approximately \$40,000 was spent on materials for these facilities. The \$27,000 rental requirement is needed to lease heavy equipment associated with the replacement of pumps at the Potomac raw water pumping station. The major service by others requirements are: (1) electrical relay calibration and testing, (2) electrical generator preventive maintenance, (3) overhauling electrical motors, (4) major repairs to rotating assemblies of pumps, and (5) installation of large new or replacement valves. Of the services by others request, \$8,500 is for the new pumping stations. The \$2000 for shop tools provides \$500 for replacement of damaged items and \$1500 for tools needed for new personnel.

NOTE: This form is adapted from one used by the WSSC.

Figure 6-9 Budget support document.

a new housing development is constructed, are extra personnel needed to maintain the distribution network? If a new pumping station is also required to service the development, can the equipment maintenance section handle it with existing personnel?

To answer these questions, the maintenance manager should estimate the number of labor hours needed to maintain the new system and add it to the hours needed for existing operations. The sum will dictate whether a request for additional staff is warranted. It is essential that the maintenance manager carefully gather and document the appropriate information on labor requirements.

In some cases, however, past experience will not be a reliable indicator of the maintenance requirements for a new system. This presents a more complex situation. If the new system is relatively small, the cost of maintaining it will be a small

Labor Estimate Form

Site: _____ Date: _____

Project: _____ Prepared By: _____

1) Direct Labor—Regular Time

A) Management/Supervision

Classification	No. in Class	Average Monthly Wage	% Time	Total
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

B) Skilled Labor

Classification	No. in Class	Average Monthly Wage	% Time	Total
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

C) Unskilled Labor

Classification	No. in Class	Average Monthly Wage	% Time	Total
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Monthly Subtotal _____
Annual Subtotal _____

NOTE: Shown is page 1 of the form. Page 2 covers direct labor overtime and administration.

Figure 6-10 Labor estimate form.

percentage of the maintenance budget. Therefore, the maintenance manager can safely cover the new system by adding a modest sum to the section's budget request. In such instances, the budget should note that future requests for funds to maintain the new system will be made based on data gathered through experience. It is also advisable to consult with the manufacturers or consulting engineers if they helped develop the new systems.

However, if the addition of a large installation is involved, greater care should be taken to ensure that the cost estimate more closely parallels actual costs. One approach is to prepare cost-estimating forms for the various line items in the budget. Figures 6-10 and 6-11 are examples of forms developed to estimate the cost of maintaining a water treatment plant (Jordan and Wyatt 1988) but are equally appropriate for use with other projects such as water pumping stations, water storage tanks, and office buildings. Other estimating forms have been prepared for other expense items such as energy and spare parts costs.

As noted above, the estimates developed before the project is implemented need to be adjusted as experience is gained from actual maintenance activities.

Controlling costs and preparing realistic budgets are critical elements for a successful maintenance management program. Therefore, the maintenance manager needs to ensure that the techniques used to gather and analyze cost information are carefully planned and executed.

Reference

1. JORDAN, J.K. & WYATT, A. *Estimating Operations and Maintenance Costs for Water Supply Systems in Developing Countries*. Water and Sanitation for Health Project, Technical Report No. 48. Roslyn, Va. (1988).

7

Training

Simply stated, training increases performance. It improves knowledge, skills, and motivation. Well-trained personnel are the most valuable resource available to the maintenance manager. Training programs, both formal (for example, classroom instruction) and informal (on-the-job training [OJT]), are needed to

- remedy deficiencies in skills or knowledge required to competently perform assigned tasks;
- inform new employees of the utility's rules and regulations and its code of conduct;
- instruct maintenance personnel of modifications in the operation of the maintenance management program;
- inform senior management of the maintenance section's capabilities to provide information from the maintenance management system;
- inform operations and other interested sections within the utility of major changes in the operation of the maintenance program, particularly emphasizing these other sections' roles in executing program modifications;
- provide employees with new knowledge to qualify them for possible promotion; and
- instruct personnel in good safety habits.

Successful training for these purposes requires planning and coordinating the efforts of many individuals.

RESPONSIBILITY FOR TRAINING

Each maintenance supervisor is responsible for instructing subordinates how to do the duties of the section. However, while this type of training is potentially valuable, it is inadequate if the utility's infrastructure is to be properly maintained. This is certainly true given the complexity of the current technology attainable. New techniques are available for the distribution system such as the renewal of pipelines by

relining, for the equipment used to process water such as electronic controls, and for buildings such as energy management systems.

Many water utilities have recognized the importance of proper training by establishing special training sections. The training supervisor's role is to coordinate the requests for training received by the other departments of the utility and to allocate available personnel and funds efficiently. The training group may also participate in the planning and delivery of training programs and contract consulting firms that specialize in training.

The maintenance manager may want to appoint an individual from his or her group as the maintenance training coordinator. This person's responsibilities include coordinating with the training section on maintenance training programs, ensuring that resources and training aids are available, and arranging for trainees' selection.

Smaller water utilities that cannot justify the need for a full-time training section need to make sure that their employees have access to training programs. Therefore, it is advisable for every maintenance section to appoint a training coordinator. However, in smaller utilities, the maintenance manager may have to fill this important role.

ASSESSING THE NEED FOR TRAINING

The first step in executing a successful training program is determining whether an actual need for training exists in the maintenance section. It is possible that a perceived deficiency in a field technician's performance may not be caused by lack of knowledge or skill, but rather as a result of other factors such as poor equipment design. Therefore, it should not be assumed that training is always the answer.

Training section personnel can help to determine if training will provide the desired result. The training group can also help the maintenance training coordinator assess needs and identify the resources available to satisfy them. Figure 7-1 shows the steps involved in identifying training needs.

STRUCTURING TRAINING PROGRAMS

Once the needs assessment is completed and assuming that training is required, the next step is to decide how to structure the training program.

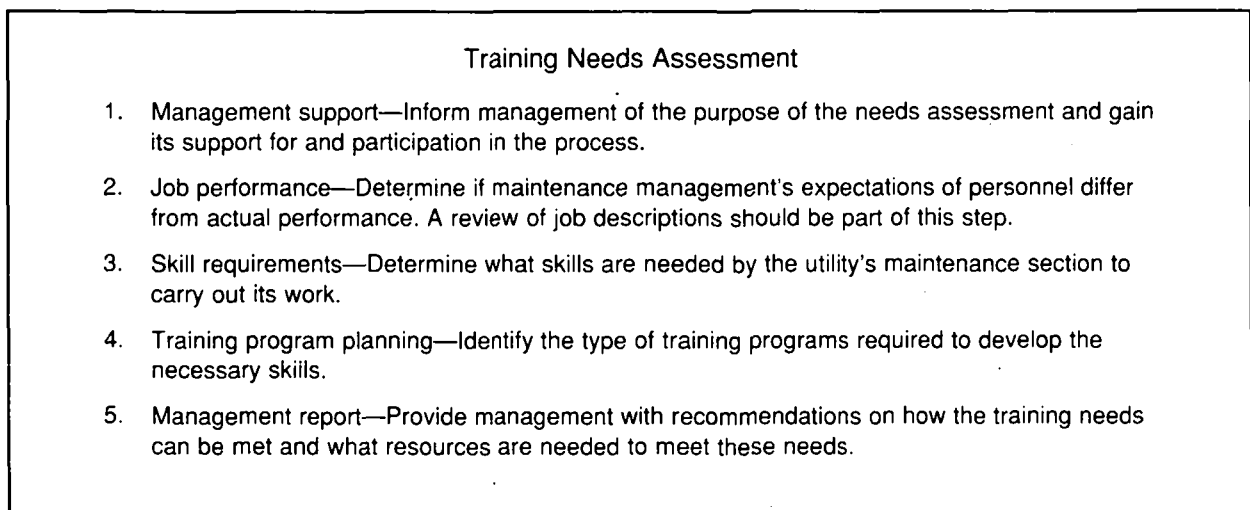


Figure 7-1 Assessing training needs.

Planning the Training Program

Before determining the types of training programs that will be used, the training section and training coordinator must

- prepare a detailed statement of the goals and objectives of the training program,
- identify the participants in the program,
- decide whether training or maintenance personnel will have primary responsibility for the training effort, and
- determine what resources are available to carry out training. For example, can maintenance personnel fill the role of trainer? Are manufacturers' or suppliers' representatives available to do the training? What are the restrictions on funds that can be used for training programs?

After these issues are resolved, it will be easier to select appropriate training programs to fulfill the requirements of the maintenance section.

Utility Policies for Training

Since the maintenance section will need to follow the utility's policies with respect to training, the training coordinator needs to answer the following questions before trying to develop the training program:

1. Will senior management support formal training courses or workshops during working hours, or must training be offered at other times? This frequently depends on whether the training course is needed to fill a basic need of the utility or whether it will enable personnel to qualify for a promotion. Some utilities believe that training programs that improve the ability of their personnel to do their work should be given during working hours as long as they do not interfere with necessary work.

2. What is the utility's policy with respect to funding external training courses, such as those offered at trade schools? Some water utilities fully or partially pay for outside courses as long as they are work related and are satisfactorily completed by the employees.

Types of Training Programs

After planning the training program and gaining management's approval for it, the maintenance section must consider what types of training to offer. Figure 7-2 lists the types of training available. The maintenance manager and training coordinator need to decide which mix of these training techniques will be most beneficial to the maintenance operation while staying within the funds available. They also need to find suitable trainers to conduct the training program.

Selecting Trainers

Selecting the right trainer is crucial if the training program is to be successful. In general, only experienced trainers can deliver effective formal training programs. When selecting trainers, the maintenance training coordinator must consider whether the utility wants to develop its own in-house training program, as well as how much money is available for training.

Because they are familiar with the water utility's operations, personnel from within the utility could be used to deliver training programs. This may also work well from a budget standpoint as it will save on hiring professional trainers. How-

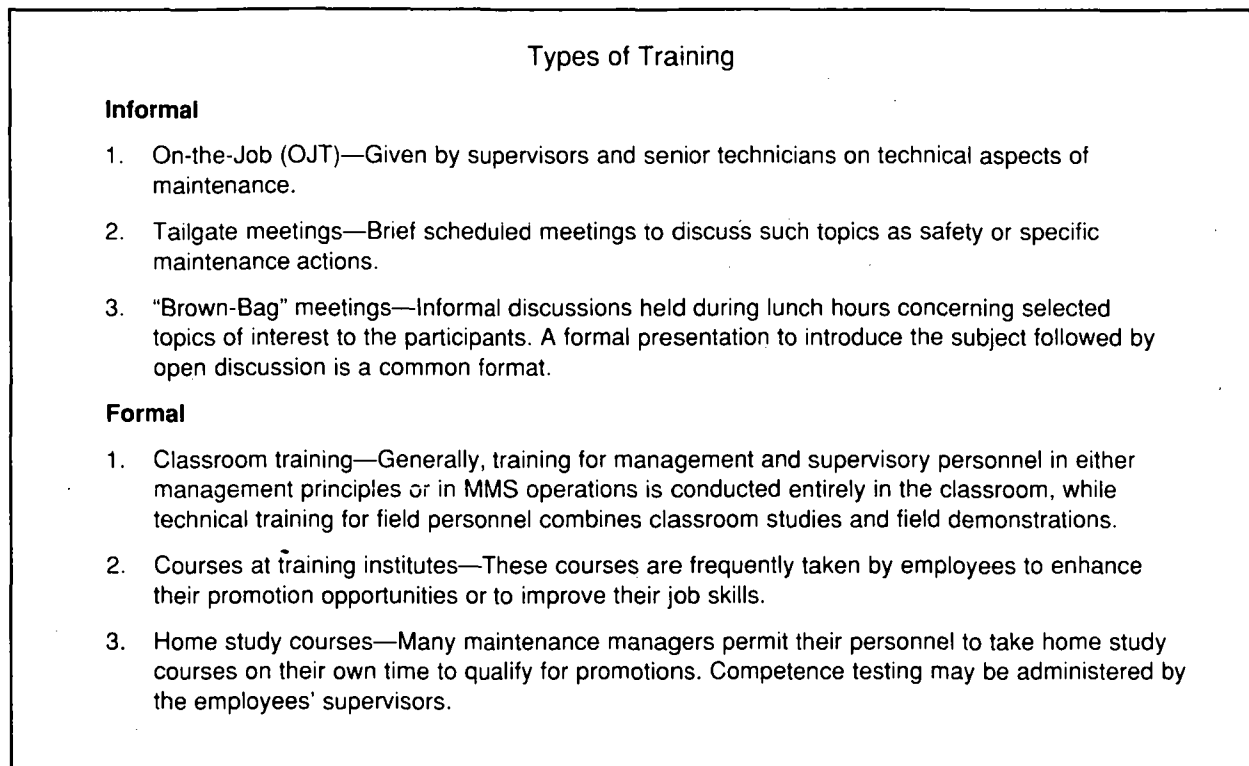


Figure 7-2 Types of training.

ever, a utility cannot select maintenance personnel and expect them to be experts in planning and carrying out training workshops. If the utility desires to develop its own training staff, it must allocate funds to train those personnel who will deliver the courses. Many sources including the utility's own training group if it has this skill, private consulting firms, universities, and professional organizations are available to carry out these “training of trainers” (TOT) programs. Larger water utilities should consider establishing their own training staff, since it is probably less costly in the long run.

One alternative to using utility staff exclusively as trainers is to use in-house trainers for frequently offered courses such as those given to field mechanics in upgrading their technical skills and courses presented to new supervisors. For the latter type of course, the presenters could include supervisors from many different sections of the utility to help the new supervisors gain a broader perspective of the problems facing other groups. Outside training consultants could present training courses given infrequently. Management courses for senior managers frequently are handled this way.

Are training funds limited? If so, perhaps a program combining limited in-house training, home study courses, and partial reimbursement for outside courses should be considered. In this case, maintenance supervisors should actively monitor the participants' progress. This approach, while not as effective from a training standpoint, limits the need for developing in-house trainers or using outside consultants to deliver training. However, since these programs are usually voluntary, the utility takes the risk of not developing the skills of its personnel to handle new assignments or meet changing technologies.

Preparing In-House Training Programs

If the utility will use its own staff to provide formal training, it must ensure that quality training programs are prepared and delivered. The preparation of the material for the course is just as important as the training of the trainer. Two alternatives can be considered by the maintenance training coordinator:

1. First, the trainer can develop his or her own instructional material based on experience and the needs of the section. This approach is likely to result in a course better tailored to the utility's operation. The trainer needs to provide accurate and thorough technical content, as well as prepare for the actual delivery of the material. To help with course delivery, the trainer might consider using techniques that will foster participant involvement. Small group activities, role playing, and field trips are effective if used under the proper circumstances. For technical training courses, hands-on programs have been found to be helpful. A trainer skilled in course preparation can help the trainer who is delivering the course to incorporate effective delivery techniques.

2. The second alternative is for the trainer to adapt training programs prepared by outside firms to the utility's operations (Figure 7-3).

These types of training programs, when coupled with the use of the utility's own equipment as models, have proven to be effective in improving the skills of the maintenance staff.

Whether the trainer elects to develop a course from scratch or to adapt a ready-made training program, he or she must also take into consideration the trainees and for what purpose they are being trained.

Consider management training, for instance. Management training programs differ from technical ones since the instructional material is presented entirely in the classroom. These programs involve less lecturing and more participant involvement, and the trainees are likely to be drawn from different departments of the utility. Techniques such as small group discussions are likely to be used more often in this type of course.

If the maintenance group is training both field and supervisory personnel how to operate a newly developed MMS, still another approach is needed. This type of training will be conducted either by the maintenance section or by a consulting firm (if one was used to develop the system). It will include trainees from inside and outside the maintenance group. Training to introduce a MMS must be prepared and delivered with the same attention to quality as with any other training program because the success of the MMS depends on the understanding and cooperation of all sections of the utility.

Training Aids

To be successful, all training courses require some type of training aids, including printed materials, overheads, and equipment models. For maintenance training, cut-out models of equipment and pipelines showing cross-sections are useful additions to the list of possible training aids. Skilled trainers will use various aids depending on the message they are trying to convey to the audience. Figure 7-4 shows a checklist that can help the trainer assess the impact and cost of different training aids (Ely 1980).

Training Sites

Where will training take place? If cut-out models can be used for training purposes, it is desirable to establish a permanent facility for technical training away from the

General and Mechanical Maintenance

Pumps

Centrifugal Pumps—1

The function, operation, and maintenance problems of centrifugal pumps and associated components are covered. This unit provides a thorough overview of all aspects of this type of pump as a basis for understanding the specifics of pump maintenance covered in the next unit.

Centrifugal Pumps—2

Building on the introduction in the preceding unit, Centrifugal Pumps—2 enables trainees to overhaul and pack a pump while supervised by a skilled mechanic. Specific topics addressed include job preparation, safety precautions, pump disassembly, impeller inspection, bearing inspection, packing problems, rotating element disassembly, component inspection, taking clearances, pump reasonably, pump packing, and operational checking.

Positive Displacement Pumps—1

This unit details the operation of various types of positive displacement pumps (gear, screw, lobe, and reciprocating) and associated components. It also describes gear and screw pump maintenance and repair problems.

Positive Displacement Pumps—2

This unit focuses on the specifics of overhauling a positive displacement pump—job preparation, safety precautions, pump disassembly, rotor and bearing inspection, pump reasonably, and mechanical seal replacement.

Couplings and Shaft Alignments

Several types of couplings and their components are covered in this unit, which is designed to prepare students to align a pump and motor using dial indicators while supervised by a skilled mechanic. Among the topics covered are the function of flexible couplings, types of couplings (jaw, steel grid, gear), disassembly and inspection, reasonable and continuing maintenance, types of component misalignment (parallel and angular), and techniques for aligning components.

Each unit of the program is designed to support four hours of instruction and includes a one-hour color videotape, student textbooks, and instructor's guide.

SOURCE: Adapted from *Training Partner Catalog, Video-Based Training Systems*. NUS Training Corp., Gaithersburg, Md. (1989).

Figure 7-3 Technical training programs for maintenance.

Checklist for Selecting Training Media							
Media	Production Costs	Duplication Costs	Type of Audience	Suitable Content			Senses Used
				Cognitive	Affective	Psychometric	
Printed materials	Very low	Very low	Individual	Excellent	Fair	Good	Sight
Lecture	Low	High	Group	Fair	Good	Poor	Sight-hearing
Audio tape	Low	Low	Group or individual	Poor	Fair	Poor	Hearing
Slides	Low	Low	Group or individual	Good	Good	Good	Sight
Overhead transparency	Mod. low	Low	Group	Good	Fair	Fair	Sight-hearing
Slides/tape	Mod. low	Low	Group or individual	Good	Good	Excellent	Sight-hearing
Television	High	Mod. low	Group or individual	Fair	Excellent	Excellent	Sight-hearing
Motion pictures	Very high	Mod. low	Group or individual	Fair	Excellent	Excellent	Sight-hearing
Simulation	Very high	Very high	Individual	Good	Good	Excellent	Sight-hearing Smell-touch Body movement

Figure 7-4 Checklist for selecting training media.

work site. In addition, training is usually more effective if the participants are away from their normal work environment. A change of scenery removes the temptation to check out current work and enables the trainees to concentrate on the course.

However, if the equipment or process needed to effectively deliver the training program cannot be replicated at the training facility, then training at the work site is probably necessary. In cases where the senses play an important role in the training, such as detecting equipment problems by smell or sound, on-site training should be part of the training program.

The trainer should decide on the training location as long as the site is consistent with the funds available and the operational needs of the utility.

Evaluating the Training Program

Regular follow-up is an important element in a successful training program. Program evaluation will alert the trainer to any deficiencies in the program and will help make training more responsive to the employees' needs.

All training programs need to be assessed for their effectiveness. Both the participants and the maintenance supervisors should have the opportunity to constructively criticize the training courses. It is most effective to have the trainees evaluate the course when it concludes. On the other hand, maintenance management will hopefully be able to see the benefits of training because of improved trainee performance. The maintenance manager and training coordinator should also visit the

training site periodically to evaluate firsthand the effectiveness of training programs in progress and to indicate their support for training.

The trainer also should participate in the evaluation process. In addition to responding to the feedback received during the training session, the trainer should plan follow-up visits with the participants to determine if the information delivered during training is being effectively used.

MEETING MAINTENANCE TRAINING REQUIREMENTS _____

The general principles covered above apply to all types of training programs. The next step is for the training section and the maintenance training coordinator to apply them so that specific maintenance training requirements are fulfilled.

A successful training program for the maintenance section requires technical training for field personnel in skills needed to properly maintain equipment and structures, as well as training for maintenance supervisors and managers. In addition, the maintenance manager needs to schedule training workshops if major changes are planned in the maintenance section's operation. For example, if the maintenance information system is to be automated, certain maintenance section workers must be trained to use the computer. Each training session needs to be structured so that it is directed toward the appropriate audience. The following four groups normally require training:

- field personnel,
- the maintenance management team,
- senior management, and
- operations personnel.

Field Personnel Training

The mechanics, electricians, carpenters, and other technicians who complete the PM and CM work orders require technical training and training in how to use the MMS. New employees need long-term technical training to adapt their skills to the water utility's particular maintenance needs. Experienced personnel need this type of training to learn state-of-the-art skills to enable them to work with new technology. This training must be an ongoing effort and may be accomplished effectively by combining classroom instruction with appropriate field exercises plus continuous on-the-job training by supervisors and crew leaders. Home study courses also can play a role in technical training.

Field personnel also must be trained how to operate the MMS because they play a key role in accurate recordkeeping for the system. A training program should be designed to cover the following aspects of MMS:

- the specific paper work requirements and why paper work is needed;
- the importance and expected benefits of the maintenance system for the effective operation of the maintenance section;
- the importance of accurate recordkeeping to the program;
- the need for accuracy, timeliness, and completeness;
- the role that operations personnel play in the MMS; and
- the use of records for tracking employees' work if this is to be done. (An example is a comparison of actual versus estimated time for completing work orders. If personnel are to be held accountable for or questioned about how long

they take to complete their work based on MMS-generated data, they must be informed of the techniques that will be used to gather and assess such information.)

It is also advisable to familiarize field employees with management reports to help them better understand the program's goals. Field personnel are typically not enthusiastic about paper work. Therefore, as program changes are implemented and tested, management should carefully monitor work orders, correct and explain errors, and reinforce the need for the new maintenance system.

Maintenance Management Team

Proper training of maintenance section managers and supervisors is an integral part of any water utility's operations. It is a mistake for senior management to assume that skilled engineers and technicians will make good managers without training. Therefore, formal management training is vital for a successful water utility.

Informal discussions among utility managers are also valuable. Many organizations recognize and encourage regular brown-bag meetings, typically held during lunch, to discuss management and other utility issues.

Because the maintenance section supervisory staff plays a major role if changes are made in the MMS, it must be trained in all aspects of the program, including paperwork requirements, management reports, and system review and maintenance.

Paper work. Supervisors must fully understand how the MMS operates so that they can guide clerical and field staff, particularly if the system is automated.

Management reports. Many maintenance programs are designed to produce progress reports on group activities. Understanding these reports and knowing the system's capability to generate special reports are essential to tracking maintenance activities.

System review and maintenance. Information in the maintenance information system should be kept current to be most useful to maintenance managers. This requires adding and subtracting equipment from the data base, modifying maintenance procedures, reviewing estimated times, and investigating useful enhancements to the maintenance management system. Field and clerical personnel can also supply information and insight that will help review the system. Management frequently overlooks updating the MMS data base. It is thus advisable to assign this work to a specific individual and to review the updating of the system periodically.

Senior Management

Training programs that are developed for senior management do not usually affect the training agenda for the maintenance group and are not discussed in this manual. However, this is not true when maintenance management is proposing to significantly modify the operation of the maintenance program. Since it is important to the success of the MMS for senior management to support new maintenance programs, brief training classes for these personnel should be scheduled during the planning and implementation stages of a new or modified system. The purpose of these sessions is to describe proposed changes in the maintenance system operation. Also, the training sessions offer an opportunity for the maintenance manager to restate the objectives of his or her section, explain the management reporting system, and provide detailed explanations of the reports on maintenance operations that senior management will receive.

Operations Personnel

As discussed earlier, the maintenance and operations sections need to work closely together. Operations personnel typically report equipment problems at treatment plants and pumping stations to the maintenance group, and operations supervisors require information on the status of equipment repairs. Thus, the equipment maintenance section manager should involve operations managers in decisions regarding changes in maintenance programs. The maintenance manager should plan to hold briefings with operations personnel, particularly supervisors, to

- explain changes in the way maintenance operates;
- solicit ideas and comments from operations personnel on MMS proposed modifications;
- describe the benefits of proposed changes to the utility;
- request their assistance in ensuring that plant operations personnel cooperate with the program by using designated forms and supplying required data, such as equipment identification numbers; and
- determine operations requirements for management reports. (For example, operations could effectively use the CM work-order status report to monitor equipment operations and availability.)

SAFETY TRAINING PROGRAMS

Promotion of safe practices among section personnel is one of maintenance management's more important responsibilities. Thus, safety training should be an integral part of the maintenance training program. Many water utilities consider safety so important that they not only deem violation of safety rules as cause for disciplinary action, but also establish award programs for the unit with the best safety record for a specified period. Some water utilities prepare their own safety handbooks and employ safety inspectors to visit job sites to make sure that proper safety practices are being followed. If the utility does not have a safety manual, the maintenance manager should consider preparing one covering maintenance activities.

The objectives of safety training are to ensure that all personnel are aware of and follow the utility's safety regulations and that safety equipment is being properly used. Thus, as part of their orientation, new employees must be thoroughly versed in the utility's safety rules. The same is true when new processes are installed at plants or other facilities; personnel need to be trained to handle these situations safely.

Types of Safety Training Programs

Water utilities generally use two types of safety training programs:

1. Safety meetings—The maintenance training coordinator should plan to meet regularly with field personnel to discuss safety issues. One common approach is to ask a supervisor or crew leader to prepare a program covering one safety-related topic and present it to the other maintenance personnel. For large water utilities with multiple maintenance workshops or depots, meetings are held at each site. Typical topics include the proper techniques for shoring a trench, handling electrical switchgear, or using power lawn mowers. These training sessions should be brief—30 minutes is usually sufficient—and attended by all employees. The maintenance manager should attend these meetings to reinforce the importance of utility safety.

2. Tailgate meetings—These are informal discussions conducted by field supervisors or crew leaders to emphasize particular safety-related issues. These sessions are conducted at the job site, last less than 30 minutes, and cover safety issues of immediate concern. For example, if the safety inspector has identified a safety violation, a tailgate meeting would be an appropriate time to discuss the safe technique for doing the work in question. Another topic could cover the safety actions required to do a maintenance procedure such as the one shown in Figure 3-1. Tailgate meetings should be held as needed to clarify safety rules or on a regular basis to remind personnel of the importance of safety on the job.

The safety coordinator should review proposed topics, ensure that the tailgate sessions are conducted regularly, and attend the meetings periodically.

References

1. ELY, D.P. *Guidelines for Media Production*. USEPA, National Training and Operational Technology Center, Cincinnati, Ohio (1980).
2. *Training Partner Catalog, Video-Based Training Systems*. NUS Training Corp., Gaithersburg, Md. (1989).

Appendix A

Computerized Maintenance Management Programs

A large variety of automated maintenance management software packages are available from commercial suppliers. A partial list for the IBM PC family of microcomputers is provided below. They range in price from \$2,000 to \$5,000. In addition, the *Journal AWWA* generally carries many advertisements from suppliers of software designed for use by the maintenance section.

FamTrac

Package features include the following:

- work orders,
- inventory control,
- equipment identification and history records,
- preventive maintenance scheduling,
- reporting, and
- cost analysis.

Available from:

Syska & Hennessy
Facilities Maintenance Group
11 West 42nd Street
New York, NY 10036

Micro Maint

Package features include the following:

- work-order entry, scheduling, and history;
- materials inventory;
- equipment history;
- reports; and
- cost history.

Available from:

Diagonal Data Corporation
2000 East Edgewood Drive
Lakeland, FL 33803

Micro-SIMS

Package features include the following:

- work request,
- work orders,
- equipment history management, and
- preventive maintenance scheduling.

Available from:

Energy Incorporated
Facility Management Systems
P.O. Box 738
Idaho Falls, ID 83402

Maintenance Management System

Package features include the following:

- work orders,
- inventory control,
- manufacturers' information,
- preventive maintenance,
- equipment run hours, and
- work history.

Available from:

Jentech Controls Inc.
Rt. 1 Box 93
Gresham, WI 54128

Operator 10—Inventory/Maintenance

Package features include the following:

- work-order generation/printing,
- equipment inventory,
- material inventory,
- equipment history,
- cost reporting,
- elapsed time meter log,
- maintenance forecasts, and
- manufacturer and vendor list.

Available from:

MACOLA, Incorporated
196 South Main Street
P.O. Box 485
Marion, OH 43302-0485

Plant Maintenance Management System (Plant)

Package features include the following:

- work orders,
- equipment inventory and history,
- activity definition,
- inventory control, and
- reporting.

Available from:

Hansen Software, Inc.
1745 Markston Road
Sacramento, CA 95825

Water Distribution Management System

Package features include the following:

- work orders,
- equipment inventory and history,
- activity definition,
- inventory control,
- reporting,
- area scheduled maintenance,
- waterline leaks,
- water test results, and
- vendor and manufacturer file.

Available from:

Hansen Software, Inc.
1745 Markston Road
Sacramento, CA 95825

Bibliography

HIGGINS, L.R. & MORROW, L.C., eds. *Maintenance Engineering Handbook*. McGraw-Hill Publishers, New York (3rd ed., 1977).

JORDAN, J.K. Establishing a Maintenance Program. *Jour. AWWA*, 79:8:32 (Aug. 1987).

———. Preventive Maintenance Programs—Must a System Be Automated? *Jour. AWWA*, 73:12:617 (Dec. 1981).

JORDAN, J.K. & MCLEOD, J.N. System Control: The Key to a Successful Management Information System. *Jour. AWWA*, 71:3:136 (March 1979).

Efficient Inventory Keeps System Running Smoothly. *Opflow*, 10:12:3 (Dec. 1984).

Plant Maintenance Program. Water Pollution Control Federation, Manual of Practice No. OM-3, Alexandria, Va. (1982).

Index

- Breakdown maintenance, 4
- Budget, 2, 81–82
- Building and grounds (B&G), 5–6
 - inventory, 59
 - performance monitoring, 55
 - work orders, 41
- Capital investment, 71
 - accounting for, 72, 74
- Construction, 2
- Contract management, 2
- Contractors, 16–17, 72
 - costs, 78, 80
- Control
 - automated, 48, 50, 52
 - manual, 44, 46, 48
- Corrective maintenance (CM), 4
- Costs
 - automated systems, 81
 - collecting data, 75, 77
 - controlling, 74–75
 - estimating, 82, 85, 88
 - manual systems, 80–81
 - types, 71–72
- Credit slip, 64
- Crew leaders, 12
- Data maintenance, 50, 52
- Discipline, 13, 15
- Distribution system, 5
 - inventory, 30, 58–59
 - performance monitoring, 54
 - work orders, 39
- Electrical and mechanical (E/M)
 - equipment, 5
- Employee evaluations, 15
- Energy costs, 80
- Equipment
 - costs, 72, 77
 - files, 30
 - identification number, 33
 - inventory, 30, 58
 - performance monitoring, 55
 - records, 29–30, 33
 - work orders, 41
- Feedback and control, 21
- Field staff, 12, 96–97
- Financing, 8
- Fire hydrants, 30
- Functional maintenance manager, 11–12
- Human resources, 8
- Inventory management, 2, 19
 - accountability, 64–65
 - automated, 65–66, 70
 - concepts, 57–58
 - control system, 22–23
 - determining quantities, 59–60
 - information systems, 60, 62–64
 - maintenance requirements, 58–59
 - water system, 29–30
- Job descriptions, 13
- Labor costs, 72, 75, 77
- Logistics, 8
- Maintenance
 - costs, 71–72, 74–75, 77–78, 80–82, 85, 88
 - definition, 4
 - department, 1–2
 - management, 2–3
 - organization, 9, 11
 - practices, 4
 - program elements, 7–8
 - water system requirements, 4–6
- Maintenance history, 21–22, 39, 41
- Maintenance management information system (MMIS), 3
- Maintenance management system (MMS)
 - automated, 28, 100–102
 - control, 44, 46, 48, 50, 52
 - definition, 18
 - elements of, 18–23, 25
 - enhancements, 22–23, 25
 - functions, 18–19
 - implementation, 27
 - manual, 28
 - monitoring, 43–44
 - needs assessment, 27–28
 - planning, 25–28
- Maintenance procedure (MP), 20
- Manpower, 2
- Materials requisition form, 64
- Meters
 - See Water meters
- Monitoring, 21
 - maintenance management system, 43–44
 - performance, 52, 54–56
- Nontechnical support staff, 13
- Operations
 - definition, 4
- Operator
 - See Water plant operator
- Overhead costs, 72, 80
- Performance
 - definition, 54
- Performance monitoring, 52, 54–55
 - purposes, 56
- Personnel
 - maintenance, 11–13, 15, 97
 - operations, 15–16, 98
 - policies, 13, 15
- Planning team, 26–27

Preventive maintenance (PM), 2, 4, 20-21
 Productivity
 definition, 54
 Promotion, 13
 Purchase order (PO), 60
 Purchase requisition (PR), 60, 62
 Purchasing system, 23

 Receiving order form, 62-64
 Records, 2, 8
 equipment and structure, 29-30, 33
 Regional manager, 12
 Repairs, 2
 Reports, 25
 management, 41-43, 80
 Resources, 8, 21

 Safety, 2, 13, 15, 25
 training, 98-99
 Scheduling, 20
 Senior management, 97
 Spare parts and supplies, 8
 costs, 72, 77-78
 Storeroom, 65
 Supervisory staff, 11-12
 System maintenance, 8

 Technical support staff, 12

Time studies, 54
 Training, 2, 8, 89
 assessing need for, 90
 evaluating, 95-96
 maintenance requirements, 96-98
 planning, 91
 policies, 91
 responsibility for, 89-90
 safety, 98-99
 structuring programs, 90-93, 95-96

 Utilization
 definition, 54

 Vehicles, 6

 Washington Suburban Sanitary
 Commission
 maintenance organization, 9
 Water meters, 30
 Water plant operator, 15-16
 Work measurement, 54
 Work order system, 19-20, 33-34
 automated, 34, 36, 39
 criteria for retaining or discarding,
 39, 41
 manual, 34
 priority, 43-44

