Maintenance Management for Medical Equipment

American Hospital Association

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Maintenance Management for Medical Equipment is designed to help hospital biomedical personnel develop, monitor, and manage a maintenance program for hospital medical equipment. This manual provides suggestions for designing an effective and thorough maintenance program that avoids burdensome paperwork. It also contains scheduled maintenance procedures and maintenance data tables for most of the equipment found in a typical modern hospital.

The goals for equipment management are twofold: (1) to provide for a safe and functional environment by ensuring the proper maintenance of all equipment and spaces and by securing the essential documentation required of all equipment and spaces, and (2) to provide for a manageable and economical maintenance system by minimizing the amount of time required to maintain and document the maintenance of all equipment and space.

This manual is a revision of the 1982 edition of Medical Equipment Management in Hospitals and is a companion to Maintenance Management for Health Care Facilities (1984), both published by the American Hospital Association.

The material in this book is based on information gathered from the development and implementation of the Equipment Maintenance Scheduling System designed by the Kaiser Permanente Southern California Regional Engineering Office for use by its nine medical centers. Data portions of the maintenance tables were gathered from the maintenance histories of equipment in those hospitals.

The material is subject to continuing review and revision by the Clinical Engineering Section of the American Society for Hospital Engineering (ASHE). Comments on any part of this book are welcome and should be directed to ASHE, American Hospital Association, 840 N. Lake Shore Dr., Chicago, IL 60611.
ACKNOWLEDGMENTS

Publication of this edition of Maintenance Management for Medical Equipment is part of the continuing efforts of the Clinical Engineering Section of the American Society for Hospital Engineering (ASHE) to provide the biomedical profession with the latest advances in maintenance concepts and techniques.

The material in the book is based on information gathered from a number of sources, including equipment manufacturers, dealers, shared clinical engineering services, hospital biomedical maintenance departments, and independent service companies. The data gathered from these sources have been compared and analyzed so that the resulting tables and procedures represent a middle-of-the-road approach to scheduled maintenance.

This edition, as well as its predecessors, is based on the original work of Michael Brinkman, president of Hospital Maintenance Consultants, Inc. The 1982 edition contained expanded instructional material and new sections on productivity, maintenance program evaluation, and vendor service contracts. Joining Mike in these efforts were Henry Alder, Richard DiMonda, Mary Ann Kelly, Malcolm Ridgway, and the Clinical Engineering Shared Service Committee. This edition continues this effort by adding maintenance concepts developed by Tom Schipper during his time as a biomedical consultant with the Hospital Council of Southern California and tested during his tenure with Kaiser Foundation Hospitals of Southern California. The expansion of the section on productivity was the work of Norman Hoekstra. Grateful acknowledgment is also made to the following contributors who provided the assistance and information necessary to produce this manual.

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DEFINITION OF TERMS

In order to understand many of the concepts contained in this book, it is necessary to define the basic terms associated with maintenance of equipment. The following definitions will be used in this book.

Scheduled Equipment Maintenance

Scheduled equipment maintenance is work performed on equipment on a scheduled rather than on a user-demand basis. The purpose of the procedure may be a mixture of one or more of the following:

- Preventive Maintenance—To clean, lubricate, adjust, check for wear, and replace components that might cause total breakdown or serious functional impairment of the equipment before the next scheduled inspection. In addition to improved performance, a major advantage of true preventive maintenance is a reduction of economic losses associated with demand repair work and loss of revenue while the equipment is nonfunctional.

- Functional Testing, Performance Verification, and Calibration—To verify that equipment is fully operational and performing within reasonable, previously specified limits. Depending on the device, it may be appropriate to specify several different levels of functional testing and performance assurance; for example, the simplest level consists of visual inspection of the device. The term calibration usually implies that the device is compared against a reliable standard.

- Safety Testing—To verify that the equipment is in compliance with one or more specified safety requirements. Such checking is frequently limited to electrical safety testing.

Scheduled Environmental Maintenance

Compared to work performed on equipment, scheduled environmental maintenance is work performed within a designated area on a scheduled basis. The purpose of the procedure is a mixture of those items mentioned under scheduled equipment maintenance, but the emphasis is changed from equipment to the area in which equipment is found and minor equipment items not inventoried. Environmental maintenance includes a review of the aesthetic appearance and the integrity of an area. Examples of items that are environmental in nature include such items as electrical beds, oxygen blenders, portable exam lamps, x-ray viewboxes, and ophthalmoscope/otoscope wall sets.
Corrective Maintenance

Corrective maintenance is work performed on a piece of equipment or environment to restore it to proper condition. The work is usually provided on an unscheduled basis following a request from the equipment operator or user, or from personnel performing scheduled maintenance. In the latter case, the repairs would be of the type not called for on the scheduled maintenance procedures even though these procedures may have been instrumental in identifying the repair.

Maintenance Inventory

As opposed to a property or equipment inventory, a maintenance inventory is specifically designed to be a tool for developing an efficient and effective biomedical maintenance management function. In developing the maintenance inventory, a hospital is divided into environmental units. The list of these units and a list of equipment requiring more care than allowed for under the provision of environment maintenance constitutes the maintenance inventory.

MAINTENANCE PHILOSOPHY

Goals

In developing a maintenance system, an attempt should be made to achieve the following goals:

1. The maintenance system should provide for a safe and functional environment by maximizing the maintenance of all equipment and spaces and providing the essential documentation required of all equipment spaces.

2. The maintenance system should provide for ease of management and economy by minimizing the amount of time required to maintain and document the maintenance of all equipment and spaces.

Objectives

These goals have been translated into a middle-of-the-road approach to maintenance management. This approach to scheduled maintenance is one of three used in hospitals. These three can be defined as follows:

- Provision of one major maintenance procedure, such as inspection, lubrication, calibration, safety testing, or testing for wear, per item per determined frequency. This procedure is supplemented by as many minor procedures as are required to keep the performance of the device within what the hospital considers to be reasonable limits and to meet the requirement of the Joint Commission on Accreditation of Healthcare Organizations (Joint Commission) for periodic testing of equipment.
- Provision of a major maintenance procedure every time the device is inspected. This approach requires considerable manpower and therefore is not considered to be cost-effective.

- Provision of periodic electrical safety inspection, with simple performance assurance and verification tests to ascertain whether the device is operating properly. This approach meets the current minimum standards, such as those defined in Plant Technology and Safety Management Standards of the Joint Commission.

The first, middle-of-the-road approach was selected because it makes the most cost-effective use of all resources and meets the goals established for effective maintenance. The second, more time-consuming approach produces no better results than the first; that is, maintenance procedures involving a major overhaul are not required under the first plan more than once a year except in unusual operational settings. And although the third approach, which involves the least investment of time, meets all the current regulatory requirements, it is not the most cost-effective because it omits true preventive maintenance when necessary, and does not reduce economic losses associated with demand repair and loss of revenue while the equipment is nonfunctional. This is especially true of the many electromechanical items that are used throughout hospitals.

The middle-of-the-road approach coincides with the maintenance level that is necessary under normal operational circumstances to keep equipment operating properly, safely, and most economically. A judgment on how these requirements are best balanced is reflected in the procedures contained in this manual. As more information becomes available, these inspection formats or their frequencies may need to be revised.

THE MAINTENANCE INVENTORY CONTROL CONCEPTS

Even with the adoption of the middle-of-the-road approach, the workload and paperwork would be overwhelming if every piece of equipment in a hospital (including such things as electronic thermometers, and patient scales) were given a separate maintenance schedule. Recognizing this, several procedures have been developed to limit the inventory. For example, such noncritical items as the electronic thermometers and patient scales are incorporated into environmental units and an entire environmental unit is placed on a maintenance schedule rather than each piece of equipment within the environment. This environmental concept, along with two other inventory control concepts, the functional unit and grouping concepts, are further explained in Part 2.

MAINTENANCE PROCEDURES

The maintenance procedures found in this book are intended to provide a middle-of-the-road guideline for scheduled maintenance. They are not intended as industry standards, but rather are to be used as models from which each hospital can develop procedures appropriate for its own equipment and special needs. Neither the procedure content nor the frequency should be considered as a fixed standard; instead, they should be varied as necessary to reflect the hospital's own environment, staff complement, equipment utilization, and
personnel skill levels. The procedures are intended only to define the scope of the maintenance performed, not to be used for detailed instructions or for training purposes. Detailed procedures for these functions should be obtained from other sources, such as the equipment manufacturer.

ACTIVITIES FOR THE MAINTENANCE PROCEDURES

The maintenance procedures cover only tasks related to the scheduled maintenance of equipment within the normal hospital setting. If the procedure is modified or if the nominal time allowance does not appear to take into account specific circumstances within a hospital, the allocated labor level should be modified accordingly.

Other activities, however, must also be taken into account in determining the productivity of an organization or an individual. Identification of such activities and a formula for determining productivity are discussed in Part 4.

The allocated labor levels include only the time required to actually perform the maintenance, and do not include time needed for travel within the facility to locate the equipment or to locate tools.
PART 2: MAINTENANCE INVENTORY CONTROL AND DOCUMENTATION

MAINTENANCE INVENTORY CONTROL

Experience shows that unless equipment inventories are limited to significant equipment, a massive paperwork system is created with demands that are not easily satisfied.

Placing items such as card embossers on the same inventory as defibrillators and monitoring systems forces biomedical departments to provide individual attention and documentation for minor equipment at the expense of time needed for maintaining essential equipment. However, the necessity, to retain some maintenance control over minor equipment is still recognized.

THE ENVIRONMENTAL CONCEPT

The premise of the environmental concept is that the basic requirement of any maintenance system is evidence that a safe and functional environment exists throughout a medical center. This manual is written to make provision for the documentation of maintenance based on facilities divided into environmental units rather than on individual pieces of equipment within these units.

An environmental unit is defined as a space of manageable size identified by a maintenance identification number. Manageable size is defined in terms of either a unit's function, such as an ICU, or the time required to perform the maintenance procedure (for example, half a general nursing floor). The entire hospital is divided into environmental units and the equipment found in an environmental unit is considered part of the unit.

Under the environmental maintenance concept, maintenance protocols and documentation are not required for individual pieces of equipment, unless they are determined to be necessary by the guidelines on page 7. Instead, scheduled maintenance programs are developed for the environmental units of the hospital, and documentation is recorded for each environment. The maintenance procedures include such items as the condition of outlets, plumbing, lighting, and paint. Equipment checks for minor equipment are part of the environmental task list and are maintained as part of the environmental unit. The entire unit, including all equipment on its task list, is then checked during a sweep of the area. When corrective maintenance is done to equipment in a unit, either during the sweep or later, it is documented under the identification number of the environmental unit and through the use of the model and serial number (if any) of the repaired items.

Through the environmental concept approach, maximum maintenance coverage is obtained yet the number of files needed to document this activity is kept to a minimum.

All areas of a hospital are divided into environmental units and are classified according to the type of patient and activity use of the area. All areas of a hospital will fit in one of these classifications. Mapping the environmental areas on floor plans has been found useful in developing and executing the environmental program. The five types of environmental units in general use today and their definitions are as follows:

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1. **Nonflammable Anesthetizing Location**
   An anesthetizing location is an area of the hospital that has been designated by the hospital to be normally used for the administration of an inhalation anesthetic agent. In most cases, this refers only to operating rooms and delivery rooms. A nonflammable location is a location that, by issuance of a hospital policy, is used only for nonflammable inhalation anesthetizing agents.

2. **Critical Care Areas**
   Critical care areas are patient care areas, classified by hospital policy and outside the operating and delivery rooms, where patients are subjected to invasive procedures and directly connected to line-operated medical devices. This class includes intensive care and catheterization areas. With a few exceptions, electrical construction provisions of these areas have basically the same requirements as the general care areas.

3. **Wet Location**
   Patient care areas that are normally subject to wet conditions, including standing water on the floor, or routine dousing or drenching of the work area. Routine housekeeping procedures and incidental spillage do not constitute cause to designate as a wet location. Generally, this classification refers only to the hydrotherapy tank rooms of physical therapy departments.

4. **General Care Area**
   Patient care areas where patients are expected to come in contact with ordinary electrical appliances (lamps, beds, televisions, and so forth) or to be connected to medical devices.

5. **Nonpatient Care Area**
   Areas where patients are not normally cared for or treated such as administrative office areas, laboratories, nursing stations, storage areas, kitchens, or medical office areas.

One key to keeping environmental maintenance scheduling to a minimum is in properly classifying an environment. Incorrect classification of an area can result in twice the required number of maintenance inspections. For example, occasional use of anesthetizing agents in a room does not require that it be classified as a nonflammable anesthetizing location.

Although it would be ideal to be able to maintain the hospital adequately by using the environmental approach, some equipment cannot be maintained appropriately in this manner. Equipment of this type is excluded from scheduled environmental maintenance and is assigned an independent inspection frequency, instruction set, and documentation file. Such items are labeled "significant equipment." To be classified as such, a piece of equipment should be included in one or more of the following criteria:
Significant Equipment Criteria

1. **Equipment considered to be essential for life support**
   Defibrillators and critical care monitors would be an examples of this type of equipment.

2. **Equipment known to be potentially involved in incidents**
   This criterion provides for documentation of work on items such as electrosurgical units and infusion devices, which normally have a higher incident risk associated with their use.

3. **Equipment needing a more intensive maintenance schedule**
   The more mechanized a piece of equipment, or the more often it is used, the less likely it is that the equipment will be able to be appropriately maintained by the environmental approach. This equipment may need a more complex set of maintenance instructions or more frequent maintenance schedule than can be provided by the environmental inspection.

4. **Equipment being supplied or maintained by an external vendor**
   This criterion refers to equipment that is not being maintained by in-house personnel. The prime reason for this criterion is that because this equipment is being maintained externally, it becomes "transparent" to the environmental maintenance of the area. Therefore, it is not part of the scheduled maintenance and documentation program without individual identification.

   Equipment types considered significant are found as class codes in the "Maintenance Data Tables" section of this reference guide.

   Examples of equipment items not considered significant are listed in figure 1.
Table 2.1. Items Generally Included in Environmental Testing

<table>
<thead>
<tr>
<th>Audiovisual Equipment</th>
<th>Nonelectrical Food Carts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autopsy Saw</td>
<td>O.R. Lamps</td>
</tr>
<tr>
<td>Baby Cribs</td>
<td>Ophthalmoscope/Otoscope Wall Sets</td>
</tr>
<tr>
<td>Bassinets</td>
<td>Ovens</td>
</tr>
<tr>
<td>Bed Lamps</td>
<td>Oxygen Blender</td>
</tr>
<tr>
<td>Buffers</td>
<td>Paraffin Baths</td>
</tr>
<tr>
<td>Business Machines</td>
<td>Parallel Bars</td>
</tr>
<tr>
<td>Calculators</td>
<td>Patient Lifts</td>
</tr>
<tr>
<td>Ceilings</td>
<td>Patient Scales</td>
</tr>
<tr>
<td>Circulating Bath</td>
<td>Pipet Shaker</td>
</tr>
<tr>
<td>Coffee Makers</td>
<td>Pipet Washer/Dryer</td>
</tr>
<tr>
<td>Computer</td>
<td>Portable Exam Lamp</td>
</tr>
<tr>
<td>Conductive Floor Testing</td>
<td>Portable Fan</td>
</tr>
<tr>
<td>Convection Oven</td>
<td>Portable Heat Lamps</td>
</tr>
<tr>
<td>Deep Fryer</td>
<td>Refrigerator (Non-Med Storage)</td>
</tr>
<tr>
<td>Diluter</td>
<td>Room Furniture</td>
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<tr>
<td>Door Latch Tensions</td>
<td>Room Grounding</td>
</tr>
<tr>
<td>Doors (Manually Operated)</td>
<td>Rotator</td>
</tr>
<tr>
<td>Drinking Fountains</td>
<td>Scrub Sinks</td>
</tr>
<tr>
<td>Electric Thermometers</td>
<td>Sewers</td>
</tr>
<tr>
<td>Electrical Beds</td>
<td>Shaker</td>
</tr>
<tr>
<td>Electrocauter Units</td>
<td>Showers</td>
</tr>
<tr>
<td>Enzyme Treatment Drains</td>
<td>Signs and Lighting</td>
</tr>
<tr>
<td>Exam Tables</td>
<td>Sinks</td>
</tr>
<tr>
<td>Exit Lighting</td>
<td>Slide Dryer/Warmer</td>
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<tr>
<td>Eye Washers</td>
<td>Stenographic Equipment</td>
</tr>
<tr>
<td>Floor Coverings</td>
<td>Stirplates</td>
</tr>
<tr>
<td>Floor Drains</td>
<td>Televisions</td>
</tr>
<tr>
<td>Floor Machines</td>
<td>Temperature Block</td>
</tr>
<tr>
<td>General Lighting</td>
<td>Test Equipment</td>
</tr>
<tr>
<td>Gurneys</td>
<td>Time Clocks</td>
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<tr>
<td>Heaters</td>
<td>Time/Date Stamp Unit</td>
</tr>
<tr>
<td>Heat Sealing Units</td>
<td>Tissue Float</td>
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<tr>
<td>Holter Tape Recorder</td>
<td>Toilet Exhausters</td>
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<tr>
<td>Hotplates</td>
<td>Toasters</td>
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<tr>
<td>I.D. Printers</td>
<td>Transformers</td>
</tr>
<tr>
<td>Immersion Heaters/Humidifiers</td>
<td>Trash Chute Doors</td>
</tr>
<tr>
<td>Insect Controllers</td>
<td>Typewriters</td>
</tr>
<tr>
<td>Isolated Power Systems</td>
<td>Ultrasonic Cleaners (Small)</td>
</tr>
<tr>
<td>Laboratory Oven</td>
<td>Vacuum Cleaners</td>
</tr>
<tr>
<td>Laminar Air Flow Hoods</td>
<td>Video Equipment</td>
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<tr>
<td>Laundry Chute Doors</td>
<td>Walls</td>
</tr>
<tr>
<td>Lawn Sprinkler System</td>
<td>Warming Cabinets</td>
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<tr>
<td>Line Integrity Isolation Monitor</td>
<td>Water Temperatures</td>
</tr>
<tr>
<td>Master Clocks</td>
<td>Wheel Chairs</td>
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<tr>
<td>Mechanical Beds</td>
<td>Window Screens</td>
</tr>
<tr>
<td>Medical Gas Outlets</td>
<td>Whirlpool Unit</td>
</tr>
<tr>
<td>Medical Vacuum Outlets</td>
<td>X-Ray Viewboxes</td>
</tr>
</tbody>
</table>

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In treating equipment as part of an environment, two questions arise:

1. What procedure should be followed if equipment cannot be checked because checking it would interfere with patient care?

2. If a piece of equipment moves frequently from one environment unit to another, how do we know if it is ever checked?

For example, how can one be sure that all hospital beds in an environment were inspected since one may have been accommodating a very sick patient or out of the unit while the unit was being checked and then returned the following day? To be sure, such equipment will occasionally be missed. This problem can be minimized if the environmental units are kept relatively large (such as a wing rather than an individual room). Even allowing for occasional misses, the hospital can still say that in general the equipment (a hospital bed for example) is safe and functional and the inspection will still be able to identify problem patterns for that class of equipment. In using the environmental unit concept, it is assumed that the principles of quality control used in manufacturing apply to hospitals as well. Portable equipment moved from environment to environment is not expected to be tested at the same frequency as the environment itself. However, testing of a large number of minor devices of a similar type is expected to alert engineers to any generic problem that may exist, and a subsequent sweep of the hospital would then eliminate the problem. If a specific type of equipment is found to be particularly troublesome, it would be removed from the environment list and given its own class code, maintenance instruction, and schedule. Discovery of problems of this type are usually found through reviews of the internal risk management data and environmental unit maintenance documentation histories.

THE FUNCTIONAL UNIT CONCEPT

Developing control over the maintenance inventory by classifying the facility into environmental units is the first concept in this approach to biomedical maintenance management. The second, the functional unit concept, provides a method for controlling the maintenance inventory of items requiring separation from the environmental approach to maintenance. This concept applies to a piece of equipment, or easily identifiable system, that is composed of several parts or modules. If the parts or modules always occur together and are functionally interdependent, the entire system can be considered as one piece of equipment on the inventory. A physiological monitor, for example, consists of a monitor screen and several plug-in units. In this way, only one maintenance protocol is developed so that the entire system is inspected at one time rather than individual parts being inspected separately. Documentation is kept for a system rather than on each individual part. The functional unit concept is very similar in nature to the environmental concept, but on a smaller scale.

THE GROUPING CONCEPT

A third method for minimizing the essential equipment inventory while assuring necessary maintenance is by adopting the grouping concept. This concept applies to a class of equipment that qualifies as significant but that occurs in such large numbers that individual treatment would become unmanageable. An
example would be electronic thermometers. A biomedical department may wish to include these as critical equipment, but because they occur in such large numbers, work orders and documentation for each electronic thermometer would be unmanageable. Under the grouping concept, all electronic thermometers would be considered one item on the maintenance inventory. One work order would be issued and all electronic thermometers would be inspected (and results documented) in a sweep of the entire building.

The key to making a maintenance and documentation system manageable is in controlling the maintenance inventory by using the three concepts described in this section.

**DOCUMENTATION**

Although a biomedical maintenance management program is designed to provide a safe and functional environment, documentation of maintenance activity has also become an important part of a complete program. As various accrediting and regulatory agencies have required more thorough documentation, hospitals have developed documentation systems, many of which require too much time and paperwork to maintain. Documentation provides evidence that the maintenance is being performed in a prescribed and acceptable manner. To determine if documentation is adequate, a breakdown of the maintenance system into its work elements is necessary. If evidence can be produced that the work involved in these activities is being performed as required, documentation can be considered adequate. Figure 2 presents a workflow model of the biomedical maintenance program. The maintenance functions forming the base for facilities activity are:

1. The installation of equipment or addition of environments
2. Scheduled maintenance
3. Corrective maintenance

Using the approach to maintenance outlined in this manual, the following work occurs within these three activities.
1. Addition of Environmental Units and Equipment
   a. A verbal or written communication is sent notifying the biomedical office of receipt of new equipment (or the addition of environmental units).
   b. New equipment is inspected, and if determined to be significant, is assigned an identification number and added to the maintenance inventory. Otherwise it is considered part of the environmental task list. Environmental units also receive an identification number and are added to the maintenance inventory.
   c. When a piece of equipment or an environmental unit is assigned a number, an instruction set and a maintenance schedule are assigned (or prepared if the instruction and schedule do not exist).
   d. Electrical safety tests are performed on all incoming equipment, and the results are documented. An environmental unit receives its initial survey using the instruction set for its classification.
   e. This information (description, identification number, maintenance instruction and schedule) along with supplemental information for equipment (such as manufacturer, serial number, date purchased, model number, vendor, life expectancy, user department, location, cost, purchase order number, and so forth) are then entered into the file.
   f. Work orders are produced for scheduled maintenance at the frequency of the assigned schedule.

2. Scheduled Maintenance
   a. A work order and procedure are produced and sent to the maintenance personnel to whom the work is assigned.
   b. If possible, maintenance is performed, results of this maintenance are recorded (including completion date and notation of any special or unusual occurrences), and the computer work order is sent to the engineering office for filing.
   c. If scheduled maintenance is not completed for some reason (for example, if necessary parts or the area are not available), the reason is recorded and kept in a file labeled "jobs outstanding."
   d. These files are then used to produce reports for the user departments notifying them of maintenance performed or not performed and also to provide a follow-up work order (indicated as "job-outstanding") if a scheduled maintenance report was not turned in or if a jobs-outstanding report was turned in. This follow-up work order is sent to biomedical personnel to remind them of the maintenance.

3. Corrective Maintenance
   a. Generally, a verbal or written communication is sent by the user department to the biomedical department notifying them of corrective maintenance to be performed. A copy of the corrective maintenance request is filed.
   b. The repair is performed.
   c. A record of the results (including the completion date) is entered into the file.

Files created by the process are used in creating reports that document system activity and provide data for making management decisions. Analysis of the workflow process example provides the following materials that are considered essential in providing an acceptable level of documentation:
1. A unique identification number for each item on the maintenance inventory

2. A protocol (procedure and testing schedule) for each inventory item

3. A permanent record of work performed

4. A historical trail showing reasonable adherence to designed protocol

5. A historical trail showing completion of requested follow-up actions

6. A history of essential information relating to the serviceable life of the environments and the equipment

7. A notification system apprising the department personnel of environmental and equipment conditions

As mentioned previously, maintenance and documentation systems often fail due to the excessive amount of time and paperwork required to keep the system functioning. This generally occurs when a hospital attempts to provide the "perfect" system. "Perfect" systems provide protocols and complete documentation for each individual piece of equipment in the hospital's inventory, including such minor items as calculators, electronic stethoscopes, and exam lamps. Often, in attempting to keep up with minor items, essential items are neglected.

The program presented in this manual ensures that minor equipment receives both function and safety testing while keeping documentation time to a minimum. Significant equipment receives separate, high-priority coverage, and the inventory control concepts of environmental maintenance, the functional unit concept, and the grouping concept ensure minimal paperwork. This approach to maintenance can provide an efficient maintenance inventory and a well-documented maintenance program with reasonable expenditures of staff time.
PART 3: USING THE MAINTENANCE DATA TABLES AND PROCEDURES

The maintenance data and procedures section of the book is divided into two groups, one for environmental units and one for medical equipment. Items were classified into these groups by using these definitions.

1. Environmental Units. This category is designed to cover each area with a set of instructions that provides adequate testing and inspections for minor electrical and mechanical equipment as well as environmental systems in areas that have been classified according to the type of patient frequenting the unit. Safety testing and other miscellaneous procedures are also included in this section.

2. Medical Equipment. This category includes all patient contact equipment as well as clinical laboratory instruments, diagnostic imaging equipment, and a variety of other devices used for medical purposes that have been identified as significant equipment.

Summary tables listing data environmental units and equipment are followed by scheduled preventive maintenance procedure sheets for the environments and equipment. The tables and procedures are correlated to produce a total approach to scheduled maintenance.

MAINTENANCE DATA TABLES

The tables contain a variety of useful values, including recommended scheduling of preventive maintenance procedures per year, the average number of hours to be spent on these procedures, and the average annual number of hours.

Most values are estimates based on real data. Although these should serve as a useful guide, actual values may differ greatly due to differences in maintenance personnel, equipment reliability and design, and equipment usage.

A description of the columns found on the maintenance data tables follows:

Class Code
Class code is a number identifying the type of environment or equipment and is used for cross-referencing the maintenance data tables to the procedure pages.

Description of Environment/Equipment
This is a general description only. A more detailed definition, when necessary, will be found in the maintenance procedures section.

Departmental Codes
These letter codes designate the departments that would most likely have this piece of equipment in its maintenance inventory:

A = Central Supply
B = Clinic Laboratory/Pathology
C = Dialysis Unit
D = Electrodiagnostic Units
E = Emergency
F = Labor, Delivery, and Obstetrics
G = Nuclear Medicine and Radioisotope Laboratory
H = Nursery, High-Risk Nursery, and Neonatal Unit
I = Pediatrics
J = Physical Therapy
K = Radiation Therapy
L = Radiology
M = Respiration Therapy and Pulmonary Function Laboratory
N = Special Care Units
O = Special Procedures
P = Surgery, Anesthesia, and Postanesthesia Recovery

Maintenance Schedule
The following letter codes are used in this column:

M = Monthly
BM = Bimonthly
Q = Quarterly
S = Semiannually
A = Annually

Some classes of equipment have more than one schedule. Such equipment has more than one set of maintenance instructions or procedures. For example, some equipment has both quarterly (Q) and annual (A) schedules. The equipment would be maintained every 3 months, but every 12th month the annual set of instructions would be used rather than the quarterly. The annual instructions would include the quarterly procedures plus the more rigorous annual procedures. Within one year, this piece of equipment would have received three quarterly inspections and one annual inspection.

Labor for Each Scheduled Maintenance

This column shows the estimated labor required for one maintenance transaction of the type shown in the previous column. For example, if there is a Q in the previous column, the labor indicated is the estimated labor, in hours, required to perform one quarterly (Q) instruction. Where more than one maintenance schedule is indicated, individual times, separated by commas, are provided for each type.

Most times are averages of actual times recorded for maintenance of actual equipment. It should be recognized that actual times may vary depending on the skills of the personnel and other possible variables. Time requirements do not include traveling time within the hospital or time required to locate the equipment. It should also be recognized that these times do not take into account major overhauls that may be necessary on the large pieces of equipment every five years or so. The assumption is made that personnel have the tools and materials available to complete the procedure.

Annual Labor Required for Scheduled Maintenance

This is the total estimated labor in hours spent performing all scheduled maintenance in one year.
Environmental units have no data because there is no "standard" environmental unit. Where no values are given, the columns remain for the user to provide an estimate.

Annual Labor Required for Corrective Maintenance

When available this column gives the estimated labor that could be expected for corrective maintenance in one year, assuming that the scheduled maintenance has been performed.

Where no values are given for annual corrective maintenance hours, the columns remain for the user to provide an estimate. There are two methods for estimating corrective maintenance labor requirements. The first, which was used to develop the data that occurs in the summary tables, is to simply calculate the average number of repair hours from the historical data of a known inventory. A second, more complex analysis, is to develop an itemized list of known ways the equipment fails. For each type of failure, a time value for corrective maintenance could then be developed. The next step is to predict the frequency of occurrence for each failure made, and from that data, produce annual values for corrective maintenance labor.

For environmental units, once they are defined and some experience in performing environmental maintenance has been gained, a facility engineer should be able to provide values for annual corrective maintenance to more accurately determine their labor requirements.

Total Annual Labor Required for Maintenance

This is the total estimated labor required for all maintenance (scheduled and corrective) performed in one year.

Annual Parts Cost

The values here are estimates of the cost of parts associated with repairs. These dollar figures are calculated on a per year, per unit basis. Although these have been calculated from real data, they should be considered rough estimates. Actual values will differ due to the following factors:

1. Values depend on the maintenance department's capabilities and philosophy. For example, if circuit boards are replaced rather than repaired, parts cost goes up while corrective maintenance labor requirements go down.

2. Values depend on the manufacturer of the equipment. Parts from some manufacturers are significantly more expensive, and some makes of equipment may have a greater failure rate. This factor also affects the corrective maintenance values.
3. Values must be adjusted for inflation depending on when the values would be used.

4. Values depend on the amount of use/abuse given the equipment.

**Annual Number of CMs**

This column gives the estimated number of corrective maintenance (repair) events that can be expected for a piece of equipment. The values are based on a per year per unit basis and are calculated from the data generated by a real inventory of equipment.

**MAINTENANCE PROCEDURES**

The maintenance procedures correspond to the required scheduled maintenance hours shown in the tables. These procedures are simplified and are intended to define the scope of the maintenance performed. They are intended to be used by personnel who are familiar with the equipment and not by trainees who have no previous experience. Neither the tables nor the procedures reflect regular duties that should be performed by personnel operating the equipment, such as daily and weekly operational routines.

If a class of equipment has more than one schedule, multiple procedure sets have been provided. For example, if the equipment has both monthly (M) and annual (A) schedules, annual procedures are provided that include the monthly procedures plus the additional requirements of the annual procedures. The labor requirements for the annual procedures show the labor required to perform all of the steps, including the monthly procedures for that month.

Throughout the maintenance procedures, there will be references made to following an electrical safety procedure or to the performance of electrical safety tests. The procedures and tests are found in Appendixes A and B. The value used for ground quality resistance in the maintenance procedures is 0.15 ohm. This value was selected because it represents the most restrictive standard and is easily met by most equipment. A resistance value of 0.5 ohm is also commonly used and may be substituted in the procedure.
PART 4: DETERMINING PERSONNEL REQUIRED FOR MAINTENANCE

The data provided in this manual can be used as a management tool to estimate roughly the number of full-time equivalents (FTEs) necessary to run a maintenance program of the type proposed in this manual. Before showing how this estimate can be calculated, some information concerning productivity must be explained.

DEFINITION OF PRODUCTIVITY

For the purposes of this book, productivity is determined by the following formula:

\[ \text{Productivity} (\%) = \frac{\text{time worked}}{\text{time available}} \times 100 \]

Time worked equals all hours charged to work orders for scheduled maintenance, repairs, and clinical engineering activities, and time available equals total time paid, less vacation, holidays, and sick leave.

The productivity figure provides key information about the relationship between direct labor (time worked or productive time) and indirect labor (time available minus time worked or nonproductive time). It can be used as one measure of the performance efficiency of an organization or an individual.

PRODUCTIVE AND NONPRODUCTIVE ACTIVITIES

Because some confusion may exist as to which activities are considered productive (direct labor) and which are considered nonproductive (indirect labor, administrative and overhead), examples of each are shown below:

<table>
<thead>
<tr>
<th>Productive Activities</th>
<th>Nonproductive Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity testing</td>
<td>Performance verification</td>
</tr>
<tr>
<td>Design modifications</td>
<td>Prepurchase evaluation</td>
</tr>
<tr>
<td>Documentation of activities</td>
<td>Preventive maintenance</td>
</tr>
<tr>
<td>In-service training</td>
<td>Repairs</td>
</tr>
<tr>
<td>Incoming inspection</td>
<td>Safety modifications</td>
</tr>
<tr>
<td>Line isolation monitor testing</td>
<td>Safety testing</td>
</tr>
<tr>
<td>Necessary travel time</td>
<td>Service contract evaluation</td>
</tr>
<tr>
<td>Operator errors</td>
<td></td>
</tr>
</tbody>
</table>

No attempt has been made in this book to provide estimates of annual hours for the productive activities not related to maintenance and repair. The required hours vary greatly from hospital to hospital, based on the equipment complement and the nature of the hospital's program.

In addition to such productive activities, a hospital department must also engage in many necessary administrative and overhead-type functions. These tasks are considered nonproductive and by definition include at least some of the following:
Nonproductive Activities

- Budgeting
- Calibration of test equipment
- Committee meetings
- Conventions/seminars
- Documentation of activities
- Keeping up with the field
- Maintenance of inventory

- Maintenance of technical library
- Personal time, breaks
- Public relations efforts
- Re-repairs/callbacks
- Supervision
- Training of personnel
- Vendor control

Similarly, no attempt has been made to provide estimates of annual hours for these necessary but administrative and overhead functions. These lists are not meant to be exhaustive, but they should provide insight into the determination of productive and nonproductive time.

Evaluating Productivity

Care is needed in using the data provided in this book to evaluate the productivity of an existing program or service. As previously mentioned, this publication deals only with repairs and scheduled maintenance; it does not provide estimated time allocations for any of the other productive activities that might be involved. Consequently, it is necessary to establish time estimates for these other productive services before any type of productivity determination can be made.

These productive activities must be accomplished at each hospital. However, some of them may be performed by an outside entity, depending on the size of the maintenance efforts.

The most accurate means of determining productivity involves using completed work orders. This method presumes that each action of each person within the group is documented on an individual work order showing a description of the work performed, the amount of time spent, and the material used. These individual work orders are then summarized over a specific period, usually a month, to provide a figure for time worked. Time available for the same period is calculated from time cards or whatever other mechanism is used to determine time for payroll purposes less time off for vacation or holiday or sick leave.

Once time worked and time available have been calculated, the latter can be divided into the former to calculate percentage productivity. For example, 1,920 hours of time available divided into 1,400 hours of time worked equals a productivity level of 75 percent.
INTERPRETING LEVELS OF PRODUCTIVITY

On the basis of historical data, the following breakdowns can be made for productivity levels:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Classification</th>
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</thead>
<tbody>
<tr>
<td>More than 85%</td>
<td>Questionable</td>
</tr>
<tr>
<td>75-85%</td>
<td>Excellent</td>
</tr>
<tr>
<td>60-74%</td>
<td>Acceptable</td>
</tr>
<tr>
<td>55-59%</td>
<td>Borderline</td>
</tr>
<tr>
<td>Less than 55%</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

Productivity of more than 85 percent is questionable because it is difficult to achieve without the use of unpaid overtime, improper documentation of time worked, or an increasing level of repeat calls. Experience has shown that a group that accounts for its work by individual job and sustains a real level of productivity of more than 85 percent for three to six months is headed for a rash of recalls and complaints.

Productivity of less than 55 percent is unacceptable because it indicates productive time per person of less than 4.5 hours per day. This workload would be insufficient to justify a staff unless the sources of outside service are a considerable distance away.

Lower-than-expected productivity generally indicates special problems requiring management attention. A partial list of those types of problems includes:

- Lengthy periods spent waiting to gain access to equipment. This problem requires some discussion with department heads to effect a mutually acceptable solution.

- Long periods of time spent tracking down equipment that has been relocated.

- Use of hospital engineering personnel to perform clerical functions that could easily be handled by a less-skilled individual. Use of inefficient test forms can require personnel to spend much more time than is necessary filling out overly detailed service reports.

- Inefficient maintenance practices, such as taking equipment back to the shop for maintenance work that could be done on the floors or routinely returning to the shop between work orders.

There is no doubt that an efficient, well-managed internal maintenance program can provide most hospitals with cost savings and other additional benefits. The challenge is in maintaining the consistently high level of management oversight needed to keep the program running in optimum fashion.

DETERMINING THE NUMBER OF PTEs

The knowledge of productivity acquired in the previous section will now be combined with the data in the tables of this manual to determine the number of PTEs required to run a maintenance program.
1. Review the content of the procedures and determine whether they are appropriate in your hospital's environmental and operational setting. Because the tables and procedures are guidelines consistent with the middle-of-the-road approach, they may need to be altered to fit any unusual circumstances or singular equipment use or abuse. For example, certain equipment may receive less use in a small or rural hospital than in a large urban one. The procedures and labor requirements will then have to be adjusted accordingly.

2. Prepare a maintenance inventory using the inventory control concepts presented in Part 2. All hospital locations must be classified according to the type of environment. Only equipment that qualifies as significant equipment should be listed individually.

3. Using the tables, determine how many hours will be required to perform scheduled and corrective maintenance on the equipment to be included in the maintenance program. Recognize that the procedures and summary tables refer to individual inspections of different pieces of equipment.
   a. Hours for scheduled maintenance and for corrective maintenance should be computed separately if the two functions may be performed by different personnel.
   b. Procedure sets should be analyzed to determine the level of skill required. Labor times for procedures to be performed by personnel of differing skill levels or by outside service vendors should be tallied separately.
   c. Labor times for environments or for equipment for that no labor requirements are listed should be estimated. Labor times for environmental units are most conveniently established by breaking large areas into units requiring no more than four-hour blocks of time or establishing time standards for small areas having department boundaries as their limits.

The result will be an inventory such as this:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Quantity (units)</th>
<th>Hours/Unit (hrs)</th>
<th>Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infusion Pump/Controller</td>
<td>175</td>
<td>2.7</td>
<td>472.5 hrs.</td>
</tr>
<tr>
<td>Aspirator</td>
<td>120</td>
<td>1.6</td>
<td>192.0 hrs.</td>
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<tr>
<td>etc.</td>
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</tbody>
</table>

Total Annual Labor for Maintenance and Repair  2,000 hours
4. The total labor needed for maintenance and repair should be adjusted for the following factors:

a. Travel/Location Time: For example, if it is estimated that for every hour of maintenance, 0.08 hour (5 minutes) is needed to travel to and from and/or locate equipment, then the total hours should be multiplied by a factor of 1 + 0.08.

2,000 hours x 1.08 = 2,160 hours

An alternative method to this calculation would be to estimate the average travel/location time for one inspection/repair and multiply by the total number of inspections/repairs anticipated in one year. The resulting number would then be added to the total annual hours required.

b. Other productive activities. If it is desired, estimated hours for other productive activities can be added at this time.

| Annual Hours for Maintenance, Repair, and Travel | 2,160 hrs. |
| + Estimated Incoming Inspections | 180 hrs. |
| + In-Service Training | 100 hrs. |
| + Documentation of Activities | 200 hrs. |
| etc. | |

Annual Hours for All Productive Activities 3,000 hrs.

5. After determining the total hours needed, determine the number of FTEs required for the maintenance management program.

a. To do this, first estimate the available working time per year of one FTE (total hours minus vacation, holidays, and sick leave).

\[
\text{Annual total hours possible} = 2,080 \text{ hrs.} \\
\text{Vacation, holidays, sick leave} = 155 \text{ hrs.} \\
\text{Annual Available Hours} = 1,925 \text{ hrs.}
\]

b. Then estimate the portion of this time that will actually be spent working on equipment by multiplying the available time by a productivity factor of 65 to 75 percent, depending on the size of the program and the productivity you expect. The lower value, 65 percent, should be used for a one-person program; the higher, 75 percent, for a program of three or more persons. The result is the equivalent value of one FTE expressed in hours.

\[
1,925 \text{ hrs. available} \times 0.65 = 1,250 \text{ hrs. worked per FTE}
\]
c. Finally, divide the annual hours needed for all productive activities by the equivalent value of one FTE in hours to determine the required number of full-time employees. Continuing with the example department used in steps 3 through 5 yields the following result:

\[
\frac{3,000 \text{ hrs. needed for productive activities}}{1,250 \text{ hrs. worked per FTE}} = 2.4 \text{ FTE}
\]

6. If you are just establishing a maintenance management program, be careful to allow sufficient time to plan the program and to put together the necessary paperwork and documentation. Depending on the amount of clerical time available, this initial effort may take several months to complete. Once a program is in operation, controlling paperwork and using the time efficiently are of prime importance. Paperwork systems and forms should be devised that minimize the entry of repetitive data.

7. When determining the personnel required for an entire maintenance department, additional FTEs should be considered for the following activities if not already accounted for.

a. Supervision
b. Maintenance of a parts and tool inventory
c. Clerical work
d. Other support functions