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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

HANDBOOK FOR MEDICAL EQUIPMENT REPAIRMEN

HEADQUARTERS, DEPARTMENT OF THE ARMY
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CHAPTER 1

INTRODUCTION

1. Purpose and Scope

This manual outlines the principles and policies to be applied in conducting the medical equipment maintenance program. It is designed to provide a text suitable for use in a course of instruction and to furnish guidance for personnel engaged in the maintenance program. The material contained herein is applicable to nuclear and nonnuclear warfare.

2. Objectives

Two primary psychological principles are fundamental to any program if it is to be successful. A maintenance program is equally dependent, if not more so, on these principles. First, there must be genuine interest and determination on the part of those who are technically and administratively associated with equipment. This includes the equipment operator, the responsible property officer or noncommissioned officer, and identified supply and maintenance personnel. Next, and equally essential, is command support. Command support must be evidenced at all levels, from the top all the way through the first line supervisor. With these two characteristics, the program will succeed and the necessary resources, i.e., manpower, materials, and money, will be attainable. Without these fundamental essentials even the most logically conceived system is doomed to failure. Although maintenance is not a problem unique to the modern Army, it has grown in stature to represent an annual multimillion dollar operation in the Army. The significant role it plays in the Army logistics system may be seen from the fact that approximately 90 percent of all line items in the supply system are repair parts. Modern equipment employs complexities not dreamed of as recently as a few years ago. Unfortunately, along with modern equipment, there has developed the inability to identify ourselves with our equipment. All too frequently, we have the "thine, not mine" complex; it is very difficult to instill in the operator of equipment or the repairman in his tools, the same sense of pride and responsibility that a person feels for his own personal property. An effective maintenance organization, including better identification with our equipment, will insure that equipment is serviceable when needed and will be kept serviceable at the lowest possible cost. This manual describes the medical maintenance system and emphasizes the preventive maintenance responsibilities of the operator, maintenance personnel, and the commander.

3. Role of Repairman

a. The medical equipment repairman has been trained in many trade skills. He will be called upon to perform varied repairs to medical equipment which involves electronics, steam pressure systems, hydraulic systems, motors, and high and low gas pressure systems; to name a few. In accomplishing these tasks he uses skills required of the machinist, welder, plumber, mechanic, and electrician. Obviously he cannot be considered a master craftsman in each of these skills but rather, a specialist in medical equipment and its many diverse components. To be most effective his talents must be properly directed in a well conceived maintenance program and coupled with effective operator maintenance.

b. There is no better way that you, the repairman, can instill in the operator a sense of pride in maintaining equipment than through pride in your own workmanship. No job should be considered complete until "good-housekeeping" functions have been accomplished. Restoring an item to serviceable condition alone is not enough. Proper adjustments, calibrations, lubrication, replacement of all panels and screws, and finally cleanliness of the item after repair will help influence the operator to maintain the item in like new condition.

c. Application of the principles described in this manual will materially assist in accomplishing the maintenance mission. Not only will conscientious application reduce the incidence of equipment failure, but the maintenance of records as described will provide invaluable information for the purpose of programming equipment replacement and formulating budgetary requirements.

4. Appendixes

a. Appendix I provides a list of publications pertaining to maintenance and supply.

b. Appendix II provides useful information for development of standing operating procedures.

c. Appendix III provides useful reference tables including wire tables, drill and tap sizes, decimal inch and millimeter equivalents of fractions of an inch, color codes for resistors, capacitors, and transformers, trigonometric functions, formulas, conversion factors and tables, specifications for gas cylinders used in the Army Medical Service, temperature comparison chart, and steam pressure and temperature chart.

d. Appendix IV discusses the care and preservation of specific materials.

CHAPTER 2

MEDICAL EQUIPMENT MAINTENANCE SYSTEM

5. General

a. Maintenance Essential to Mission. The maintenance of medical equipment is essential to the successful mission accomplishment of medical units of the Armed Services. Maintenance that is inadequate either in quality or extent can usually be traced to lack of proper training for supervisory personnel and maintenance technicians. Other contributing factors are failure to stress preventive maintenance, shortage of maintenance personnel, and the misuse of supplies and equipment, or their shortage. There are no deficiencies presently existing in the system of medical equipment maintenance that will not be eliminated by the adherence to, and the practice of, the principles and guidelines provided in Army regulations and technical publications.

b. Commander's Responsibility. Commanders must realize that maintenance of medical equipment is a primary factor in the accomplishment of the medical mission. Allocations of personnel, tools and test equipment, and technical assistance are sufficient to each unit to insure proper maintenance. However, there is a continual requirement for proper supervision, training, and administrative support to insure highest quality performance.

c. Maintenance Prerequisites. The various maintenance operations which must be performed on each item of medical equipment have been allocated to different echelons of maintenance (par. 7). The echelon where the work is performed must be determined by the situation, nature of repairs, the time available, the skills of available personnel, and the availability of tools, test equipment, and parts. Sound maintenance practices in each echelon can be achieved only if all of the following prerequisites are met:

(1) Personnel must possess the necessary training, knowledge, skill, and judgment.
(2) Sufficient personnel to perform the maintenance operation without diversion from other missions.
(3) Tools, equipment, space, facilities, and needed parts.
(4) A maintenance staff and organizational structure adequate to provide technical and administrative direction, maintenance discipline, and command supervision.

6. Maintenance Problems

a. Difficulties in Maintaining Medical Equipment. Difficulties are primarily related to the variety, special nature,

and complexity of the many makes and models. Medical equipment ranges from the simple stethoscope to the complex electronic units which record the heartbeat or brain waves. Nonstandard items of medical equipment are making an appearance (scalers, counters, spectrometers, and scanners used with radio isotopes), and these forecast further technological advances for an ever increasing complexity. As the loss of a single piece of equipment often seriously impairs the operating efficiency of the unit, efficient maintenance is essential.

b. Indications of Improper (Inefficient) Maintenance.

(1) *Poor housekeeping.* Frequently breakdowns are the result of nothing more than dirt accumulations. This may be the result of either operator or organization repairman neglect. It is also the result of inefficient or infrequent unit inspection. Certainly poor housekeeping indicates a rupture of the principles upon which good maintenance discipline is built.

(2) *Repair parts hoarding.* An accumulation of stocks or repair parts beyond authorized levels demonstrates a lack of supervision and training. The storage, transportation, and accounting places demands on personnel and facilities that are inadequate for this unforecasted load. Frequently, after a few moves, the stocks of such parts become nothing more than a jumbled mass of unidentified junk. Cannibalization as a source of repair parts is now authorized (AR 750–50) but is subject to strict controls.

(3) *Excess equipment.* Excess equipment also places demands for additional personnel that have not been provided. Similarly tools, supplies, and parts have not been provided. There is a waste of funds and manpower in attempting to train additional repairmen and/or operators and in establishing supplemental maintenance facilities.

(4) *Abuses of equipment.* Abuses of equipment are one of the surest indicators of ineffective maintenance. Evidences of such abuses are—

(*a*) Improper, careless, or negligent use of equipment.

(*b*) Overlubrication, lack of lubrication, or the use of the incorrect lubricant.

(*c*) Deferred maintenance, servicing, or adjusting.

(*d*) Inadequate maintenance inspection.

(*e*) Unqualified personnel attempting repairs, or the use of improper or inadequate tools and equipment.

(*f*) Failure to assign direct maintenance responsibility for organizational equipment.

c. Maintenance Deficiencies and Their Effects. All maintenance deficiencies lead to ineffective unit operation. Equipment is deadlined, operators are made idle, and the maintenance man is overworked. All this results in a loss of time, money, and manpower. Following is a list of some common effects of poor medical equipment maintenance and operation.

Maintenance and Operation Deficiencies	*Effects*
Improperly adjusted x-ray unit valve tube filament circuit.	Gassy valve tubes. High tension cable breakdown. Damaged x-ray or valve tube.
Improper positioning of brush rig on the engine of a dental operating unit.	Damaged commutator Short circuit in engine armature. Excessive brush wear.
Failure to maintain proper level of oil in an x-ray table gear transfer box.	Damaged gears. Damaged bearings.
Failure to detect and replace frayed steel cable on x-ray tube support assembly.	Damaged x-ray tube. Personal injury to patient.
Failure to replace weak batteries in an electrocardiograph or failure to remove batteries prior to storage or prolonged periods of nonuse.	Acid corrosion damage.
Corroded electrocardiograph electrodes.	Artifacts on cardiogram.
Not polarized or improperly grounded electrocardiograph.	Artifacts on cardiogram.
Failure to detect and replace deteriorated high pressure tubing on gas anesthesia apparatus.	Confusion in the operating room during an operation. Explosion.
Failure to clean autoclave strainer.	Unsterile surgical packs.
Improper neutralization of short wave diathermy.	Damaged electronic tubes. Radio and TV interference. Complaints from FCC.
Adjustment of line compensator switch or KVP selector switch under load.	Damaged selector switch. Premature failure of x-ray and valve tubes.
Failure to replace exhausted soda lime in BMR apparatus.	Inconclusive record. Lost manhours.

7. Definitions of Categories and Echelons

Over the years the Army has evolved echelons of maintenance wherein repairs of ascending complexity are performed. It is essential that every medical equipment repairman have a thorough understanding of this system which is explained in detail in AR 750–5.

8. Medical Maintenance Facilities in CONUS and in Theater of Operations

a. Facilities for the repair of medical equipment in the CONUS are as follows: (See ch. 4 for details.)

(1) *Organizational maintenance shops.* Every medical organ-

ization is capable of establishing and maintaining its own shop for the operation and organizational maintenance of the medical equipment it uses. These shops are normally simple in design and contain tools and test equipment required for organizational maintenance.

(2) *Field maintenance facilities.* Fixed field maintenance facilities in the CONUS are listed in AR 750–870. The facilities listed are authorized to perform field maintenance of Army medical equipment and provide parts support for satellited activities.

(3) *Depot maintenance facilities.* Depot medical maintenance missions are listed in AR 780–870. These facilities (shops) perform maintenance on materiel in stock in support of the Military Medical Supply Agency (MMSA) which, within the single manager concept, is under the Navy as the designated single manager for medical materiel. Additionally, these shops support lower echelons where maintenance exceeds local capabilities. This support is normally accomplished by means of repair and return of materiel to the user (SB 8–63) and/or on site service calls in response to emergency requests.

b. Facilities for the repair of medical equipment in a Theater of Operations are as follows:

(1) *Organizational maintenance shops.* Each unit normally establishes and maintains a shop for organizational maintenance of the medical equipment it uses. Personnel, equipment, and tools are authorized commensurate with the equipment to be supported.

(2) *Field maintenance facilities.* This service is provided by the Army Medical Depot supporting the field Army. Inspection and supervision of organizational maintenance is included in the depot capabilities.

(3) *Depot maintenance facilities.* Depot maintenance support for all theater army forces is provided by the medical depot, communications zone.

c. Repair parts are an integral part of the maintenance system. Most maintenance operations performed require repair parts as well as trained operators and maintenance personnel. Repair parts must be readily accessible to using units if maintenance operations are to be performed efficiently and in a minimum of time. Details of the medical repair parts supply system are given in chapter 5.

9. Technical Assistance Program

a. Regional Maintenance Representatives. Regional maintenance representatives are assigned to certain depots and serve

specified geographical areas. The regional maintenance representatives furnish technical assistance on problems related to the operation and maintenance of medical and dental equipment. For details as to frequency of visits and scope of assistance refer to AR 750–807.

b. Manufacturers' Representatives. In some instances, procurement contracts for technical medical equipment may include a requirement for installation and initial servicing by the manufacturer. Any questions should be referred to the contracting officer.

c. Industrial and Commercial Technical Services. Employees of manufacturing, engineering, or consulting organizations may be obtained on a nonpersonal service contract basis under provisions of AR 750–22. These personnel serve as technical advisors and instructors on installation, operation, and organizational maintenance techniques. Requirements for such services are submitted through appropriate channels to The Surgeon General for review and necessary action.

CHAPTER 3

PREVENTIVE MAINTENANCE

Section I. GENERAL

10. General

Preventive maintenance is the heart and soul of the entire maintenance system. At first glance the vast complex that makes up that system might give the impression that maintenance by the user is unnecessary, that the equipment can be driven until it fails and then unloaded on the broad shoulders of higher echelons. This is in complete contradiction to the fact that the entire system assumes that the using unit will care for the equipment to avoid such failure. The system will bog down completely if equipment is not properly operated, cleaned, lubricated, tightened, and adjusted on a systematic basis by the user, or qualified personnel. The minor repairs and parts replacement authorized for second-echlon maintenance of equipment are preventive—being designed to forestall the more complex and time-consuming repairs that will otherwise result.

11. Definition of Preventive Maintenance

Preventive maintenance is the systematic care, servicing, and inspection of equipment for the purpose of maintaining it in serviceable condition and detecting and correcting incipient failures before they occur, or before they develop into major defects.

a. Daily preventive maintenance is that maintenance performed by the operator of the equipment. The operator is responsible for the proper care and use of his equipment, also to note any minor defects and immediately report same to the proper authority.

b. Monthly preventive maintenance is a systematic preventive maintenance program set up by the maintenance officer or senior medical equipment repairman. This insures that a large percentage of all the medical equipment of an organization is checked every thirty (30) days. A record of this maintenance is kept by the maintenance personnel on DA Form 8-230 (Preventive Maintenance Record for Medical Equipment). Although we have listed preventive maintenance as daily and monthly, we must bear in mind that all personnel (user and maintenance man) should ever be alert to detect any and all minor defects of any piece of equipment at any time to prevent failures before they occur.

12. Responsibility for Preventive Maintenance

a. Operator. The operator is required to perform first echelon maintenance, which includes the proper care, use, operation, cleaning, and preservation plus minor operating adjustments of such equipment. The preventive maintenance service performed by maintenance personnel does not in any way relieve an individual operator of the responsibility to his own equipment.

b. Medical Equipment Repairman. The preventive maintenance reponsibilities of the medical equipment repairman entail the following:

(1) To assist the maintenance officer in establishing and/or maintaining a proper preventive maintenance program in conformance with density and type of equipment in use at a station.

(2) To obtain, file, and keep abreast of latest information, such as manufacturers' literature, AR's, and all pertinent publications on preventive maintenance of equipment in use or anticipated use.

(3) To inspect electrical and mechanical medical equipment for malfunction, misalinement, wear, or any deviation from normal operation.

(4) To initiate materiel complaints noting any deficiencies in design of manufacture or malfunction under the provisions of AR 700–6500–15.

(5) To remove dirt, grease, and foreign matter not accessible to the operator.

(6) To adjust and lubricate at proper intervals.

(7) To instruct operating personnel in the proper care and operation of medical equipment.

(8) Inspect to anticipate repair parts requirements and assist in establishing proper repair part stock levels.

(9) To initiate inspection reports of deficiencies in the care, use, and operation of medical equipment by the using organization.

c. Maintenance Officer. It is the reponsibility of the maintenance officer to establish and maintain a proper preventive maintenance program as outlined by AR's and SR's, with modifications to fit the local situation as to density and any special types of equipment.

d. Commanding Officers at All Levels. Commanders are required to insure that all equipment issued or assigned to their command is maintained in a serviceable condition and is properly used and cared for; that personnel under their command comply with pertinent technical publications and regulations as listed in appendix I.

13. Prevention of Equipment Abuses

It is the responsibility of the commander to prevent the abuse of materiel under his control. Evidence of abuse (par. 6*b*) will be investigated and corrective action taken.

Section II. OPERATOR PREVENTIVE MAINTENANCE SERVICE

14. General

The operator of medical equipment is one of the most important single factors in preventive maintenance. Improper operation is a major cause of electrical or mechanical failure. Inexperienced or careless operators can nullify all efforts at proper equipment maintenance. Each operator is required to perform certain preventive maintenance services on his equipment which will do much to prolong the life of his equipment, thus avoiding major repairs by higher echelons of maintenance. This also assures the operator that his equipment will perform its mission consistently and dependably.

15. Publications Used by Operator

a. Operating instructions must be read and comprehended completely before any attempt is made to operate the equipment.

b. Technique charts must be followed if the proper results are to be obtained.

c. Tube rating charts must be read, understood, and followed to prevent damage to expensive x-ray tubes.

d. Applicable technical manuals serve as a guide for the proper operation and utilization of medical equipment.

e. Manufacturer's data when read and comprehended will give the operator and repairman a better understanding of the operation and limits of the equipment.

f. Lubrication charts, if applicable, must be followed so that damage to equipment will not result from either under or over lubrication.

g. Cleaning and preservation instructions are to be followed to the utmost degree so as to prolong the life and use of medical equipment.

h. Technical bulletins must be read and understood to enable the repairman to better service the using organization, and thus prolong the life expectancy of the equipment.

16. Daily Preventive Maintenance Service

a. General. Daily preventive maintenance is the responsibility of the operator. It is not practical for the maintenance section to

have enough personnel to cover all the equipment daily at an installation. Preventive maintenance accomplished by the maintenance section is usually set up on a monthly basis. Daily preventive maintenance is the responsibility of the NCO in charge of a clinic or department. It is his responsibility to make sure that the operators handle the equipment with care and keep it clean. When preventive maintenance is not performed the medical equipment repairman should report the condition to the chief of the department or clinic. The repairman should always be alert, when passing through wards, departments, or clinics, to detect discrepancies on any item of medical equipment.

b. Before Operation. The operator should make a preliminary inspection of his unit or piece of equipment prior to operation. A quick glance will immediately detect broken knobs or frayed cords. These defects should be reported at once. A good operator will report anything that appears to be deteriorating or not in serviceable condition.

c. During Operation. When operating his unit the good operator will ever be alert to be sure that everything is functioning normally. If the unit is not performing as it should, he will turn it off immediately and report this to his supervisor.

d. After Operation. The operator performs the necessary measures commensurate with good housekeeping such as remove line cord and roll it up neatly; clean and store accessories; replace cover on unit. While the operations mentioned may not apply to all units, still every piece of equipment has a certain number of "after operation" services that the operator should perform before leaving the unit.

17. Operator Adjustments

a. Importance of Operator Adjustments. Adjustments are necessary to keep equipment in good operating condition. These adjustments must be made in a proper manner. Proper operator adjustments keep maintenance service to a minimum, prolong the life of the equipment and parts, reduce the need for higher echelon repair, and allow the equipment to be operated in the most efficient manner. Proper adjustments are necessary for SAFE operation of medical equipment, from both the patient and operator's point of view.

b. Types of Operator Adjustments. The adjustments that the operator is allowed to make must pertain strictly to setting up a unit or piece of equipment to perform some function for a patient, (e.g. if an x-ray specialist had a unit with manual filament control, he would adjust his filament temperature for the desired MA which would give him a good diagnostic radiograph. However, if the

unit had automatic filament settings then the technician would not be allowed to remove the panels from the machine and adjust the filament resistors). Keeping unauthorized tools out of the operator's hands is one way of reducing maintenance calls.

18. Reporting Equipment Deficiencies

Part of the operator's preventive maintenance responsibility is the reporting of any unusual sounds or odors, deficiencies in performance, or any other signs of abnormal operation, immediately upon detection, through proper maintenance channels. The reporting procedure to procure the services of a medical equipment repairman will be outlined and defined in the SOP of the activity. The operator of medical equipment can be of valuable assistance to repairman. The alert operator will notice immediately anything that reflects an abnormal operation of his unit. He will then report this fact to his supervisor in order that the repairman can be informed. The operator can also explain to the repairman what happened at the time of breakdown, thus saving the repairman valuable time. It is to the advantage of the repairman to impress on all operators of medical equipment the fact that every defect of their units should be reported as soon as possible. This is preventing minor defects from becoming major repair problems.

PM/MFP (Preventive Maintenance Means Fine Performance)

Section III. ORGANIZATIONAL PREVENTIVE MAINTENANCE SERVICES

19. General

Organizational preventive maintenance services are performed by the maintenance section. Usually this is set up on a monthly basis and an effort is made to effect preventive maintenance on every piece of medical equipment in the wards, clinics, and departments. Here again the end result will depend upon the density of equipment and the number of maintenance personnel available. By proper scheduling and efficient use of personnel, a proper job of organizational preventive maintenance can be accomplished.

20. Periodic Maintenance Services

a. Importance of Scheduled Services. Scheduling is an important part of a good preventive maintenance program. The maintenance section, when necessary, should schedule the preventive maintenance for equipment in a clinic with the operators or Chief of Service to insure that this service can be accomplished without interruption. There will always be emergencies at a hospital to interrupt schedules, but these can be overcome by

cooperation between the maintenance section and the ward, clinic, or department.

b. Responsibility of Scheduling Services. Since it is the function of the maintenance section to keep the records on preventive maintenance, it is their responsibility to schedule the preventive maintenance. The repairman knows when he can do the job, what equipment is due for preventive maintenance and the time required to accomplish the preventive maintenance. Preventive maintenance will be accomplished on a regularly scheduled basis by the maintenance section of the Supply and Services Division of the hospital.

c. Use of DA Form 8–230 (Preventive Maintenance Record for Medical Equipment). Use of this card is covered in AR 750–808. A preventive maintenance card will be prepared by maintenance personnel for each item of technical medical equipment requiring preventive maintenance and repair service.

21. Procedure

a. Mobile Preventive Maintenance Cart. Any wheeled cart of sufficient size with rubber wheels and ease of mobility should suffice. The cart should have ample drawer and shelf space and should be kept neat and clean.

b. Tools and Equipment. Necessary tools to adequately perform preventive maintenance and on the spot repairs should be carried on the cart. Common repair parts such as nuts, bolts, screws, gasket material, packing, cleaning materials, and necessary lubricants should also be available on the cart.

c. Operator—Medical Equipment Repairman Relationship. The trustworthy and capable operator can be of invaluable assistance to the repairman. This type of operator not only takes good care of his equipment, but he recognizes any abnormal symptoms pertaining to malfunction immediately. The good operator will be able to converse intelligently with the repairman on the telephone about his problems, enabling the maintenance man to have some idea of what trouble he is going to encounter even before he leaves the maintenance shop. Unfortunately not all operators of medical equipment are of this caliber, and it may be necessary at times for the repairman to report some operators to their superiors or to the maintenance officer for abuse of equipment. However, the repairman should strive to get the maximum cooperation from operators of medical equipment.

d. Relationship With Professional Personnel. Medical officers are accustomed to working with others as a team for the good of the patient. They recognize the important role the medical equipment repairman and maintenance shop play in the function of a

hospital. The medical officer has a large assortment of medical equipment at his disposal for the diagnosing of patient's ailments, and he has every right to expect that this equipment will be ready to use whenever the occasion demands. One of the demands of a medical officer is that he receive honest, straight-forward information as to the condition of his equipment. If a piece of equipment is to be out of commission for a week, or a month, tell him so immediately. He understands that parts are difficult to procure for some items of equipment and in some cases he may be of assistance in speeding up the normal procurement routine. Give the professional staff all the cooperation possible and they will cooperate with you.

e. Supply (Expendables) Discipline and Accounting. The repairman doing preventive maintenance will of necessity require a large number of repair parts. These will be procured by the maintenance section according to the SOP of the medical supply officer. The repairman must have some method of accounting for the parts he uses in his preventive maintenance duties. DA Form 811 (Work Request and Job Order) can be used to list the parts expended performing preventive maintenance for any one ward, clinic, or department. As an example—today the repairman does preventive maintenance on ward #1. He uses 12 male plugs, 6 lamp sockets, and 20 feet of lamp cord. He then issues, or has the ward make up a work request and job order. The repair parts expended are listed on the job order, which in turn, is signed by the NCOIC of the ward, or another responsible person. In this manner the repairman and maintenance section have accounted for all parts expended. The repairman should not use parts such as male plugs, lamp cords, nuts, bolts, or screws indiscriminately. While these are small parts and may seem insignificant it doesn't take long for these small parts to run up a large bill in the terms of dollars and cents. Use these small parts wisely. Don't stint where these parts are needed but do not waste them.

CHAPTER 4

MAINTENANCE SHOPS

Section I. GENERAL

22. General Objective

The general objective of this chapter is to provide medical equipment repairman with basic information pertaining to organizational, field, and depot maintenance shops. Shops in each of these categories perform specified echelons of maintenance. Organizational shops normally perform second echelon maintenance, field maintenance shops perform third and fourth echelons, and depot maintenance shops perform fifth echelon repairs. Responsibilities and policies for the operation of maintenance shops are delineated in AR 750–5. The organization, function, and mission of each type of shop is discussed in paragraphs 23 through 37.

Section II. ORGANIZATIONAL MAINTENANCE SHOPS

23. Mission

The primary mission of any organizational maintenance shop is to apply second echelon repair techniques in maintaining organizational equipment in a serviceable condition.

24. Organization

a. The shop organization is determined by the size and scope of the required maintenance which in turn determines the number of technically qualified and other personnel required.

b. The size of the shop and the number of personnel assigned will be fixed primarily by equipment density, type of equipment in use, and with due consideration to an effective preventive maintenance program. Examples of variations which may be encountered are—

(1) The TOE unit, such as a small station hospital with one medical maintenance repairman authorized, may have a shop that consists of nothing more than a tool kit and a bench in a corner of the supply room and is integrated in the organizational chart as part of the supply section.

(2) The larger station hospital with satellited dental clinics, outlying dispensaries, and possibly a recruiting station in a nearby metropolitan area may require a staff consisting of a maintenance officer, ten qualified medical maintenance repairmen plus an administrative clerk, a

supply clerk, and sufficient shop area to accommodate the work load. The organizational chart for such an operation is shown in figure 1. Shop personnel may be distributed as shown in figure 2.

TYPICAL ORGANIZATIONAL CHART

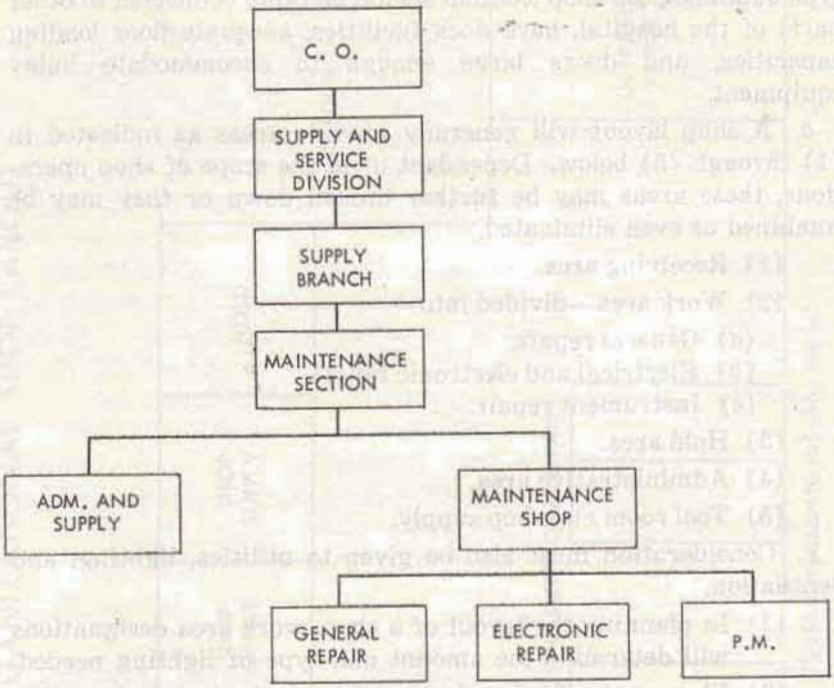


Figure 1. Typical organizational chart.

TYPICAL DISTRIBUTION OF MAINTENANCE PERSONNEL

Figure 2. Typical distribution of maintenance personnel.

25. Shop Location and Layout

a. The location of the shop should be such that medical equipment needing repair can be brought to and from the shop without unnecessary handling and exposure to the elements. In a multistoried permanent installation, the service or utility area of the basement usually offers the most ideal location. For cantonment type buildings, the shop location should be ramp connected to other parts of the hospital, have dock facilities, adequate floor loading capacities, and doors large enough to accommodate bulky equipment.

b. A shop layout will generally provide areas as indicated in (1) through (5) below. Dependent upon the scope of shop operations, these areas may be further broken down or they may be combined or even eliminated.

(1) Receiving area.

(2) Work area—divided into—

(*a*) General repair.

(*b*) Electrical and electronic repair.

(*c*) Instrument repair.

(3) Hold area.

(4) Administrative area.

(5) Tool room and shop supply.

c. Consideration must also be given to utilities, lighting, and ventilation.

(1) In planning the layout of a shop, work area designations will determine the amount and type of lighting needed.

(2) Placement of electrical outlets and electrical service requirements must be considered. This will be determined by the type and quantity of shop machinery, number of work benches, and the electrical characteristics of medical equipment being repaired or tested.

(3) Other utilities such as steam, gas, compressed air, and water may be needed for testing. Due consideration should be given to the placement and distribution of these utilities in the shop.

d. Layout of areas should be such that flow of work can progress without "bottlenecks" and repeated handling. For example, the receiving area should be close to access doors of sufficient size to permit easy entrance of all medical equipment. Equipment taken from the receiving area for a repair operation will generally be moved into one of the shop work areas. This suggests that the approach to individual work areas should not interfere with each other. Figure 3 shows a typical organizational shop layout.

TYPICAL ORGANIZATIONAL SHOP LAYOUT

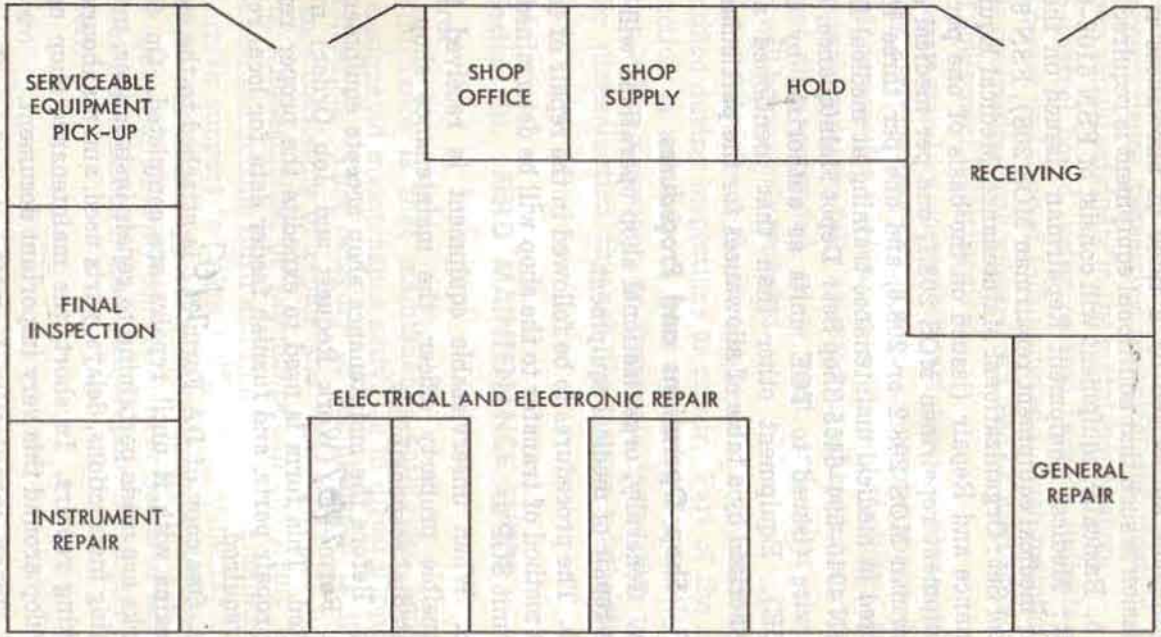


Figure 3. Typical organizational shop layout.

26. Shop Equipment

a. The equipment of an organizational maintenance shop is authorized by approved tables of allowances for non-TOE units and by the TOE for TOE units. TOE units may have additional equipment authorized by a table of allowances if the assigned mission is such that additional equipment is required.

b. Basically, equipment will consist of FSN 5108–611–7923 Tool Kit: Medical Equipment Repairman (issued on the basis of one per medical equipment repairman MOS 208), FSN 5108–611–7924 Tool Set: Organizational Maintenance, Medical Equipment, Maintenance and Repair (issued on the basis of one per four medical equipment repairmen MOS 208.1, one per medical equipment repairman MOS 208.2 or 208.6, and one per three instructors engaged in medical maintenance training at medical facilities), and FSN 4910–594–6455 Shop Set: Depot Maintenance, Army Medical Service (issued to TOE units as authorized by the applicable TOE). Equipment other than that mentioned above will be authorized by a table of allowances for the particular unit.

27. Shop Operations and Procedures

a. Generally, organizational shop operations will be limited to the repair of medical equipment.

b. The procedures to be followed in the repair of equipment and the method of transfer to the shop will be determined and outlined in unit SOP's.

c. When unserviceable equipment is received from the responsible property officer, the maintenance shop assumes full custodial responsibility.

d. Before the maintenance shop accepts equipment for repair, DA Form 2407 (Work Request and Job Order) must be completed. This form is used to expedite the proper repair, account for repair parts, and furnish feeder data for local reports as may be required.

e. One copy of DA Form 2407 is attached to the equipment and remains with it until repairs are completed. On this copy, remarks are made pertaining to repair instructions, priority rating, testing instructions, delays, parts used, and manhours expended in making repairs. In short, the maintenance shop operation will develop around this very important document.

f. In an organizational maintenance shop whose mission includes second echelon maintenance for satellited units, pertinent information for DA Form 811 may be extracted from the DA Form 8–230 (Preventive Maintenance Record for Medical Equipment) on file in the shop administrative area.

g. A technical library, consisting of appropriate technical manuals, manufacturer's literature, repair parts section of the federal supply catalog, MWO's, supply bulletins, and technical bulletins pertinent to maintenance and other current references must be established and maintained for use by maintenance personnel. Correspondence requesting technical information from manufacturers should originate in the maintenance shop.

h. A job control board, using colored tags to indicate at a glance the amount and type of jobs assigned to each maintenance repairman is desirable. Such a board can also be used to indicate the status of equipment being repaired.

i. Emergency stand-by rosters of maintenance personnel for off-duty hours are prepared in the shop and copies forwarded to hospital headquarters for publication in the daily bulletin. Maintenance personnel must be fully oriented on all emergency procedures so that time expended, parts used, and other required information will be properly recorded.

j. Operator deficiencies in the care and use of equipment can be readily identified during inspections or repair. Part of the maintenance function is not only to give operating instructions to operators but, when necessary, to formulate instructive memorandums for dissemination through the proper administrative channels.

Section III. FIELD MAINTENANCE SHOPS

28. General

Field maintenance is that maintenance authorized and performed by designated maintenance activities in direct support of using organizations. This category of maintenance is limited to maintenance consisting of repair and replacement of unserviceable parts, subassemblies, or assemblies. In the Army in the field, mobile and semimobile third and fourth echelon maintenance activities furnish support to using units. In continental United States, field maintenance support is normally provided by fixed shops under control of ZI army commanders or heads of technical services. Field maintenance is essentially repair of equipment and return to user.

29. Mission

Upon examination of the missions of the medical field shops presently in operation, it will be noted that they do not provide, as yet, third and fourth echelon support to a specified geographical area, but rather are established for the purpose of supporting a relatively large Class II hospital and its satellites.

30. Organization

Personnel, tools, and equipment allocated to field maintenance shops are determined by a table of distribution and table of allowances based on equipment density and the overall mission of the Class II installation supported.

31. Establishment of Field Maintenance Shops

Non-TOE field maintenance shops are not established, discontinued, or transferred nor are their missions changed without prior approval of Headquarters, Department of the Army. Major commanders and heads of Department of the Army agencies must initiate written requests forwarded through appropriate channels to the Deputy Chief of Staff for Logistics for the authority to establish a field maintenance shop (AR 750–5).

32. Basis for Establishment

At present, there are relatively few established field maintenance shops in the medical service complex; however, from time to time, as the need arises more may be added. In general, the establishment of medical field maintenance shops at Class II AMEDS installations and activities is considered appropriate when—

a. Third and fourth echelon repair operations are routinely performed under the cognizance of the technical service chief.

b. The technical and medical equipment in use at an installation requires the assignment of specially qualified military and civilian maintenance personnel.

c. The TD provides for eight or more personnel for the medical equipment maintenance function including one commissioned maintenance officer.

33. Field Maintenance Shop Operation

Since in accordance with regulations, the field maintenance shop affords third and fourth echelon support, it follows that the administrative, operational procedures, and responsibilities would be similar to those of a depot operation. Successful and efficient operation of any shop is predicated on intelligent management of a competent work force equipped with the necessary tools, equipment, and space to accomplish its assigned mission. In addition to judicious planning and programming for the assigned maintenance function, it becomes necessary to accumulate data for the preparation of the quarterly report of Maintenance Readiness and Field Maintenance Costs, RCS CSGLD–931. (See AR 750–15.)

Section IV. DEPOT MAINTENANCE SHOPS

34. Mission

a. The depot maintenance division is responsible for repair and overhaul of medical equipment for return to depot stock and for the fabrication or manufacture of certain parts required for the accomplishment of its assigned mission. At a branch or general depot, the depot maintenance division operates under the depot commander.

b. Repair and return service is provided for medical organizational and field maintenance activities as prescribed by The Surgeon General. Information pertaining to this service is contained in Supply Bulletin 8–63. Depots may perform this service for units located within a designated distribution area.

35. Organization

The organization of the depot maintenance division of branch and general depots is as prescribed in AR 780–10. Generally, the organizational elements of the division will include the offices or branches mentioned in paragraphs *a* through *d* below. Personnel assigned will be in accordance with tables of distribution established for the particular depot. The scope and mission of the depot will determine personnel requirements. Depots in the United States utilize civilians where possible. In oversea locations, the depot may be staffed predominantly with service personnel and supplemented with indigenous employees.

a. Office of Chief. The chief of the division has overall responsibility for efficient operation of the division.

b. Production Control and Inspection Office. The functions of production control and inspection are usually combined and performed by personnel of this office. However, if the workload warrants, two separate offices may be established. In some general depots, a consolidated production control and inspection office may perform these functions for all sections (i.e. Quartermaster, Signal, Medical) of the depot.

c. Repair Branch. The organization of the repair branch is dependent primarily upon the volume of repairs. The repair branch may be divided into a general shops section, special shops section, and a service shops section. The service shops provide services such as welding, painting, sheet metal, etc. These functions may be assigned to the general shop section thus eliminating the service shop section from the organization. Included in the special shop section will be those responsible for repair of electronic equipment and precision instruments.

d. Supply and Administration Branch. An account for depot maintenance repair parts may be established in the supply section. If this is the case, stock records will be maintained and repair parts requisitioned direct from designated supply sources. Stock levels must be determined and maintained and repair parts stocked and issued. An officer from the depot maintenance division is usually appointed accountable officer for the supply account.

36. Shop Layout

The shop layout is dependent primarily upon building facilities and the scope of operation. In planning a layout or changes to an existing shop, consideration should be given to providing for the following:

a. Smooth Flow of Material. The layout should be such that material will be received, repaired, and disposed of with the least amount of confusion due to handling and moving of the material.

b. Supply and Administration. The area designated for supply and administration or any activity which must contact personnel in all of the shops or vice versa should be centrally located, if possible.

c. Grouping of Shops. It is desirable that shops in the general shop section and those in the special shop section should be grouped in one area to facilitate supervision and routing of equipment.

d. Holding Area. Areas should be provided for holding items to be repaired that cannot be immediately accepted by the specific shop and for items that must be held due to nonavailability of repair parts. This area should be located to provide for minimum handling and transporting.

37. Shop Operation and Procedures

Administrative policy for shop operation will normally originate in the depot maintenance division. Administrative policy may vary according to the size of the activity, its location, and/or mission.

a. The production control office plans and establishes production schedules in accordance with the priorities established. Coordination of activities within the depot maintenance division, preparation of reports, maintaining liaison with the inspection office and supply branch, and analyzing job productivity are some of the functions of the production control office.

b. The inspection office inspects equipment received for repair, all equipment repaired in shops, work in progress, and maintains staff supervision to insure that shop practices, procedures, and performance of work comply with provisions of technical manuals, modification work orders, and similar directives.

c. Technical medical equipment assistance to Class I and II installations is normally provided by depots as authorized in AR 750–807. A regional maintenance representative makes annual visits to these installations. He assists in the improvement of organizational and field maintenance, assists in inspection where necessary, and gives advice on unusual problems arising from technical difficulties involving the installation, repair, salvage, or shipment of medical equipment.

CHAPTER 5

SUPPLY

Section I. GENERAL

38. General

a. Each medical equipment repairman must be familiar with the supply system. He must know how to use the various Department of the Army supply manuals, how to identify and requisition supplies and repair parts correctly, and how to account for material for which he is responsible.

b. This chapter is intended to acquaint the medical equipment repairman with the proper methods for obtaining, identifying and handling medical supplies and repair parts.

39. Supply Operations

The medical maintenance officer, in performing his assigned mission, must be assured that repair parts are stocked in the quantities authorized and that they are available at his request. He must be realistic in computing requirements for his maintenance shop operation to prevent overstockage of slow moving items. His source of supply is the medical supply officer; therefore, he must keep this source informed of his requirements. The medical maintenance officer must be familiar with supply manuals published by other technical services. When requesting nonstandard repair parts the maintenance officer must furnish detailed descriptions of the part desired; cite any known commercial source which may stock the part; list electrical and/or physical characteristics; state the application of the part; list the manufacturer's model and serial number of the end item on which the part is to be used, and furnish a firm or estimated cost of the part desired. The NCOIC of the shop will be responsible for performing the above duties in the absence of the maintenance officer.

40. Repair Parts Supply

Lists of repair parts required for the maintenance of medical equipment are published in the repair parts section of the Federal Supply Catalog of Medical Materiel, Department of Defense Section. This section of the catalog lists certain parts required to maintain specific items of medical equipment. The parts listed within this section of the catalog, in addition to being classified as expendable and nonexpendable, are further classified as common parts and peculiar parts. The single manager has determined that

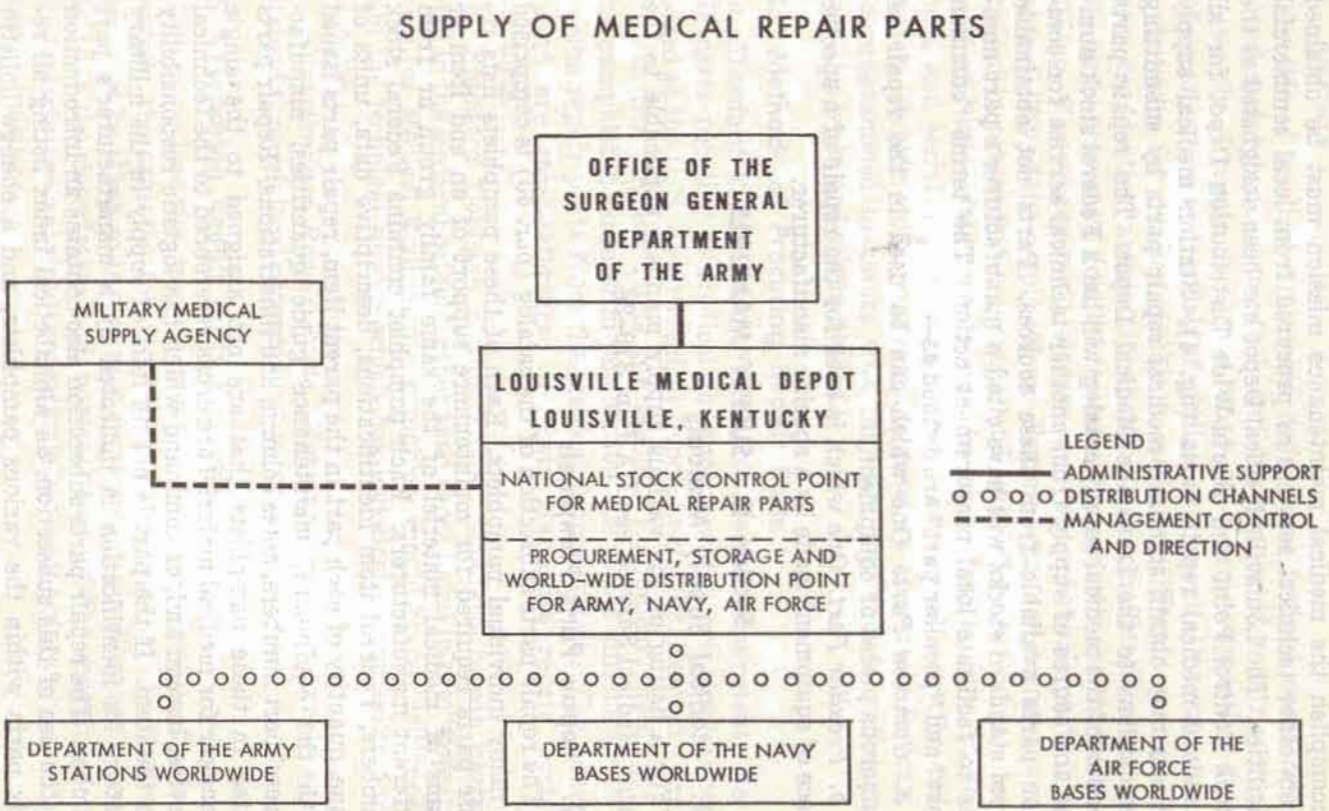


Figure 4. Supply of medical repair parts.

only the parts peculiar to medical equipment will be stocked at his wholesale distribution depot; therefore, many parts required to accomplish the medical maintenance mission must be obtained from other technical services or procured from local commercial facilities. The Louisville Medical Depot has been designated as the Stock Control Point and World-Wide Distribution Depot for all standard medical repair parts (fig. 4). Station medical supply officers may obtain standard medical repair parts by submitting requisitions to the Louisville Medical Depot. The repair parts section of the medical supply catalog will list a Federal stock number and source of supply from another technical service for common parts available from these sources. Parts not obtainable from standard stocks will have cited a manufacturer's part number to facilitate local procurement action. The terms "common part" and "peculiar part" are defined as—

a. Common Part. One which can be used in the repair of numerous pieces of equipment.

b. Peculiar Part. One which is used for the repair of a specific piece of equipment made by a specific manufacturer.

Section II. SUPPLY MANUALS

41. Medical Supply Manuals

For a listing of the various supply manuals applicable to the Army Medical Service, see DA Pam 310–28.

42. Repair Parts Pamphlets

The repair parts subsection of the catalog (par. 40) is comprised of many individual pamphlets. Each of these pamphlets lists repair parts required for maintenance support of an end item or items of medical materiel of the same family group or from different manufacturers. Each pamphlet contains Federal stock numbers, Federal item identifications, descriptive data, units of issue, quantity of each part in the parent item, repair parts issued with the equipment, maintenance guide quantities, manufacturers' part numbers, notes column, and illustrations. Repair parts listed in these pamphlets that are not assigned to the single manager for medical materiel are cross-referenced to the technical service, bureau and/or command which has logistic responsibility for the item. If the part is not an item of supply in the military system, its identification is indicated by a manufacturer's part number. The repair parts subsection also contains an introduction on the use of this subsection, an alphabetical index listing all repair parts within the various pamphlets, and a change bulletin which is cumulative and will be published and issued as often as is deemed necessary.

Section III. SUPPLY OF REPAIR PARTS

43. General

The life of medical equipment depends on trained operators, trained maintenance personnel, and the supply of repair parts. The supply of repair parts is a broad and complex operation due to the many types and models of medical equipment. In some cases repair parts for similar machines made by different manufacturers are identical and interchangeable. Proper identification of these parts requires a detailed technical background and extensive training. The procurement, storage, and issue of repair parts is a responsibility of the supply officer. Extreme care and accuracy are required in procurement, storage, and issue of repair parts. Accurate and up-to-date records must be maintained by type, make, model, and serial number of equipment as well as quantity and location. Repair parts requirements must be accurately forecast and programmed to assure that they are available in sufficient quantities when and where needed.

44. Methods of Procuring Repair Parts

a. Standard Repair Parts Peculiar to Medical Equipment. Repair parts peculiar to medical equipment which are stored and stocked at the U. S. Army Medical Depot, Louisville, Kentucky are listed in the "Repair Parts for Medical Equipment" pamphlet. This pamphlet is an interim publication due to the elimination of common repair parts from the medical supply system. The items stocked are cross-referenced to their respective repair parts pamphlets.

b. Standard Common Repair Parts. Standard repair parts listed in the Federal catalog, other than those listed in the "Repair Parts for Medical Equipment" pamphlet, should be requisitioned from the technical service which has logistical responsibilty for the items.

c. Nonstandard Repair Parts. Nonstandard repair parts are obtained through local procurement procedures.

45. Preparing Repair Parts Requests

The procedure for preparing repair parts requests is fundamentally the same as for requesting other supplies. Particular care must be taken to insure that correct part numbers are given and that the description and nomenclature of the machine for which parts are required are completely and accurately shown on the requisition.

a. Standard Parts. The Federal stock number, complete nomenclature, unit of issue, unit cost, total cost, quantity desired and

the basis for the request must be included on the requisition. Each request will also have the authority for the request indicated on the face of the requisition.

b. Nonstandard Parts. Inasmuch as these repair parts are nonstandard, extreme care must be taken in preparation of the request. The request should give a complete description of the part, manufacturer's part number (if known), and the stock number, nomenclature, make, serial number, and model of the end item. The unit of issue, unit cost, total cost, quantity desired, basis for request, and authority must also be included on the request.

CHAPTER 6

MODIFICATION OF MATERIEL

46. Definition and Purpose

a. A modification is a specific authorized change in the design or assembly of an adopted item of materiel to meet revised specifications or to correct defects.

b. Modifications of medical equipment are usually authorized to accomplish one of the following purposes:

(1) Increase the operating effectiveness of medical equipment.
(2) Correct design or construction deficiencies to increase the useful life of equipment.
(3) Provide greater safety for patients, operating personnel, or maintenance personnel.
(4) Increase the manufacturing efficiency.
(5) Reduce excessive maintenance.

47. Responsibility for Modification of Materiel

No alteration or modification of equipment is made except in compliance with an authorized MWO. Modifications are normally made by using organizations, field or depot maintenance shops, or by incorporating them into manufacturing specifications. Receipt of a MWO is the directive to accomplish the modification and the authority to procure necessary parts and materiel.

48. Utilization of Facilities for Modification

Commanders responsible for modification of equipment may utilize all qualified personnel and facilities available to them to accomplish the modifications as quickly as possible. The commanders establish the procedures and methods consistent with directives from The Surgeon General. They may use the facilities of all maintenance units, using organizations, and other such local facilities as available.

49. System of Classification

a. Modification work orders are classified as either "urgent" or "normal" (AR 750–5).

b. The "urgent" classification requires that the modification be accomplished on all items in the field immediately and on items in depot stock prior to their being issued. Exceptions in application are clearly described in the modification work order.

c. The "normal" classification requires that the modification be accomplished as soon as practical in the field with current resources and within the time limit prescribed.

50. Modification Work Order

a. Based on unsatisfactory equipment reports, suggestions, reports from depot shops or from the field, engineering advancements, etc., modifications are directed if, after thorough investigation, they are warranted. The directive for modification is printed as a Modification Work Order. An example of the numbering system follows:

MWO 8–6525–200–20/1

MWO	8	65	25	200	20	1
Modification Work Order	Technical Service (Medical)	Group Subnumber (Medical)	Class Subnumber (X-ray)	Technical Manuals Numerical Sequence	Echelon or Maintenance (2d and higher)	Numerical Sequence Identification

b. The maintenance shop should maintain a record of all modification work performed on the technical medical equipment. These records provide the data for such periodic reports as may be required by higher headquarters. The form used for maintaining these records is DA 8–230 (Preventive Maintenance Record for Medical Equipment).

c. Equipment coming into a maintenance shop for service should be checked to determine if all applicable modification work has been accomplished or if any is required. The MWO file in the shop and DA Form 8–230 pertaining to the item of equipment assists in determining the status of modification programs. During command and spot check inspections, equipment is checked to determine if appropriate MWO's have been accomplished.

51. Medical Materiel Complaints

a. General. When an item of standard equipment proves to be defective or deficient, a report of the deficiencies is made to higher authority through the individual in charge of the organization or activity. The Army Medical Service is exempt from the provisions of AR 700–38 and will report all medical materiel complaints in accordance with provisions of AR 700–6500–15.

b. Preparing Report. The report will be prepared so as to include all information, as applicable, required by AR 700–6500–15. The report is used when a standard item of equipment is determined to be unsatisfactory in design or because of malfunction attributable to defects in material, workmanship, quality control inspection, or other unsatisfactory performance including hazardous conditions that are considered to be of sufficient importance

to warrant reporting. The report should not be made for equipment failures, isolated defects, or malfunction of equipment which is due to normal wear and tear or accidental damage. Recommendations for correction of the unsatisfactory condition should be included in the report.

c. Disposition of Report. The report is made out in quadruplicate and forwarded as outlined in AR 700–6500–15 with the original going to the Military Medical Supply Agency (Code SC–0), one copy to the Army Medical Supply Support Activity, and one copy to The Surgeon General, Department of the Army. The MMSA will evaluate the report and upon determination of action to be taken will notify AMSSA who will issue appropriate instructions to retail stock points and consumers. If a modification is justified, a modification work order is prepared and distributed to all units using that particular type of equipment. Necessary special parts, tools, or other material required for the modification are listed in the work order and may be requisitioned by the organization affected. The modification work order itself serves as a basis for issue of these supplies.

CHAPTER 7

SAFETY

Section I. GENERAL

52. General

Safety requirements and practices must include premises, equipment, and personnel. The establishment of safe operating practices and standards, and the prevention of accidents are the responsibility of commanders (AR 385–10). Maintenance personnel should assist the commander by eliminating, controlling, or reporting accident-producing hazards. Safety measures should be initiated, and personnel should be trained in safe practices and in reporting hazardous conditions. Safety color code marking (AR 385–30) should supplement safe practices, by guarding or eliminating hazardous conditions. Marking a hazard with a standard color must not be used as a substitute for the elimination of the hazard where possible. Fire prevention, detection, reporting, and control should be covered by unit fire regulations. All personnel should become familiar with these regulations. Fire reporting procedures, the location of fire exits, and the location and manner of use of fire fighting equipment must be known by every serviceman and employee. The following paragraphs contain safety information pertinent to maintenance operations. This information includes operating requirements and safe practices essential in the maintenance of medical equipment.

53. Operating Requirements

a. Appraisal of Job. Before beginning operations, the supervisor should study conditions and estimate requirements.

b. Selection and Assignment of Personnel. Individual capabilities should be considered in making work assignments.

c. Congestion. Work areas should permit freedom of operation. Equipment, tools, materials, and personnel not immediately required should be kept from the area.

d. Instruction. No job should be started until the supervisor is assured that participants have received adequate instructions, including safety requirements and the use of protective equipment.

e. Protection of Personnel. Personnel should be given the benefit of such protective clothing and equipment as is essential to the safe performance of an assigned task. Consideration should also be given to adequate ventilation.

f. Sanitary Conveniences. All maintenance shops should be provided with—

(1) An adequate supply of fresh, pure, and properly dispensed drinking water.
(2) Adequate facilities for maintaining personal cleanliness.
(3) Adequate facilities for disposal of waste.
(4) Adequate toilet facilities.

g. Tools, Equipment, and Machines. Sufficient and properly designed tools and equipment should be supplied for every job. Machine guards will be employed where mechanical hazards exist or are likely to be encountered. Elimination or control of physical hazards generally includes protection from all moving parts of machinery, including—

(1) Gears.
(2) Friction drives and belts.
(3) The removal of protruding setscrews.
(4) The guarding of points of contact on machinery having cutting, punching, or sawing edges.
(5) The guarding of electrical fuse boxes and switching apparatus.
(6) The grounding of all electrical machines.
(7) The placement of limit or safety switches on equipment.

h. Warning Signs and Protective Devices. Warning signs and protective devices should be employed to assure protection to all personnel. Warning devices include informative signs, and color markings to point out physical hazards, to show location of safety equipment, and to identify fire and other protective equipment (AR 385–30). Protective devices include handrails, toeboards, and nonslip floor surfaces on platforms, walkways, stairways, or around engine flywheels.

i. Housekeeping. Provisions should be made for establishing and maintaining high standards of housekeeping. The following partial list includes items to be considered:

(1) Adequate lighting.
(2) Clean machines, equipment, and working surfaces.
(3) Ample and orderly tool and material storage.
(4) Sufficient and approved waste containers including covered metal containers for the storage of oily rags.
(5) Systematic removal and disposal of waste.

j. Accident Reporting. All personnel should be instructed to report promptly personal injuries and property damage no matter how slight. Reports should be prepared in accordance with AR 385–40.

54. Safe Practices

a. Report all injuries promptly so that proper first aid or medical treatment can be given.

b. Understand the safe way to perform any task given. Help new workmen to avoid unsafe practices. Promptly contact the supervisor in any instance where instruction is required.

c. Bring to the attention of the supervisor, at the first opportunity, any unsafe conditions observed.

d. When using tools, observe the following precautions:

(1) Inspect all tools, rope, and similar equipment before using. Report broken or defective equipment immediately.

(2) Use only tools that are in good condition. Burred or mushroomed heads on cold chisels, hammers, and other tools must be dressed before using. Replace splintered, broken, rough, or loose tool handles before using. Keep cutting edges sharp.

(3) Always use the proper tool for a job. For example, use hammers, pinch bars, and nail pullers for opening boxes; do not use a screwdriver for a chisel.

(4) Store sharp-edged tools in a safe place. Never carry unshielded tools in pockets. Return all tools to supply room or tool kit.

(5) Observe all the specific safety rules for particular tools, as well as the general safe practices listed above.

e. Do not wear thin soles on shoes, lose and ragged sleeves, unbuttoned coats, neckties, or oversized work trousers. Keep shoe laces tied. Remove rings, wrist watches, and other jewelry before starting work on any kind of equipment.

f. Never engage in horseplay or practical jokes.

g. Maintain "good housekeeping" at all times.

h. When handling material, use gloves for rough or sharp objects and avoid pinching fingers between objects.

i. Lifting and carrying requires care—improper methods cause unnecessary strains. Observe the following precautions:

(1) *Preliminary.* Before attempting to lift or carry—

(*a*) Size up the object to see if it can be safely lifted or carried.

(*b*) Ascertain whether nails, wire, or rough edges must be avoided.

(*c*) Select the shortest safe route to travel with the object, avoiding holes, ruts, and slippery spots.

(2) *Lifting.* To obtain best results practice the following rules:

(*a*) Ask for help when, because of excessive weight, bulk, or awkward shape, the load cannot be handled easily by one person.

(*b*) Remove grease or other slippery substances from the hands. Get a good handhold.

(*c*) Be sure to have good footing, then lift with a smooth, even motion.

(*d*) When lifting a heavy object, shift the body until in a position to make a straight lift. Never lift while in an awkward position.

(*e*) When making a lift from the floor keep arms and back as straight as possible, bend knees, and then lift with the leg muscles.

(*f*) When it is necessary to lift objects from an elevation such as a bench, table, or shelf, bring the object as close to the body as possible to avoid an unbalanced position. Keep the back as nearly vertical as possible and lift with leg muscles.

(*g*) In two-man lifts, lift simultaneously and avoid changes in levels which throw undue strains on one man.

(3) *Carrying.* Safe carrying of materials requires adherence to the following rules:

(*a*) Keep the load close to the body.

(*b*) Avoid carrying heavy objects too great a distance without help and without resting.

(*c*) Do not stack material to be carried in such a manner as to obstruct the view.

(*d*) When carrying a long object, such as a board or pipe, keep the front end high to avoid injury to others. Avoid collisions at blind corners.

(*e*) In two-man carries, the object should be on the same respective shoulder or arm, and normally the men should be in step. Avoid changes in level when possible.

j. Wear goggles approved for the particular job when grinding, chipping, welding, cutting, pouring or handling hot metal or acid, and when doing any work where flying material may injure eyes.

k. Do not attempt to repair or adjust any electrical or mechanical equipment unless it is part of an assigned job. Treat all electrical wires as live wires. Do not disconnect ground wires.

l. Do not talk to anyone while operating machines. Pay attention to the job.

m. Do not overreach. Stretching to reach overhead objects may result in falls or strains. Use a ladder when it is necessary to

climb. Do not reach around, over, or under a moving part of any machine.

Section II. SAFETY IN SHOPS

55. Repair Shops

a. Operating Requirements. In addition to the aforementioned operating requirements, the requirements listed below are pertinent to most medical maintenance shop operations:

(1) Effective general ventilation should be provided in buildings where diesel or gasoline engines are running. Exhausts should be properly vented to the outside. Shop atmosphere should be checked periodically for presence of carbon monoxide.

(2) Special metal containers with metal covers should be provided for waste, oily rags, and other flammable materials.

(3) A suitable fire extinguisher should be accessible to all operations involving flammables.

(4) Each power tool should be provided with an individual control switch or belt shifter easily accessible to the operators.

(5) Provisions should be made for frequent removal of chips, shavings, and scrap on or around machinery.

(6) Wheels and saws should be operated at the safe speeds for which they are designed.

(7) Cracked or chipped grinding wheels should be taken out of service immediately.

(8) An abrasive wheel dresser with a guard over cutters should be used in dressing the face of wheel.

(9) Only "safe" lathe dogs, chucks, and drill spindles should be used. Only countersunk setscrews should be used.

(10) Cutting tools should be kept clean and free from dust, chips, and other foreign material.

b. Safe Practices. The following safe practices will be found applicable to medical maintenance shop operations, in addition to those previously mentioned.

(1) In the use of hand wrenches observe the following rules:

(*a*) Select the proper wrench for the job and be sure it fits snugly.

(*b*) Pull on the wrench, don't push. When necessary to push because of restricted space, use open hand to avoid injury to fingers if wrench slips.

(*c*) Use wrenches with long handles when working in small recesses or near hot objects.

(*d*) Do not use a pipe or another wrench over the handle of a wrench to increase leverage.

(*e*) Stand out of the line of the tool's movement when pulling on a wrench in overhead use.

(*f*) When working in a stooping position or when lying on the back in close quarters, be careful not to be thrown off balance or struck in the face should the wrench slip. Stand in such a position that you will not be struck by the wrench if it slips or if the nut or bolt loosens suddenly.

(*g*) Keep moving parts of adjustable wrenches clean and lubricated. Keep handles, jaws, adjusting screws, and other parts tight.

(*h*) The jaws of monkey wrenches should be parallel. Place the wrench so that the pull will be in the direction that the jaws point.

(*i*) Use pipe wrenches on round objects only. Place the wrench so the teeth in the center of the jaw grip the object.

(*j*) Repair or discard wrenches with fractures, broken handles, springs, or other parts; jaws which are sprung, out of shape, bent, loose, with dull teeth, or out of alinement.

(2) In working with a portable electric tool, particularly when in a damp or oily place, check the insulation on the cord. Be sure tool housing or framework is grounded.

(3) Store waste, oily rags, and other flammable material in suitable metal receptacles provided for that purpose.

(4) All work must be blocked up before working under it. Never depend on jacks or chain hoists alone to support the load. Place blocks as load is raised.

(5) Be sure feet and all other parts of the body are clear of aisles or moving machinery when working under equipment.

(6) Do not keep gasoline in open containers. Never use gasoline to clean parts.

(7) Use safety grip (thumb and fingers on same side of handle) when necessary to crank engines by hand.

(8) Be on guard against flashes or explosions of gasoline vapors, antifreeze solution vapors, and hydrogen from storage batteries. Keep flames, sparks, and hot surfaces away.

(9) If clothes become soaked with oil or gasoline, change them immediately. Don't risk catching on fire.

(10) Never allow grease or oil to remain on the floor. Keep aisles free of tools and other obstructions.

(11) Never consider a job complete until it has been checked to make sure all the lockwashers and cotter pins are in place.

(12) Operate power tools only when authorized to do so. Start power tools only when they are in proper adjustment and when all safety devices are in place. Do not remove or alter safety devices. Do not allow power tools to run unattended. Stop power tools while instructions are being given.

(13) Caution personnel not to handle the starting button or controls of a machine undergoing repairs. A good practice is to remove line fuses when possible or post a "Do Not Energize" sign.

(14) Use a brush to remove shavings, chips, or drillings, rather than a rag or waste.

(15) When using grinding wheels observe the following precautions:

(*a*) Stand to one side when starting the grinding wheel.

(*b*) Use the tool rest. Adjust tool rest close to grinding wheel.

(*c*) Do not grind on the side of the wheel.

(*d*) Do not "crowd" a grinding wheel. Cold wheels are particularly dangerous. Pressure should be applied gradually, giving the wheel a chance to warm up.

(16) When using drill presses and lathes observe the following precautions:

(*a*) Hold small work in a jig, clamp, or vise while drilling.

(*b*) Do not loosen chucks or tapered drill shanks unless the power is turned off. Use only the drift pin when loosening the chuck or drill.

(*c*) Always remove chuck wrench from chuck before turning on power.

(*d*) Do not hammer wrench in tightening chuck.

(*e*) Remove material which has jammed only after spindle has stopped revolving.

(*f*) Remove chucks and face plates on lathes by hand and not by power.

(*g*) Change and adjust cutting tools only when the lathe action is stopped.

(*h*) On milling machines, secure cutter on arbor before starting machine. Tighten arbor nut by hand and not by power.

56. Oxyacetylene and Electric-Arc Welding

a. Operating Requirements. In addition to the safety requirements previously mentioned, the following safety requirements are pertinent to oxyacetylene and electric-arc welding operation.

(1) Compressed gas cylinders should be properly marked to identify their contents.

(2) Regulators or reducing valves should be provided on both oxygen and acetylene cylinders.

(3) Cylinders of oxygen should not be stored with cylinders of acetylene.

(4) Gas cylinders in storage and in use should be secured in an upright position. Storage areas should be dry and well ventilated.

(5) Cylinders should not be exposed to the heat of stoves, radiators, or furnaces. Where cylinders are stored in the open, protect them from the direct rays of the sun.

(6) Different colors should be used for oxygen hose and acetylene hose to avoid interchanging.

(7) Electric generators for furnishing alternating or direct current should be well protected, both mechanically and electrically, against accidental contact on the part of the operator or others.

(8) Electrode holders, as well as the connecting cable, should be fully insulated.

(9) Fire extinguishers should always be readily accessible at all welding operations.

(10) Welding or cutting should not be undertaken in areas where there are special fire hazards (presence of fire forbidden), nor should work of this nature be performed near flammable materials unless proper precautions are taken.

(11) Where possible, flammable materials attached to or near equipment requiring welding, cutting, or brazing should be removed. If it is not practicable to remove the parts to be welded or to move flammable materials to a safe location, a suitable shield of asbestos or other effective heat resistant material should be provided to protect the flammable materials.

b. Safe Practices. In addition to the safe practices heretofore mentioned the following safe practices are pertinent to oxyacetylene and electric-arc welding operations.

(1) Handle compressed gas cylinders carefully to avoid knocks and falls.

(2) Use a specially constructed hand truck to move cylinders.

(3) Correct leaks of gas at cylinder valve connections immediately. The location of leaks can be determined by applying soapy water to the fittings and watching for bubbles.

(4) Close cylinder valves when a cutting or welding operation is finished, and when cylinder is empty.

(5) Do not use oxygen and acetylene regulators interchangeably.

(6) Do not attempt to transfer any gas from one cylinder to another.

(7) Use only the special wrench provided for operating the cylinder valves. Open valves slowly by not more than one turn of the spindle at a time.

(8) Keep oxygen cylinders and fittings free of oil and grease.

(9) Do not open cylinder valves by hammering.

(10) Whenever long lengths of hose must be used, take care that the hose does not become kinked or tangled and that it is protected from damage and from being run over by trucks or stepped on.

(11) At least once every week, inspect all hose for leaks, worn places, and loose fittings. Never repair hose with tape.

(12) If torch becomes overheated, cool it by immersing in water. In such cases, shut off acetylene gas before immersing the torch, but allow the oxygen to bubble through to keep water from entering the blow pipe.

(13) Do not attempt to shut off the gas, even temporarily, by crimping or kinking the hose.

(14) During welding and cutting operations, the heat of the flame brings out certain gases, fumes, and dusts, which are often poisonous. For this reason, weld only in well ventilated places or see that personnel have proper respiratory protection.

(15) Do not attempt to weld or cut on tanks, drums, or other metal containers.

(16) Inspect welding cables periodically for poor insulation, breaks, and loose fittings.

(17) Do not dip hot electrode holders in water.

(18) Place screens of nonflammable material around all electric welding operations to protect the eyes of other workers from harmful electric-arc rays. Do not permit others to watch an electric-arc welding operation.

(19) Before performing welding operations in spray booths or ducts that may contain combustible composites, first make sure that they are free of combustible material.

(20) Shut down electrical generating equipment and turn off all gas valves if it is necessary to leave work.

57. Compressed Air Equipment

a. Operating Requirements. Specific safety requirements for handling compressed air equipment are as follows:

(1) Operating speed of compressor should not be greater than that listed by the manufacturer.

(2) Complete inclosure of compressors is desirable. Guards should be installed on all belts, pulleys, flywheel pits, cranks, and other moving parts.

(3) Air tank drain pipe valves should be opened and tank drained at regular and frequent intervals. Where automatic traps are used they should be inspected frequently and regularly.

(4) Air receivers should not be operated without a pressure gage and a spring pop safety valve.

(5) A spring pop safety valve should be set to blow at a pressure slightly higher than the blowing pressure of the safety valve on the air tank. If a stop valve is installed between the compressor and the receiver, the spring pop safety valve should be on the compressor side of the stop valve.

(6) All spring pop safety valves should be tested at regular and frequent intervals and receivers should be inspected, at least, once a year by a qualified inspector.

(7) Filters, valves, discharge pipes, and receivers should be cleared at frequent and regular intervals.

(8) Kerosene or any other flammable substance should not be used to soften carbon formation on valves or other parts.

(9) All air lines (both pipe and hose) should be inspected at regular and frequent intervals.

(10) Where antifreeze solutions are used in the air system, proper filters should be installed to prevent the release of unsafe vapors.

(11) Standard fittings should be used for making all hose connections. Makeshift connections should not be allowed.

b. Safe Practices. The safe practices listed in (1) through (4) below are for specific use in operation of compressed air machinery and equipment.

(1) Do not operate air receiver at a pressure higher than the maximum allowable working pressure, except when the safety valve or valves are blowing, at which time the

maximum allowable working pressure should not be exceeded by more than 6 percent.

(2) Do not apply too much oil to air compressors. Excessive oil may increase the danger of explosion.

(3) Never wear gloves when operating a portable air drill or reamer.

(4) Never point a pneumatic machine at anyone and do not stand in front of operators of such machines, even though they are equipped with tool holders.

58. Personal Protective Equipment

a. Safety shoes should be worn in all work areas where injury might result from falling objects such as boxes, stock metal, or when moving or lifting heavy equipment.

b. Safety goggles (clear hard lens) should be worn to afford protection against flying objects such as metal chips. Filter (or colored) lens should be worn to protect the eyes from harmful light radiation. In welding or cutting operations, the shade of lens should not vary more than two consecutive numbers from the following:

(1) Clear lenses and filter lenses, up to and including shade No. 2, may be used for resistance welding and for stray light from nearby cutting and welding operations.

(2) Shade No. 5 filter lenses are intended for light gas cutting and gas welding.

(3) Shade No. 6 filter lenses are intended for gas cutting, medium gas welding, and for electric-arc welding up to 30 amperes.

(4) Shade No. 8 filter lenses are intended for heavy gas welding and electric-arc cutting and welding exceeding 30, but not exceeding 75 amperes.

(5) Shade No. 10 filter lenses are intended for electric-arc welding and cutting exceeding 75, but not exceeding 200 amperes.

(6) Shade No. 12 filter lenses are intended for electric-arc welding or cutting exceeding 200, but not exceeding 400 amperes.

(7) Shade No. 14 filter lenses are intended for electric-arc welding or cutting exceeding 400 amperes.

c. Additional protection while welding or cutting is afforded by the wearing of appropriate clothing such as—

(1) Flameproof gauntlet gloves, except when engaged in light work.

(2) Flameproof aprons made of leather, asbestos, or other suitable material are desirable as protection against radiated heat and sparks.

(3) Fire resistant legging, high boots, or equivalent for heavy work.

(4) Capes or shoulder covers for overhead operations.

(5) Helmets when exposed to sharp or heavy falling objects.

d. Appropriate respiratory protective devices should be worn when there is danger of gases, dust, or fumes containing industrial poisons such as lead, zinc, cadmium, fluorine, or oxides of nitrogen. For example, paint-spraying operations require the use of face masks incorporating filtering devices to prevent inhalation of paint-laden air.

Section III. SAFETY IN HOSPITALS

59. General

Medical equipment is designed by the manufacturer with one of the prime considerations being that the physical design of the item must provide for the maximum degree of safety. The "designed-in" safety factors and controls incorporated in the equipment are intended to prevent injury to personnel or damage to the equipment in cases of misuse or functional failure. Carefully prepared instructions are also provided for the installation and operation of the equipment. Design, then, is the greatest contributing factor to safety. Normally, medical equipment repairmen will not be involved in the design of equipment, but they are concerned in the operation and maintenance which are the major factors affecting safety once an item is received by the Army Medical Service. A full awareness by maintenance and operating personnel of the potential dangers inherent in the equipment and a knowledge of the proper operating and control procedures is necessary if unsafe practices are to be avoided. In spite of the elaborate precautions taken by the manufacturers, accidents will and do occur. Some causes of these accidents are carelessness, unfamiliarity with the equipment, disregard of operating instructions, and failure to maintain equipment and safety devices in proper operating condition.

60. Operating Rooms

a. Static electricity is a major cause of fire and explosion in anesthetizing locations. Sparks of ignitable energy may occur in the vicinity of explosive mixtures of combustible anesthetic gases if equipment in operating suites include electrically nonconductive materials (which readily acquire electrostatic charges through

handling) or if floors are made of highly resistant materials that prevent proper neutralization of charges. Sparks have occurred at the edge of a breathing mask when it was touched by an attendant. It seems likely, from postexplosion inspections that small spark discharges may have occurred occasionally at barrier points inside anesthesia machines when nonconductive rubber bags or breathing tubes were handled, or large high-potential charges developed nearby. The presence of static charges can give rise to incendiary sparks and is a constant threat to patients and personnel in anesthetizing locations. Many anesthetic gas mixtures, particularly those rich in oxygen, are highly explosive and easily ignited by static sparks. Some can be ignited by extremely low energy sparks.

b. There are a number of ways of preventing the development of static electricity in operating rooms, the most important being the replacement of articles of electrically nonconductive charge-producing materials with conductive materials. Whether or not all of these substitutions are made, conductive floors and conductive contacts from equipment to floors should be provided to take care of any exigencies, such as the possible introduction into the operating room of material electrically charged or likely to become charged.

Application of preventive measures must be thorough to assure maximum removal of the static-electricity hazard from anesthetizing locations.

c. Garments of wool, silk, or synthetic materials such as rayon, nylon, orlon, etc., are prohibited in anesthetizing locations. Wool blankets, plastic sheets, and most of the usual synthetic-fabric material should not be used around anesthetic-gas equipment or patients anesthetized with combustible-gas mixtures. Cotton blankets and sheets are satisfactory, but if stored in a warming compartment, means should be provided to keep them from losing moisture. Before new types of materials are admitted to operating or delivery suites, they should be competently tested under low relative humidity to be sure they cannot readily develop high potential charges. Should nonconductive mattresses, pads, or pillows be used, complete inclosure of them with conductive covers is necessary to prevent accumulation of electrostatic charges.

d. Conductive rubber breathing tubes, masks, and bags should be installed on existing anesthesia machines. They are standard equipment on all new machines.

e. Stools with smooth rounded feet and bare metal tops are the most satisfactory electrically. If covers are needed for comfort or to prevent sliding, they should be conductive. Wide cross straps of

adhesive tape are not objectionable, but at least 50 percent of the seat should be left exposed.

f. Conductive floors should be used in all rooms where combustible anesthetics are used. An effort should be made to keep floors within the limits recommended below and, preferably, well above the lower limit. The floor should have not less than 25,000, nor more than 1,000,000 ohms resistance as measured between two electrodes placed 3 feet apart on any part of the floor. The resistance as measured from ground to any point on the floor should be at least 25,000 ohms. Such floors will remove static adequately from any conductive bodies properly connected to them and prevent disconcerting, if not dangerous, shock due to possible defects in electrical equipment such as lamps and heaters.

g. Isolating transformers must be installed before, or at the same time, conductive flooring is installed. Conductive floors produce a dangerous shock hazard if the electrical system is not isolated.

h. Casters, tires, and stool-leg tips on all equipment used in administration of combustible anesthetics or in handling of anesthetized patients should be made of conductive material. Until it is possible for a hospital to install conductive type flooring in all hazardous areas, some form of intercoupling to keep operating equipment and personnel at or near ground potential is imperative for safety. Wet towels draped so as to connect operator's shoes and equipment can serve this purpose. If resistance-type intercouplers are employed, they must be kept in good repair and tested frequently.

i. Personnel wearing ordinary rubber or synthetic soled shoes may carry static regardless of the type of floors. Conductive shoes should be worn by all personnel who work around combustible anesthetics or anesthetized patients. Such shoes should have a resistance of not less than 100,000 ohms each but should not have an individual resistance of more than 1,000,000 ohms. Floors and shoes of unnecessarily low resistance may give rise to spark and shock hazard. A suitable measuring instrument should be installed in a convenient and safe place for testing the conductivity of shoes of all personnel entering areas where explosive gaseous anesthetics are administered.

j. Electical wiring and equipment should be in conformity with the latest approved regulations of the National Fire Protection Association for hospital operating rooms wherever possible. The use and proper installation of electric lamps, motors, plugs, and explosion-proof receptacles that carry a third wire for positive grounding will reduce greatly the chance of electric-power shock.

61. Compressed Medical Gases

(See AR 700–8120–1)

a. General Rules.

(1) Never permit oil, grease, or other readily combustible substance to come in contact with cylinders, valves, regulators, gages, or fittings and hoses. Oil and certain gases such as oxygen or nitrous oxide may combine with explosive violence.

(2) Never lubricate valves, regulators, gages or fittings with oil or any other combustible substance.

(3) Do not handle cylinders or apparatus with oily hands or gloves.

(4) Connections to piping, regulators, and other appliances should always be kept tight to prevent leakage. Where hose is used it should be kept in good condition.

(5) Never use an open flame to detect gas leaks. Use soapy water.

(6) Prevent sparks or flame from any source from coming in contact with cylinders and equipment.

(7) Never interchange regulators or other appliances used with one gas with similar equipment intended for use with other gases.

(8) Fully open the cylinder valve when cylinder is in use.

(9) Never attempt to mix gases in cylinders. (Mixtures should be obtained already prepared from recognized suppliers.)

(10) Before placing cylinders in service, any paper wrappings should be removed so that the cylinder label is clearly visible.

(11) Do not deface or remove any markings which are used for identification of contents of cylinder. This applies to labels, decals, tags, stenciled marks and upper half of shipping tag.

(12) No part of any cylinder containing a compressed gas should ever be subjected to a temperature above 125° F. A direct flame sohuld never be permitted to come in contact with any part of a compressed gas cylinder.

(13) Never tamper with the safety devices in valves or cylinders.

(14) Never attempt to repair or alter cylinders.

(15) Never use cylinders for any purpose other than to contain gas.

(16) Cylinder valves should be closed at all times except when gas is actually being used.

(17) Notify the supply officer if any condition has occurred which might permit any foreign substance to enter cylinder or valve, giving details and cylinder number.
(18) Do not place cylinders where they might become part of an electric circuit.
(19) Cylinders should be repainted only by the supplier.
(20) Compressed gases should be handled only by experienced and properly instructed persons.

b. Moving Cylinders.

(1) Where caps are provided for valve protection, such caps should be kept on cylinders when cylinders are moved.
(2) Never drop cylinders nor permit them to strike each other violently.
(3) Avoid dragging or sliding cylinders. It is safer to move large cylinders even short distances by using a suitable truck, making sure that the cylinder retaining chain or strap is fastened in place.

c. Storing Cylinders.

(1) Cylinders should be stored in a definitely assigned location.
(2) Full and empty cylinders should be stored separately with the storage layout so planned that cylinders comprising old stock can be removed first with a minimum of handling of other cylinders.
(3) Storage rooms should be dry, cool, and well ventilated. Where practical, storage rooms should be fireproof. Storage in subsurface locations should be avoided. Storage conditions should comply with local and state regulations.
(4) Cylinders should be protected against excessive rise of temperature. Do not store cylinders near radiators or other sources of heat. Do not store cylinders near highly flammable substances such as oil, gasoline, waste, etc. Keep sparks and flames away from cylinders.
(5) Do not store reserve stocks of cylinders containing flammable gases in the same room with those containing oxygen or nitrous oxide. (It is good practice to store cylinders containing carbon dioxide in the storage room with those containing flammable gases, since carbon dioxide is in itself a fire extinguisher.)
(6) Cylinders should never be stored in the operating room.
(7) Small cylinders may best be stored in bins, grouped as to the various gases, or mixtures of gases.
(8) Large cylinders should be placed against a wall to offer some protection against being knocked over. They should not be placed along an aisle used for trucking traffic. The

best practice is to provide means for a chain fastening of large cylinders to the wall.

(9) Be careful to protect cylinders from any object that will produce a cut or other abrasion in the surface of the metal. Do not store cylinders in locations where heavy moving objects may strike or fall on them. Where caps are provided for valve protection, such caps should be kept on cylinders in storage.

(10) Cylinders may be stored in the open but in such cases should be protected against extremes of weather and from the ground beneath to prevent rusting. During winter, cylinders stored in the open should be protected against accumulations of ice or snow. In summer, cylinders stored in the open should be screened against continuous direct rays of the sun.

(11) Cylinders should not be exposed to continuous dampness and should not be stored near corrosive chemicals or fumes. Rusting will damage the cylinders and may cause the valve protection caps to stick.

(12) Never store cylinders where oil, grease, or other readily combustible substance may come in contact with them. Oil and certain gases such as oxygen or nitrous oxide may combine with explosive violence.

(13) Cylinders should be protected against tampering by unauthorized individuals.

(14) Valves should be kept closed on empty cylinders at all times.

d. Withdrawing Cylinder Contents.

(1) Never attempt to use contents of a cylinder without a suitable pressure regulating device. Pressure regulators are used for reducing pressure from cylinders.

(2) Do not remove valve protection cap until ready to withdraw contents or to connect to a manifold.

(3) Where compressed gas cylinders are connected to a manifold, such a manifold must be of proper design and equipped with one or more pressure regulators where necessary.

(4) After removing valve protection cap, slightly open valve an instant to clear opening of possible dust and dirt.

(5) When opening valve, point the outlet away from you. Use nonadjustable wrenches or tools of nonferrous material. Never hammer the cylinder valve in attempting to open or to close it.

(6) Regulators, pressure gages, and manifolds provided for

use with a particular gas or group of gases must not be used with cylinders containing other gases.

(7) It is important to make sure that the threads on regulators or other auxiliary equipment are the same as those on cylinder valve outlets. Never force connections that do not fit.

(8) After attaching regulator and before cylinder valve is opened, be sure the regulator is turned to the OFF position. In the case of regulators equipped with a pressure adjusting screw and handle, this is accomplished by turning the screw counterclockwise until it is free.

(9) Never permit gas to enter the regulator device suddenly. Open the cylinder valve slowly.

(10) Before regulating device is removed from a cylinder close the cylinder valve and release all pressure from the device.

(11) Always close valves in empty cylinders.

e. Transfilling Cylinders. Never under any circumstances transfill cylinders.

62. Radiation

a. All persons authorized to use and repair x-ray equipment should be cognizant of the danger of excessive exposure to x-radiation. Effects harmful to the health may be experienced by anyone exposed to an excessive amount of x-radiation. To avoid exposure, various protective materials and devices such as lead aprons and lead gloves are available and should be used.

b. Greatest consideration should be given to protection of the operator and all others against the direct beam. However, when x-radiation strikes any material there is produced a secondary or scattered radiation, and since this is potentially as dangerous as the direct beam radiation, protective measures must be adequate to guard against it as well.

c. All repairmen should be well acquainted with the contents of TB MED 62 which is invaluable when determining adequate protection against x-radiation. Adequate protection should be confirmed by r-unit measurements taken to determine that the x-radiation at any location does not exceed the accepted tolerance dose; or a less accurate but frequently used means for confirming protection is by placing unexposed films at several strategic locations for a given period before development; or by use of a fluorescent screen after the eyes have become accommodated. Another worthwhile procedure is that of the semiannual blood examination of the personnel engaged in radiological work.

CHAPTER 8

INSPECTIONS

63. General

Command maintenance inspection and spot check inspections are required by AR 750–8 and AR 750–825; however, these are not intended to prohibit other formal or informal maintenance inspections conducted at the discretion of the unit or installation commander. The nature of command maintenance and spot check inspections is to evaluate the maintenance performed by units and organizations. The standards applied are a measurement of the diligence, of the unit or organization, in applying the principles of maintenance. Serviceability standards are an important part of maintenance inspections; however, the application of these standards alone is only a measure of the life expectancy of equipment.

64. Purpose of Inspection

Maintenance inspections enable commanders to gage the quality of maintenance and the condition of equipment; they permit a determination that standards and maintenance principles have been applied; they provide an opportunity for the correction of errors, and the elimination of waste; they enable commanders to determine the level of skills of personnel and serve as a means of keeping personnel informed. Commanders are interested in all factors relating to maintenance. Inspectors will examine such areas as to—

a. Operational status of equipment.

b. Maintenance procedures.

c. Supply procedures and the availability of repair parts.

d. Accuracy of records.

e. Availability and use of technical manuals, manufacturers' literature, and other related maintenance publications.

f. Skills of operators and medical equipment repairmen.

65. Importance of Inspections

Inspections are a basic element in any operation. Without inspections, errors, omissions, and deficiencies tend to go unnoticed until a breakdown occurs. Inspections are a source of information for commanders to determine unit readiness and efficiency. Reliable information obtained through inspections help commanders avoid errors in planning and programming.

66. Command Maintenance and Spot Checks Inspections

Command maintenance and spot check inspections are conducted in accordance with AR 750–8 and AR 750–825, respectively. Technically qualified personnel are assigned as inspectors. It is essential that medical equipment repairmen be familiar with these regulations.

CHAPTER 9

INSTALLATION OF MEDICAL EQUIPMENT

67. General

a. Installation of technical medical equipment, whether simple or complex, presents a problem which requires efficient resolution based upon an orderly approach to all factors affecting the item. These factors include the building, facilities, use of the item, operators of the equipment, and patients. The orderly approach is best made to any enterprise by the formulation of a plan. Planning is a method or scheme of action the use of which materially contributes to efficient utilization of time, personnel, and material.

b. The more important aspects of planning for the installation of medical equipment from the time the need for a new or replacement item is recognized to the time the maintenance technician has completed his work, are presented herein as a guide and helpful reminder.

68. Planning

a. Primary planning should be projected into the future to assure that the needs of the installation will be met. Considerations should be given to—

(1) Department remodeling.
(2) The addition of space to provide for bed, ambulatory, and outpatients.
(3) The time required to accomplish the installation.
(4) The arrangement of equipment to provide minimum movement and travel of patients and equipment operators in the performance of the examination or treatment.
(5) The presentation of effective operational and preventive maintenance instruction to the professional staff.

b. Planning for the installation of medical equipment in any department or clinic is a team venture. The more representative the team, the better will be the plan. The team should consider function and efficient operation as objectives to be attained. The team should consist of, but not be limited to, the medical equipment maintenance officer, the chief of the supply and service division, the chief of the section in which the medical item is to be installed, and the post engineer.

c. In planning the installation of certain items of medical equipment, it is necessary to consider the room layout in order to provide ease of entry of such additional equipment as wheeled litters,

oxygen tents, anesthesia apparatus, and hospital beds with extension apparatus. The equipment should be placed so as to utilize all available natural light sources, and provide for—privacy, quiet, safety, fresh air, and adequate and expeditious service. Literature furnished by manufacturers usually contain helpful information relative to the above.

d. Prior to installing heavy equipment, the post engineer should inspect the building structure to determine whether or not reinforcements are necessary, existing electrical wiring, plumbing, and other utilities are adequate or in need of modification or replacement. Roughing-in plans usually supplied by the manufacturers are reliable guides in the preparation of DA Form 5–35 (Work Requests) to the post engineers.

e. In the overall planning for the installation of an item of medical equipment, it might be expedient to make a scale drawing of the room and scaled templates of the equipment to be installed, in order to arrive at the most practical arrangement. A poorly planned installation would lower the efficiency and detract from the usefulness of the department regardless of the qualifications of its medical and technical staff.

69. Utilities

a. The post engineers are responsible for the installation, modification, and maintenance of all utilities from their source to the designated area where the medical item is being installed. Among those most common are—transformers, electric power lines, convenience outlets, fused service switches, hot and cold water, waste lines, atmospheric vents, exhaust fans, compressors, compressed air lines, and gas lines.

b. Before beginning an installation of medical equipment, the medical equipment repairman should be sure all required utilities are installed or modified to comply with the manufacturer's specifications and the plans for the installation. The date and time for the installation should be fixed in coordination with the chief of the using agency in order that the patient load may be scheduled accordingly. Coordination with the post engineers during installation or modification of utilities will insure compliance with required specifications and will facilitate and expedite completion of the installation of the medical equipment. Coordination with the medical supply officer will facilitate delivery of the equipment to be installed when it is required by the medical equipment repairman.

70. Personnel

Competent supervision and efficient use of a minimum number of best qualified personnel will insure an effective installation with

the least possible delay. The additional personnel present over the minimum requirements create confusion, possible safety hazards, loss of time, and wasted manpower.

71. Installations

a. During preparation for installation of medical equipment, the item to be installed should be given a thorough inspection. Inspection should include uncrating, assembling when practical, testing, operation, inventory of accessories, and a complete scrutiny of castings, moving parts, devices, and components to reveal in-transit damage. Two copies of the manufacturer's "Manual of Instruction" will accompany new and rebuilt items of medical equipment. One copy is intended for use by maintenance personnel and should be filed in the maintenance shop. The other copy is intended for use by operating personnel and should be available to personnel who operate the equipment. This copy is left with the chief of the service after the installation is completed. It is important that the sequence of assembly suggested by the manufacturer be adhered to, thereby avoiding error and noticeably reducing time involved in completing the installation.

b. When required to relocate an item of medical equipment, care must be exercised in preparing the necessary diagrams, notes, sketches, and lead identifications. This will contribute to ease of reinstallation in the new location. Should problems arise during the installation of new or used medical equipment that cannot be resolved locally, requests for technical assistance can be made through provisions of AR 750–807.

c. Installations of medical equipment performed by commercial contractors should be supervised by the medical equipment maintenance officer or his representative. In-progress inspections should be made frequently in order to determine whether the quality of materials and workmanship comply with the contract specifications. Operational tests should be conducted by medical equipment maintenance personnel prior to final acceptance.

d. Upon completion of all installation of technical medical equipment, the medical equipment repairman will initiate and file one copy of DA Form 8–230 (Preventive Maintenance Records for Medical Equipment) in the medical equipment maintenance section. He should instruct the department supervisor and equipment operators in all matters pertaining to operation, safety precautions, and preventive maintenance requirements.

APPENDIX I

PUBLICATIONS PERTAINING TO MAINTENANCE AND SUPPLY

1. Army and Special Regulations

37–64	Working Capital Funds, Army Stock Fund, Uniform Accounting and Reporting Criteria for Branch Offices.
385–20	Administration of the Army Safety Program.
385–30	Safety Color Code Marking.
700–20	Classification of Unserviceable Supplies at Posts, Camps, and Stations.
700–6500–15	Reporting and Processing Materiel Complaints.
700–8120–1	Safe Handling, Storing, Shipping, Use, and Disposal of Compressed Gas Cylinders.
711–10	Supply Economy.
711–16	Installation Stock Control and Supply Procedures.
711–41	Army Supply Status Reporting System, Unit and Organizational Equipment Status Report (RCS CSGLD–212).
711–840	Army Supply Status Reporting System, Army Medical Service List of Reportable Property.
715–55–5	Materiel Inspection and Receiving Reports.
725–5	Preparation, Processing, Documentation for Requisitioning, Shipping, and Receiving.
735–4	Expendable Property.
735–5	General Principles and Policies.
735–10	Accounting for Lost, Damaged, and Destroyed Property.
735–11	Accounting for Lost, Damaged, and Destroyed Property.
735–35	Supply Procedure for TOE Units, Organizations and Non-TOE Activities.
735–60	Financial Inventory Accounting, General Principles and Policies.
735–67	Financial Inventory Accounting Reports.
742–607–1	Serviceability Standards for Classification of Technical Medical Equipment.
750–1	Concept of Maintenance.
750–5	Maintenance Responsibilities and Shop Operations.

750–6	Maintenance Planning, Allocation and Coordination.
750–8	Command Maintenance Inspections.
750–804	Performance and Allocation of Maintenance Functions, Rebuild, Overhaul, and Repair for Medical Equipment.
750–807	Technical Assistance in Maintenance of Medical Equipment. Repair Limitations for Medical Equipment.
750–808	Repair Limitations for Medical Equipment.
750–825	Maintenance Spot Check Inspections and Reports, Medical Service Equipment.
750–870	Medical Field Maintenance Shops and Missions.
780–10	Organization and Command Relationship.
780–40–1	Stock Control and Supply Procedures.
780–870	Depot Missions, Army Medical Service.

2. Modification Work Orders

MWO MED 12	Modification of Anesthesia Apparatus, Gas, Nitrous Oxide, Oxygen and Ether, 4 cylinder Capacity.
MWO MED 13	Modification of Anesthesia Apparatus, Gas, Nitrous Oxide, Oxygen and Ether, Portable, 4 cylinder Capacity.
MWO MED 14	Modification of X-Ray Apparatus, Dental.
MWO MED 15	Modification of Cabinet, Bedside, Metal.
MWO MED 16	Modification of Light, Bed, Universal Clamp.
MWO 8–6525–200–20/1	Modification of X-Ray Apparatus, Dental, Wall mounted, Profexray Models.
MWO 8–6515–200–20/1	Anesthesia Apparatus, Gas, Nitrous Oxide, Oxygen and Ether, 4 cylinder Capacity.
MWO 8–6525–201–20/1	Modification of X-Ray Apparatus, Photofluorographic, 70-mm, and Photofluorographic and Roentgenographic Accessory Assembly, 70-mm.

3. Supply Bulletins

8–63	Army Medical Service Depot Maintenance Repair and Return Service.
8–66	Use of Controlled Cannibalization of Medical Equipment as a Source of Low Mortality Repair Parts Supply.

4. Technical Bulletins

TB ENG 39	Safe Handling of Compressed Gases.
TB MED 35	Health Hazards from Industrial Solvents.

TB MED 62	Medical X-Ray Protection.
TB MED 186	Moistureproofing and Fungiproofing (Tropicalizing) Medical Department Equipment.
TB MED 254	Permissible Dose From External Sources of Ionizing Radiation.
TB MED 256	Hazards to Health from Ozone.
TB SIG 222	Solder and Soldering.
TB SIG 327	Harmful Effects of Carbon Tetrachloride on the Human Body.

5. Technical Manuals

5-764	Electric Motor and Generator Repair.
8-280	Military Roentgenology.
8-281	X-Ray Film Processing.
8-282	Principles of Radiographic Exposure.
8-613	Case, Bone Operating, 110 volt AC–DC.
8-620	Serological Water Baths.
8-621	Lamp, Therapeutic, Mercury Arc, Air-Cooled, Mobile, Complete, 110 volt, 60 cycle.
8-625	Cassette Changer, Stereoscopic, Upright, Magnetically Controlled.
8-632	X-Ray Field Unit, Machine, Chassis and Table.
8-633	X-Ray Field Unit, Fluoroscopic, Foreign Body Localization, Complete.
8-638	Engine, Handpiece, Straight; Engine, Handpiece, Angle.
9-237	Welding, Theory and Application.
9-867	Maintenance and Care of Hand Tools.
9-1007	Ordnance Maintenance; Materials used for Cleaning, Preserving, Abrading, and Cementing Ordnance Materiel, and Related Materials including Chemicals, Lubricants, Indicators, and Hydraulic Fluids.
9-1861	Cleaning and Black Finishing of Ferrous Metals.
9-6140-200-15	Operation and Organizational, Field, and Depot Maintenance: Storage Batteries, Lead Acid Type.
11-661	Electrical Fundamentals (Direct Current).
11-662	Basic Theory and Application of Electron Tubes.
11-663	Electronic Power Supplies.
11-664	Theory and Use of Electronic Test Equipment.
11-670	Special Purpose Oscillators and Amplifiers.
11-671	Cathode-Ray Tubes and their Associated Circuits.
11-672	Pulse Techniques.

6. Miscellaneous Publications

Cat. No. 143	Lessening Anesthesia Hazards. Source: Ohio Chemical and Surgical Equipment Co., 1400 East Washington Avenue, Madison 10, Wisconsin.
Cat. No. 180	Progress in Prevention of Anesthetic Explosions. Source: Ohio Chemical and Surgical Equipment Co., 1400 East Washington Avenue, Madison 10, Wisconsin.
Cat. No. 203	Hazards of Fire and Explosion of Anesthetic Agents—II. Source: Ohio Chemical and Surgical Equipment Co., 1400 East Washington Avenue, Madison 10, Wisconsin.
Cat. No. 204	Hazards of Fire and Explosion of Anesthetic Agents—III. Source: Ohio Chemical and Surgical Equipment Co., 1400 East Washington Avenue, Madison 10, Wisconsin.
Pamphlet	Form #2117. Safety in Hospitals. Source: Ohio Chemical and Surgical Equipment Co., 1400 East Washington Avenue, Madison 10, Wisconsin.
Bulletin 520 (Bureau of Mines)	Static Electricity in Hospital. Operating Suites. Source: Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.
NBFU No. 50	Acetylene Equipment. Source: National Board of Fire Underwriters, 85 John Street, New York 38, New York.
NFPA No. 51	Gas Systems for Welding and Cutting. Source: National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.
NFPA No. 54	Gas Piping and Gas Appliances in Buildings. Source: National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.
NFPA No. 56	Code for Use of Flammable Anesthetics (Safe Practice for Hospital Operating Rooms). Source: National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.
NFPA No. 565	Standard for Nonflammable Medical Gas Systems. Source: National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.
NFPA No. 70	National Electrical Code. Source: National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.

Pamphlet P–2	Characteristics and Safe Handling of Medical Gases. Source: Compressed Gas Association, Inc., New York, New York.
C 42.2: EL/959	Electric Current Abroad. Source: Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

APPENDIX II

DEVELOPMENT OF AN SOP

1. Definition and Need

a. AR 320–5 defines a standing operating procedure, SOP, as "a set of instructions having the force of orders, covering features of operation which lend themselves to a definite or standardized procedure without loss of effectiveness. The procedure is applicable unless prescribed otherwise in a particular case. Thus, the flexibility necessary in special situations is retained."

b. It is sometimes necessary, in the interest of economy and efficiency, for an installation or organization commander to publish a series of standing operating procedures.

c. SOP's are for general distribution within the organization or installation; therefore, they will be authenticated by the commander.

d. An example of a subject that may be effectively treated by an SOP is "Services of the Medical Maintenance Shop." In all probability the commander would require the maintenance officer or senior maintenance NCO to draft such an SOP. Paragraph 2 is a discussion of some factors that must be considered when writing an SOP.

2. Preparation of SOP

a. General. Prior to writing an SOP, facts and requirements relating to the subject must be known. The writer must be versed in the subject before he can effectively inform others.

b. Research. Research may be required to fix clearly in mind the purpose of the SOP. You should define for yourself the limits of your subject, and establish a plan. Recall what you already know about the subject. Take time to make an outline of the major ideas which you feel will give a workable solution to the problem. Under each idea, list the minor points needed for support and development. Once the outline is developed you are ready to use the resources of your library.

c. Format. In the final development of the SOP consideration should be given to the format. Regulations do not specify any definite form; however, the format of a numbered or an unnumbered memorandum is generally used. The following areas should receive consideration:

(1) *References.* Supporting references, such as AR's or TM's, should be noted in the first paragraph. These ref-

erences are generally the authority for an action, or a limitation, or they may provide a guideline for a given situation. Pertinent official publications should be searched to insure that actions taken are not unauthorized.

(2) *Organization and responsibility.* It is sometimes useful to include an organizational chart. Simple charts are often easier to understand than a written paragraph on the same subject. Areas of responsibility must be clearly defined, particularly where there is a possibility of overlapping authority.

(3) *Procedures.* In presenting the main instructions, answer the questions, "who," "what," "when," and "where." When applicable, "how" and "why" should also be answered.

(4) *Safety.* Certain subject areas require safety considerations. Depending upon the complexity of the subject being discussed, safety may be covered in the main instructions or under a separate paragraph.

(5) *Rescissions.* It will prove useful to reserve the final paragraph to list any publications rescinded by the SOP.

(6) *Authentication.* It must be remembered that the SOP will be signed by the commander. You are verifying facts and suggesting policy when you submit a draft. Be sure of your ground, be neat and complete. Submit only material that you would not object to signing yourself.

d. Coordination. The SOP in draft form should be discussed with various department heads in an effort to discover, prior to publishing, those areas of overlapping responsibility, conflicts of schedules, or other errors. Remember the maintenance shop is a service function and must in every way avoid interfering with the efficiency of other sections of the medical unit.

e. Review. SOP's should be up-to-date for maximum effectiveness. They should be constantly reviewed for accuracy, clarity, and applicability. Changes in organization, personnel, mission, or the introduction of new equipment are some factors which might indicate the need for the revision of an SOP.

APPENDIX III

REFERENCE TABLES

1. Wire Tables

a. Size 4/0 through 36. (Approximate Dimensions and Resistance of Commercial Copper Wire, American Standard (Brown & Sharpe) Wire gage.)

B & S gage No.	Diameter bare wire		Area in cir mil (square of mils)	Ohms per 1,000 ft	
	In.	Mils		70°F	167°F
4/0	0.460	460	211,600	0.050	0.060
3/0	.410	410	167,800	.062	.075
2/0	.365	365	133,100	.080	.095
0	.325	325	105,600	.100	.119
1	.289	289	83,690	.127	.150
2	.258	258	66,560	.159	.190
3	.229	229	52,441	.202	.240
4	.204	204	41,620	.254	.302
5	.182	182	33,120	.319	.381
6	.162	162	26,240	.403	.480
7	.144	144	20,740	.510	.606
8	.128	128	16,380	.645	.764
9	.114	114	13,000	.813	.963
10	.102	102	10,400	1.02	1.216
11	.091	91	8,230	1.29	1.532
12	.081	81	6,530	1.62	1.931
13	.072	72	5,180	2.04	2.436
14	.064	64	4,110	2.57	3.071
15	.057	57	3,260	3.24	3.873
16	.051	51	2,580	4.10	4.884
17	.045	45	2,060	5.15	6.158
18	.040	40	1,620	6.51	7.765
19	.036	36	1,290	8.21	9.792
20	.032	32	1,020	10.3	12.35
21	.028	28	812	13.0	15.57
22	.025	25	640	16.5	19.63
23	.024	24	511	20.7	24.76
24	.020	20	404	26.2	31.22
25	.018	18	320	33.0	39.36
26	.016	16	253	41.8	49.64
27	.014	14	202	52.4	62.59
28	.013	13	159	66.6	78.93
29	.011	11	128	82.8	99.52
30	.010	10	100	106	125.50
31	.009	9	79	134	158.20
32	.008	8	64	165	199.50
33	.007	7	50	210	251.60
34	.006	6	40	266	317.30
35	.005	5.6	31	337	400.00
36	.005	5	25	423	504.50

b. Allowable Current-Carrying Capacities of Conductors in Amperes. (Based on Room Temperature of 30°C. or 86°F.)

(1) Not more than three conductors in raceway or cable.

Size AWG MCM	Type R Type RW Type RU Type T Type TW	Type RH	Type TA Type AVB	Type AVA Type AVL
14	15	15	25	30
12	20	20	30	35
10	30	30	40	45
8	40	45	50	60
6	55	65	70	80
4	70	85	90	105
3	80	100	105	120
2	95	115	120	135
1	110	130	140	160
0	125	150	155	190
00	145	175	185	215
000	165	200	210	245
0000	195	230	235	275
250	215	255	270	315
300	240	285	300	345
350	260	310	325	390
400	280	335	360	420
500	320	380	405	470
600	355	420	455	525
700	385	460	490	560
750	400	475	500	580
800	410	490	515	600
900	435	520	555	----------
1,000	455	545	585	680
1,250	495	590	645	----------
1,500	520	625	700	785
1,750	545	650	735	----------
2,000	560	665	775	840

(2) Single conductor in free air.

Size AWG MCM	Type R Type RW Type T Type TW	Type RH	Type TA Type AVB	Type AVA Type AVL
14	20	20	30	40
12	25	25	40	50
10	40	40	55	65
8	55	65	70	85
6	80	95	100	120
4	105	125	135	160

Size AWG MCM	Type R Type RW / Type T Type TW	Type RH	Type TA / Type AVB	Type AVA Type AVL
3	120	145	155	180
2	140	170	180	210
1	165	195	210	245
0	195	230	245	285
00	225	265	285	330
000	260	310	330	385
0000	300	360	385	445
250	340	405	425	495
300	375	445	480	555
350	420	505	530	610
400	455	545	575	665
500	515	620	660	765
600	575	690	740	855
700	630	755	815	940
750	655	785	845	980
800	680	815	880	1,020
900	730	870	940	----------
1,000	780	935	1,000	1,165
1,250	890	1,065	1,130	----------
1,500	980	1,175	1,260	1,450
1,750	1,070	1,280	1,370	----------
2,000	1,155	1,385	1,470	1,715

c. Conductor Insulation for Wiring Circuits Under 600 Volts.

Trade name	Type letter	Insulation	Outer covering	Use
Code	R	Code Grade Rubber.	Moisture-Resistant Flame-Retardant Fibrous Covering.	General Use.
Moisture-Resistant.	RW	Moisture-Resistant Rubber.	Moisture-Resistant Flame-Retardant Fibrous Covering.	General Use Especially in Wet Locations.
Heat-Resistant.	RH	Heat-Resistant Rubber.	Moisture-Resistant Flame-Retardant Fibrous Covering.	General Use.
Latex Rubber.	RU	90 percent Unmilled Grainless Rubber.	Moisture-Resistant Flame-Retardant Fibrous Covering.	General Use.
Thermoplastic	T and TW	Flame-Retardant Thermoplastic Compound.	None	T–General Use; TW–in Wet Locations.
Thermoplastic and Asbestos.	TA	Thermoplastic and Asbestos.	Flame-Retardant Cotton Braid.	Switchboard Wiring Only.

Trade name	Type letter	Insulation	Outer covering	Use
Asbestos and Varnished Cambric.	AVA	Impregnated Asbestos and Varnished Cambric.	Asbestos Braid.....	Dry Locations Only.
Asbestos and Varnished Cambric.	AVB	Same as Type AVA.	Flame-Retardant Cotton Braid.	Dry Locations Only.
Slow Burning.	SB ..	3 Braids Impregnated Fire-Retardant.	Outer Cover Finished Smooth and Hard.	Dry Locations Only.
Slow Burning Weatherproof.	SBW	2 Layers Impregnated Cotton Thread.	Outer Fire-Retardant Coating.	Open Wiring Only.

2. Drill and Tap Sizes

a. National Coarse Machine Screws.

Size of tap	Threads per inch	Tap drill	Body drill
1	64	53	48
2	56	50	43
3	48	47	37
4	40	43	32
5	40	38	30
6	32	36	27
8	32	29	18
10	24	25	9
12	24	16	2

b. National Fine Machine Screws.

Size of tap	Threads per inch	Tap drill	Body drill
2	64	50	43
3	56	45	37
4	48	42	32
5	44	37	30
6	40	33	27
8	36	29	18
10	32	21	9
12	28	14	2

c. National Coarse Standard Screws.

Size of tap	Threads per inch	Tap drill
1/4	20	7
5/16	18	F
3/8	16	5/16
7/16	14	U
1/2	13	27/64
9/16	12	31/64
5/8	11	17/32
3/4	10	21/32
7/8	9	49/64
1	8	7/8
1 1/8	7	63/64

d. NF or S.A.E. Standard Screws.

Size of tap	Threads per inch	Tap drill
1/4	28	3
5/16	24	I
3/8	24	Q
7/16	20	25/64
1/2	20	29/64
9/16	18	33/64
5/8	18	37/64
3/4	16	11/16
7/8	14	13/16
1	14	15/16
1 1/8	12	1 3/64

e. Twist Drill Sizes and Decimal Equivalents.

Size	Decimal equiv.	Size	Decimal equiv.	Size	Decimal equiv.	Size	Decimal equiv.
1/2	0.5000	23/64	0.3594	K	0.2810	7/32	0.2187
31/64	.4844	T	.3580	J	.2770	3	.2130
15/32	.4687	S	.3480	I	.2720	4	.2090
29/64	.4531	11/32	.3437	H	.2660	5	.2055
7/16	.4375	R	.3390	17/64	.2656	6	.2040
27/64	.4219	Q	.3320	G	.2610	13/64	.2031
Z	.4130	21/64	.3281	F	.2570	7	.2010
13/32	.4062	P	.3230	E 1/4	.2500	8	.1990
Y	.4040	O	.3160	D	.2460	9	.1960
X	.3970	5/16	.3125	C	.2420	10	.1935
25/64	.3906	N	.3020	B	.2380	11	.1910
W	.3860	19/64	.2969	15/64	.2344	12	.1890
V	.3770	M	.2950	A	.2340	3/16	.1875
3/8	.3750	L	.2900	No. 1	.2280	13	.1850
U	.3680	9/32	.2812	2	.2210	14	.1820

Size	Decimal equiv.	Size	Decimal equiv.	Size	Decimal equiv.	Size	Decimal equiv.
15	0.1800	27	0.1440	38	0.1015	50	0.0700
16	.1770	9/64	.1406	39	.0995	51	.0670
17	.1730	28	.1405	40	.0980	52	.0635
11/64	.1719	29	.1360	41	.0960	1/16	.0625
18	.1695	30	.1285	3/32	.0937	53	.0595
19	.1660	1/8	.1250	42	.0935	54	.0550
20	.1610	31	.1200	43	.0890	55	.0520
21	.1590	32	.1160	44	.0860	3/64	.0469
22	.1570	33	.1130	45	.0820	56	.0465
5/32	.1562	34	.1110	46	.0810	57	.0430
23	.1540	35	.1100	47	.0785	58	.0420
24	.1520	7/64	.1094	5/64	.0781	59	.0410
25	.1495	36	.1065	48	.0760		
26	.1470	37	.1040	49	.0730		

3. Decimal Inch and Millimeter Equivalents of Fractions of an Inch

Inches			Decimal equivalent	Millimeter equivalent
1/64			.0156	0.397
	1/32		.0313	0.794
3/64			.0469	1.191
		1/16	.0625	1.588
5/64			.0781	1.985
	3/32		.0938	2.381
7/64			.1094	2.778
		1/8	.1250	3.175
9/64			.1406	3.572
	5/32		.1563	3.969
11/64			.1719	4.366
		3/16	.1875	4.762
13/64			.2031	5.159
	7/32		.2188	5.556
15/64			.2344	5.953
		1/4	.2500	6.350
17/64			.2656	6.747
	9/32		.2813	7.144
19/64			.2969	7.541
		5/16	.3125	7.937
21/64			.3281	8.334
	11/32		.3438	8.731
23/64			.3594	9.128
		3/8	.3750	9.525
25/64			.3906	9.922
	13/32		.4063	10.319
27/64			.4219	10.716
		7/16	.4375	11.112

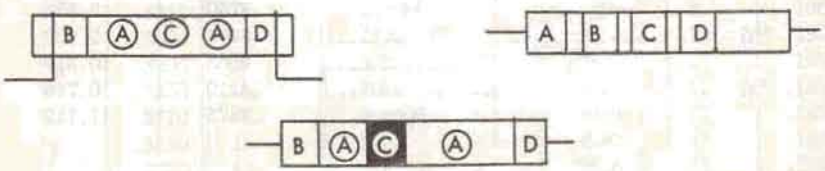
Inches			Decimal equivalent	Millimeter equivalent
29/64			.4531	11.509
	15/32		.4688	11.906
31/64			.4844	12.303
		1/2	.5000	12.700
33/64			.5156	13.097
	17/32		.5313	13.494
35/64			.5469	13.891
		9/16	.5625	14.287
37/64			.5781	14.684
	19/32		.5938	15.081
39/64			.6094	15.478
		5/8	.6250	15.875
41/64			.6406	16.272
	21/32		.6563	16.669
43/64			.6719	17.067
		11/16	.6875	17.463
45/64			.7031	17.860
	23/32		.7188	18.238
47/64			.7344	18.635
		3/4	.7500	19.049
49/64			.7656	19.446
	25/32		.7813	19.842
51/64			.7969	20.239
		13/16	.8125	20.636
53/64			.8281	21.033
	27/32		.8438	21.430
55/64			.8594	21.827
		7/8	.8750	22.224
57/64			.8906	22.621
	29/32		.9063	23.018
59/64			.9219	23.415
		15/16	.9375	23.812
61/64			.9531	24.209
	31/32		.9688	24.606
63/64			.9844	25.004
		1.0	1.0000	25.400

4. Color Codes for Resistors, Capacitors, and Transformers

a. Resistors.

RETMA STANDARD REC-116

MILITARY STANDARD MIL-R-11A



Color	1st digit A	2d digit B	Multiplier C	Tolerance D
Black	0	0	1	–
Brown	1	1	10	–
Red	2	2	100	–
Orange	3	3	1,000	–
Yellow	4	4	10,000	–
Green	5	5	100,000	–
Blue	6	6	1,000,000	–
Violet	7	7	10,000,000	–
Gray	8	8	100,000,000	–
White	9	9	–	–
Gold	–	–	0.1	±5%
Silver	–	–	0.01*	±10%
No Color	–	–	*RETMA ONLY	±20%

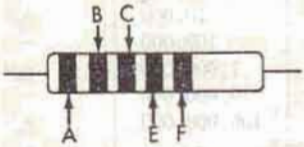
Insulation Coding

*RETMA: Insulated resistors with axial leads are designated by a background of any color except black. The usual color is natural tan. Noninsulated resistors with axial leads are designated by a black background color.

MILITARY (MIL): Same as RETMA with the additon of: Noninsulated resistors with radial leads designated by a black background color or by a background the same color as the first significant figure of the resistance value.

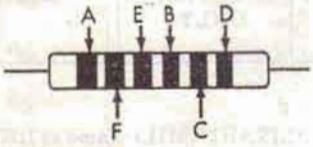
b. Ceramic Capacitors.

Ceramic Capacitor Color Code
RETMA STANDARD REC–107A
MILITARY STANDARD JAN–C–20A

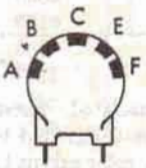


TUBULAR CAPACITORS
(VOLTAGE RATING IS ALWAYS 500V.)

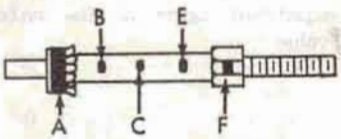
FEED THROUGH CAPACITORS
(RETMA ONLY)



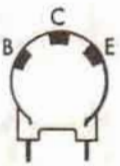
TUBULAR CAPACITORS
(OLD RMA)



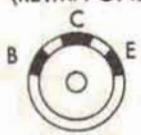
5 DOT DISC CAPACITORS
(RETMA ONLY)
(VOLTAGE RATING IS ALWAYS 500V.)



STAND-OFF CAPACITORS
(RETMA ONLY)



3 DOT DISC CAPACITORS
(RETMA ONLY)
(VOLTAGE RATING IS ALWAYS 500V.)
TOLERANCE IS ALWAYS - 0)



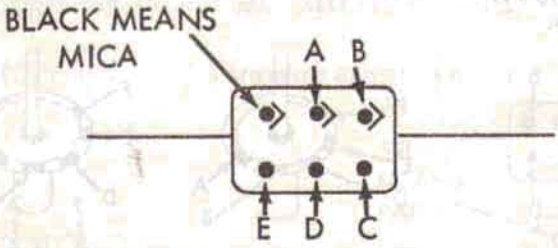
3 DOT BUTTON CAPACITORS
(RETMA ONLY)

Color	Digits of capacitance (μμf)			Multiplier E	Tolerance F	
	B	C	D		10 μμf or less (μμf)	Over 10 μμf (%)
Black	0	0	0	1	±2.0	±20*
Brown	1	1	1	10	±0.1*	±1
Red	2	2	2	100	----------	±2
Orange	3	3	3	1,000	----------	±2.5*
Yellow	4	4	4	10,000*		
Green	5	5	5	----------	±0.5	±5
Blue	6	6	6			

Color	Digits of capacitance (μμf)			Multiplier E	Tolerance F	
	B	C	D		10 μμf or less (μμf)	Over 10 μμf (%)
Violet	7	7	7			
Gray	8	8	8	0.01	±0.25	
White	9	9	9	0.1	±1.0	±10
Gold						

*RETMA only.

c. Mica Capacitors. MILITARY STANDARD MIL–C5–A.



Color	Digits of (μμf) capacitance		Multiplier C	Tolerance % D
	A	B		
Black	0	0	1	±20
Brown	1	1	10	
Red	2	2	100	±2
Orange	3	3	1,000	
Yellow	4	4		
Green	5	5		
Blue	6	6		
Violet	7	7		
Gray	8	8		
White	9	9		
Gold			0.1	±5
Silver			0.01	±10

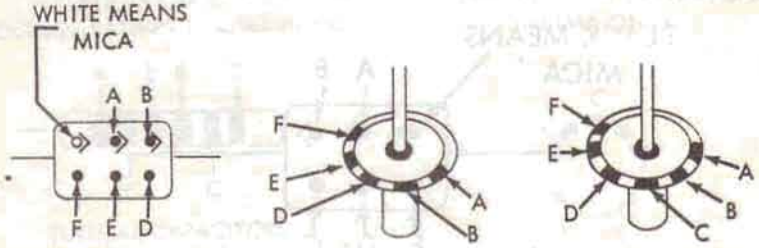
Voltage Rating

(Indicated by dimensions rather than color coding)

Maximum inches			Style CM	Capacitance (μμf)	Rating (v dc)
Long	Wide	Thick			
35/64	5 5/16	7/32	15	5–510	300
51/64	15/32	7/32	20	5–510	500
				560–1000	300

Maximum inches			Style CM	Capacitance (μμf)	Rating (v dc)
Long	Wide	Thick			
1 7/64	15/32	7/32	25	51–1000	500
53/64	53/64	9/32	30	560–3300	500
53/64	53/64	11/32	35	3600–6200	500
				68,000–10,000	300
1 1/32	41/64	11/32	40	3300–8200	500
				9100–10,000	300

d. Mica Capacitor. RETMA STANDARD REC–115A.



Color	Digits of capacitance			Multiplier D	Tolerance % E
	A	B	C		
Black	0	0	0	1	±20
Brown	1	1	1	10	
Red	2	2	2	100	±2
Orange	3	3	3	1,000	±3
Yellow	4	4	4	10,000	
Green	5	5	5	----------	±5
Blue	6	6	6		
Violet	7	7	7		
Gray	8	8	8		
White	9	9	9		
Gold	----------	----------	----------	0.1	
Silver	----------	----------	----------	0.01	±10

Votage Rating

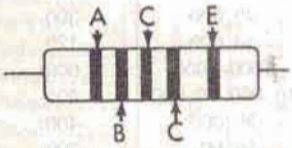
(Indicated by dimensions rather than color coding)

Maximum inches			Style	Capacitance (μμf)	Rating (v dc)
Long	Wide	Thick			
51/64	15/32	7/32	20	5–510	500
				560–1000	300
1 7/64	15/32	7/32	25	5–1000	500
				1100–1500	300

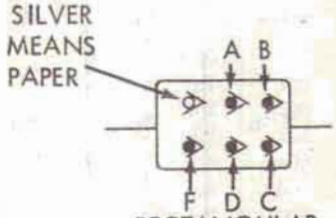
Maximum inches			Style	Capacitance (μμf)	Rating (v dc)
Long	Wide	Thick			
53/64	53/64	9/32	30	470–6200	500
				Over 6200	300
53/64	53/64	3/8	35	3300–6200	500
				Over 6200	300
1 1/32	41/64	11/32	40	100–2400	1,000
				2700–7500	500
				Over 7500	300

e. Paper Capacitor Color Code. MILITARY STANDARD MIL–C–91A.

(Commerical codes are same except as noted)



TUBULAR CAPACITORS
(COMMERCIAL ONLY)



RECTANGULAR
CAPACITORS

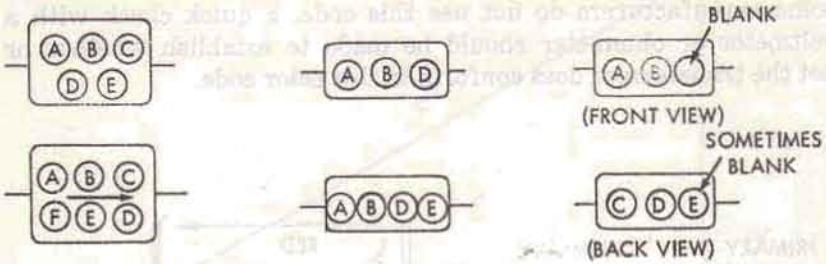
Color	Digits of capacitance (μμf)		Multiplier C	Tolerance % D	Tubular voltage rating (v dc) E
	A	B			
Black	0	0	1	±20	
Brown	1	1	10	----------	100
Red	2	2	100	----------	200
Orange	3	3	1,000	±30	300
Yellow	4	4	10,000	----------	400
Green	5	5	----------	----------	500
Blue	6	6	----------	----------	600
Violet	7	7	----------	----------	700
Gray	8	8	----------	----------	800
White	9	9	----------	----------	900
Gold	----------	----------	----------	----------	1,000
Silver	----------	----------	----------	±10	

Voltage Rating for Rectangular Capacitors

(Indicated by dimensions rather than color coding)

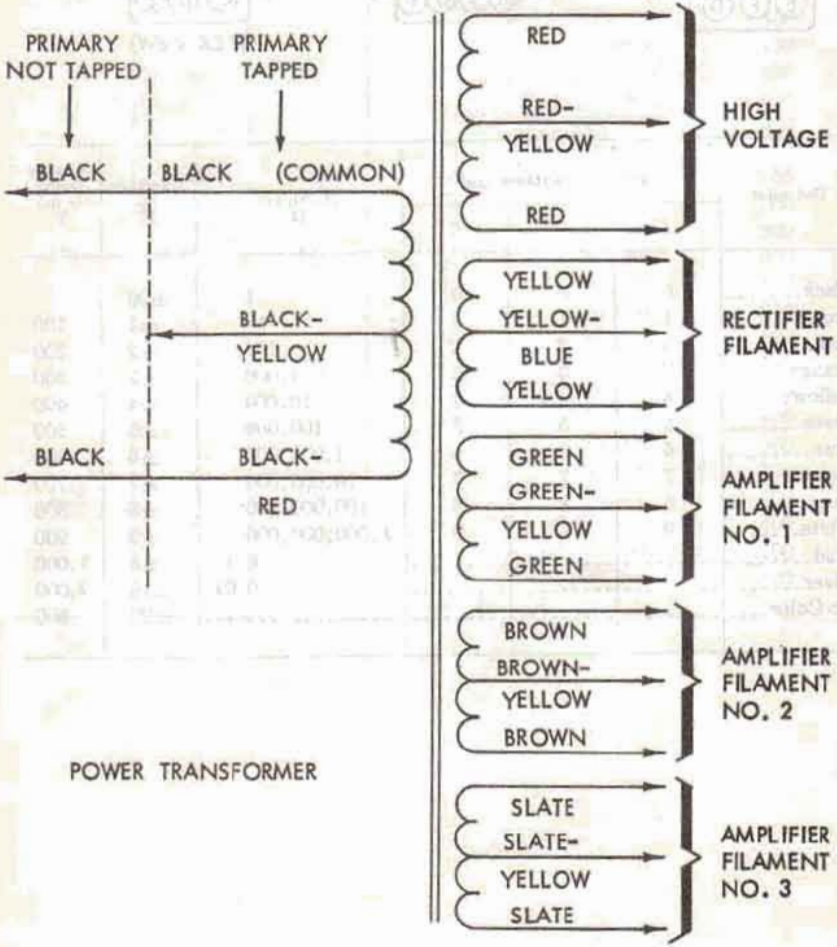
Maximum dimensions (inches)			Style CN	Capacitance ($\mu\mu$f)	Voltage rating (v dc)
Length	Width	Thickness			
51/64	13/32	7/32	20	1000	400
				2000–6000	200
				10,000	120
57/64	37/64	17/64	22	2000–3000	400
				6000–10,000	300
				20,000	120
53/64	53/64	9/32	30	1000–2000	800
				3000	600
				6000–10,000	400
				20,000	120
53/64	53/64	11/32	35	3000	800
				6000–10,000	600
				20,000	300
1 1/4	41/64	9/32	41	3000–6000	600
				10,000	400
				20,000	300
				30,000	120
1 15/32	49/64	11/32	42	1000–6000	1,000
				10,000–20,000	600
				30,000	400
				50,000	300
				100,000	120
1 15/32	49/64	13/32	43	10,000	1,000
				20,000–30,000	600
				50,000–100,000	400
				200,000	120

f. Obsolete Mica Capacitors.



Dot color	Digits of capacitance (μμf)			Multiplier D	Tolerance % E	Voltage rating (v dc) F
	A	B	C			
Black	0	0	0	1	±20	
Brown	1	1	1	10	±1	100
Red	2	2	2	100	±2	200
Orange	3	3	3	1,000	±3	300
Yellow	4	4	4	10,000	±4	400
Green	5	5	5	100,000	±5	500
Blue	6	6	6	1,000,000	±6	600
Violet	7	7	7	10,000,000	±7	700
Gray	8	8	8	100,000,000	±8	800
White	9	9	9	1,000,000,000	±9	900
Gold	---	---	---	0.1	±5	1,000
Silver	---	---	---	0.01	±10	2,000
No Color	---	---	---	---	±20	500

g. Transformers. The color code for transformers shown here is used by most manufacturers. However, due to the fact that some manufacturers do not use this code, a quick check with a voltmeter or ohmmeter should be made to establish whether or not the transformer does conform to this color code.



5. Trigonometric Functions

The trigonometric functions of the acute angles of right triangles are expressed as the ratio of two sides. The six possible ratios or functions of angle A of the right triangle (fig. 5) are listed below the triangle.

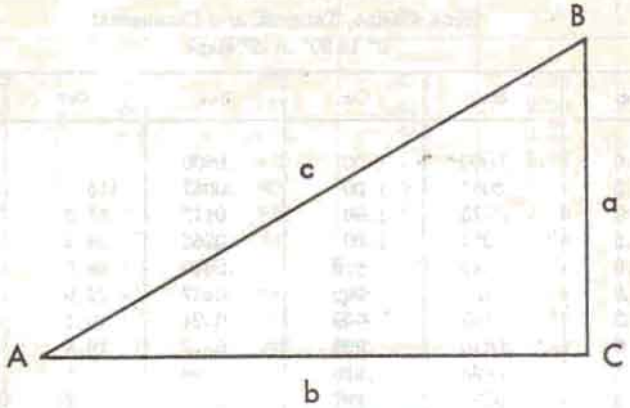


Figure 5. Right triangle.

Sine of Angle A $= \sin A = \dfrac{\text{side opposite } \angle A}{\text{hypotenuse}} = \dfrac{a}{c}$

Cosine of Angle A $= \cos A = \dfrac{\text{side adjacent } \angle A}{\text{hypotenuse}} = \dfrac{b}{c}$

Tangent of Angle A $= \tan A = \dfrac{\text{side opposite } \angle A}{\text{side adjacent } \angle A} = \dfrac{a}{b}$

Cotangent of Angle A $= \cot A = \dfrac{\text{side adjacent } \angle A}{\text{side opposite } \angle A} = \dfrac{b}{a}$

Secant of Angle A $= \sec A = \dfrac{\text{hypotenuse}}{\text{side adjacent } \angle A} = \dfrac{c}{b}$

Cosecant of Angle A $= \csc A = \dfrac{\text{hypotenuse}}{\text{side opposite } \angle A} = \dfrac{c}{a}$

Also:

$\sin A = \cos B$	$\csc A = \sec B$
$\cos A = \sin B$	$\sec A = \csc B$
$\tan A = \cot B$	$\cot A = \tan B$

The hypotenuse is equal to the square root of the sum of the squares of the two sides. Thus:

$$c = \sqrt{a^2 + b^2}$$

$$b = \sqrt{c^2 - a^2}$$

$$a = \sqrt{c^2 - b^2}$$

The expression "arc sin" means "the angle whose sine is" . . . ; likewise "arc tan" indicates "the angle whose tangent is" . . . etc.

Table of Trigonometric Functions

(Sine, Cosine, Tangent, and Cotangent)

0° to 90° in .5° steps

Deg.	Sin	Cos	Tan	Cot	Deg.
0.0	.0000	1.00	.0000		90.0
0.5	.0087	1.00	.0087	115	89.5
1.0	.0175	1.00	.0175	57.3	89.0
1.5	.0262	1.00	.0262	38.2	88.5
2.0	.0349	.999	.0349	28.6	88.0
2.5	.0436	.999	.0437	22.9	87.5
3.0	.0523	.999	.0524	19.1	87.0
3.5	.0610	.998	.0612	16.4	86.5
4.0	.0698	.998	.0699	14.3	86.0
4.5	.0785	.997	.0787	12.7	85.5
5.0	.0872	.996	.0875	11.4	85.0
5.5	.0958	.995	.0963	10.4	84.5
6.0	.105	.995	.105	9.51	84.0
6.5	.113	.994	.114	8.78	83.5
7.0	.122	.993	.123	8.14	83.0
7.5	.131	.991	.132	7.60	82.5
8.0	.139	.990	.141	7.12	82.0
8.5	.148	.989	.149	6.69	81.5
9.0	.156	.988	.158	6.31	81.0
9.5	.165	.986	.167	5.98	80.5
10.0	.174	.985	.176	5.67	80.0
10.5	.182	.983	.185	5.40	79.5
11.0	.191	.982	.194	5.14	79.0
11.5	.199	.980	.203	5.92	78.5
12.0	.208	.978	.213	4.70	78.0
12.5	.216	.976	.222	4.51	77.5
13.0	.225	.974	.231	4.33	77.0
13.5	.233	.972	.240	4.17	76.5
14.0	.242	.970	.249	4.01	76.0
14.5	.250	.968	.259	3.87	75.5
15.0	.259	.966	.268	3.73	75.0
15.5	.267	.964	.277	3.61	74.5
16.0	.276	.961	.287	3.49	74.0
16.5	.284	.959	.296	3.38	73.5
17.0	.292	.956	.306	3.27	73.0
17.5	.301	.954	.315	3.17	72.5
18.0	.309	.951	.325	3.08	72.0
18.5	.317	.948	.335	2.99	71.5
19.0	.326	.946	.344	2.90	71.0
19.5	.334	.943	.354	2.82	70.5
20.0	.342	.940	.364	2.75	70.0
20.5	.350	.937	.374	2.67	69.5
21.0	.358	.934	.384	2.61	69.0
21.5	.367	930	394	2.54	68.5
22.0	.375	927	.404	2.48	68.0
22.5	.383	.924	.414	2.41	67.5
Deg.	Cos	Sin	Cot	Tan	Deg.

Deg.	Sin	Cos	Tan	Cot	Deg.
23.0	.391	.921	.424	2.36	67.0
23.5	.399	.917	.435	2.30	66.5
24.0	.407	.914	.445	2.25	66.0
24.5	.415	.910	.456	2.19	65.5
25.0	.423	.906	.466	2.14	65.0
25.5	.431	.903	.477	2.10	64.5
26.0	.438	.899	.488	2.05	64.0
26.5	.446	.895	.499	2.01	63.5
27.0	.454	.891	.510	1.96	63.0
27.5	.462	.887	.521	1.92	62.5
28.0	.469	.883	.532	1.88	62.0
28.5	.477	.879	.543	1.84	61.5
29.0	.485	.875	.554	1.80	61.0
29.5	.492	.870	.566	1.77	60.5
30.0	.500	.866	.577	1.73	60.0
30.5	.508	.862	.589	1.70	59.5
31.0	.515	.857	.001	1.66	59.0
31.5	.523	.853	.613	1.63	58.5
32.0	.530	.848	.625	1.60	58.0
32.5	.537	.843	.637	1.57	57.5
33.0	.545	.839	.649	1.54	57.0
33.5	.552	.834	.662	1.51	56.5
34.0	.559	.829	.675	1.48	56.0
34.5	.566	.824	.687	1.46	55.5
35.0	.574	.819	.700	1.43	55.0
35.5	.581	.814	.713	1.40	54.5
36.0	.588	.809	.727	1.38	54.0
36.5	.595	.804	.740	1.35	53.5
37.0	.602	.799	.754	1.33	53.0
37.5	.609	.793	.767	1.30	52.5
38.0	.616	.788	.781	1.28	52.0
38.5	.623	.783	.795	1.26	51.5
39.0	.629	.777	.810	1.23	51.0
39.5	.636	.772	.824	1.21	50.5
40.0	.643	.766	.839	1.19	50.0
40.5	.649	.760	.854	1.17	49.5
41.0	.656	.755	.869	1.15	49.0
41.5	.663	.749	.885	1.13	48.5
42.0	.669	.743	.900	1.11	48.0
42.5	.676	.737	.916	1.09	47.5
43.0	.682	.731	.933	1.07	47.0
43.5	.688	.725	.949	1.05	46.5
44.0	.695	.719	.966	1.04	46.0
44.5	.701	.713	.983	1.02	45.5
45.0	.707	.707	1.000	1.00	45.0
Deg.	Cos	Sin	Cot	Tan	Deg.

6. Formulas

a. Conductor Calculations.

(1) Direct-current, single-phase and two-phase alternating-current circuits.

To find size of conductor required:

$$\text{Circular Mils} = \frac{21.6 \times \text{Current in Amperes} \times \text{Distance in Feet}}{\text{Volts Drop}}$$

To find the voltage drop in a circuit:

$$\text{Volts Drop} = \frac{21.6 \times \text{Current in Amperes} \times \text{Distance in Feet}}{\text{Circular Mils}}$$

To find current flowing:

$$\text{Current} = \frac{\text{Circular Mils} \times \text{Voltage Drop}}{21.6 \times \text{Distance in Feet}}$$

To find allowable length of circuit for given voltage drop or loss:

$$\text{Length of Circuit} = \frac{\text{Circular Mils} \times \text{Voltage Drop}}{21.6 \times \text{Current in Amperes}}$$

(2) Three-phase alternating-current circuits.

To find size of conductor required for a three-phase circuit:

$$\text{Circular Mils} = \frac{10.8 \times \text{Current in Amperes} \times \text{Distance in Feet} \times 1.73}{\text{Volts Drop}}$$

To find voltage drop in a three-phase circuit:

$$\text{Volts Drop} = \frac{10.8 \times \text{Current in Amperes} \times \text{Distance in Feet} \times 1.73}{\text{Circular Mils}}$$

To find current in a three-phase circuit:

$$\text{Current (Amperes)} = \frac{\text{Circular Mils} \times \text{Voltage Drop}}{10.8 \times \text{Distance in Feet} \times 1.73}$$

To find length of a three-phase circuit for a given voltage drop:

$$\text{Distance in Feet} = \frac{\text{Circular Mils} \times \text{Voltage Drop}}{10.8 \times \text{Current in Amperes} \times 1.73}$$

b. Direct-Current Formulas.

(1) Ohm's law (direct-current).

Known values	Formulas for determining unknown values of . . .			
	I	R	E	P
I & R			IR	I^2R
I & E		$\frac{E}{I}$		EI
I & P		$\frac{P}{I^2}$	$\frac{P}{I}$	

Known values	Formulas for determining unknown values of . . .			
	I	R	E	P
R & E	$\frac{E}{R}$			$\frac{E^2}{R}$
R & P	$\sqrt{\frac{P}{R}}$		$\sqrt{PR}$	
E & P	$\frac{P}{E}$	$\frac{E^2}{P}$		

I = Current in Amperes
E = Potential in Volts
R = Resistance in Ohms
P = Power in Watts

(2) Series circuits.

$R_T = R_1 + R_2 + R_3$, etc.

$E_T = E_{R1} + E_{R2} + E_{R3}$, etc.

$I_T = I_{R1} = I_{R2} = I_{R3}$, etc.

(3) Parallel circuits.

Two resistors in parallel.

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

Any number of resistors in parallel.

$$R_T = \frac{1}{1/R_1 + 1/R_2 + 1/R_3}, \text{ etc.}$$

$E_T = E_{R1} = E_{R2} = E_{R3}$, etc.

$I_T = I_{R1} + I_{R2} + I_{R3}$, etc.

c. Alternating-Current

(1) Ohm's law for alternating-current circuits.

Known values	Formulas for determining unknown values of . . .			
	I	R	E	P
I & Z			IZ	$I^2Z \cos\theta$
I & E		$\frac{E}{I}$		$IE \cos\theta$
I & P		$\frac{P}{I^2 \cos\theta}$	$\frac{P}{I \cos\theta}$	
Z & E	$\frac{E}{Z}$			$\frac{E^2 \cos\theta}{Z}$
Z & P	$\sqrt{\frac{P}{Z \cos\theta}}$		$\sqrt{\frac{PZ}{\cos\theta}}$	
E & P	$\frac{P}{E \cos\theta}$	$\frac{E^2 \cos\theta}{P}$		

$$\text{Power Factor} = \cos\theta = \frac{P}{EI} = \frac{R}{Z}$$

(2) Peak, RMS (effective), and average values of voltage and current.

To determine	Multiply
Peak	RMS × 1.414 or Avg. × 1.57
RMS	Peak × .707 or Avg. × 1.11
Avg	Peak × .637 or RMS × .9

(3) Series Circuits

(*a*) Capacitance and inductance.

$$Z = X_L - X_C$$

(*b*) Resistance and capacitance.

$$Z = \sqrt{R^2 + X_C^2}$$

$$R = \sqrt{Z^2 - X_C^2}$$

$$X_C = \sqrt{Z^2 - R^2}$$

(*c*) Resistance and inductance.

$$Z = \sqrt{R^2 + X_L^2}$$

$$R = \sqrt{Z^2 - X_L^2}$$

$$X_L = \sqrt{Z^2 - R^2}$$

(*d*) Resistance, inductance, and capacitance.

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$R = \sqrt{Z^2 - (X_L - X_C)^2}$$

$$X_L = \sqrt{Z^2 - R^2 + X_C}$$

$$X_C = X_L - \sqrt{Z^2 - R^2}$$

(*e*) Any number of resistors, inductors, and capacitors in series.

$$Z = \sqrt{(R_1+R_2+R_3\ldots)^2 + (X_{L1}+X_{L2}+X_{L3}\ldots - X_{C1}-X_{C2}-X_{C3}\ldots)^2}$$

(4) Parallel circuits.

(*a*) Capacitance and inductance.

$$Z = \frac{X_L X_C}{X_L - X_C}$$

(*b*) Resistance and capacitance.

$$Z = \frac{RX_C}{\sqrt{R^2 + X_C^2}}$$

(*c*) Resistance and inductance.

$$Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}}$$

(*d*) Resistance, inductance and capacitance.

$$Z = \frac{RX_L X_C}{\sqrt{X_L^2 X_C^2 + (RX_L - RX_C)^2}}$$

(*e*) Two circuits in parallel.

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

(f) Inductance and series resistance in parallel with capacitance.

$$Z = \sqrt{\frac{R^2 + X_L^2}{R^2 + (X_L - X_C)^2}}$$

(g) Inductance and series resistance in parallel with capacitance and series resistance.

$$Z = \sqrt{\frac{(R_L^2 + X_L^2)(R_C^2 + X_C^2)}{(R_L + R_C)^2 + (X_L - X_C)^2}}$$

d. Transformers.

(1) Ratio of voltage, turns, and current.

$$\frac{E_P}{E_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

(2) Efficiency.

$$\text{Expressed in "percent"} = \frac{P_S}{P_P} \times 100$$

(3) Power factor $= \dfrac{P}{EI} = \cos\theta$

(4) Impedance.

$$Z_P = \frac{E_P}{I_P}$$

(5) Impedance matching.

$$\sqrt{\frac{Z_P}{Z_S}} = \frac{N_P}{N_S} = \text{turns ratio}$$

e. Inductors.

(1) Inductance of a coil.

$$L = \frac{.4\pi\mu A N^2 10^{-8}}{l}$$

L = self inductance in henrys.
μ = permeability of core in electro-magnetic units.
A = cross sectional area of core in square cm.
N = number of turns of coil.
l = mean length of core in cm.

(2) Inductive reactance.

$$X_L = 2\pi FL$$

$$L = \frac{X_L}{2\pi F}$$

$$F = \frac{X_L}{2\pi L}$$

(3) Inductors in series.

(a) With no flux linkage between coils.

Inductance

$L_T = L_1 + L_2 + L_3$, etc.

Reactance.

$X_{LT} = X_{L1} + X_{L2} + X_{L3}$, etc.

or $2\pi F L_T$

(*b*) With flux linkage.

Fields aiding.

$L_T = L_1 + L_2 + 2M$

Fields opposing.

$L_T = L_1 + L_2 - 2M$

M = mutual inductance in henrys.

$M = K\sqrt{L_1 L_2}$

K = coefficient of coupling (expressed as a decimal factor).

(4) Inductors in parallel.

With no flux linkage between coils.

Inductance.

$$L_T = \frac{}{1/L1 + 1/L2 + 1/L3}, \text{ etc.}$$

Reactance.

$$X_{LT} = \frac{1}{1/X_{L1} + 1/X_{L2} + 1/X_{L3}}, \text{ etc.}$$

(5) Impedance of a coil.

$Z = \sqrt{R^2 + X_L^2}$

(6) Q of a coil.

$$Q = \frac{X_L}{R_L}$$

f. Capacitors.

(1) Capacitance.

$$C = \frac{8.84 \times 10^{-8} \times K \times A}{d}$$

C = capacitance in microfarads

K = dielectric constant

A = area of one plate in square centimeters

d = distance between plates in centimeters.

(2) Capacitive reactance.

$$X_C = \frac{1}{2\pi FC} = \frac{.159}{FC}$$

$$C = \frac{1}{2\pi FXC}$$

$$F = \frac{1}{2\pi X_C C}$$

(3) Capacitors in series.

(*a*) Two capacitors.

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

(*b*) Any number of capacitors.

$$C_T = \frac{1}{1/C1 + 1/C2 + 1/C3, \text{ etc.}}$$

(*c*) Reactance.

$$X_{CT} = X_{C1} + X_{C2} + X_{C3}, \text{ etc.}$$

(4) Capacitors in parallel.

(*a*) Any number of capacitors.

$$C_T = C_1 + C_2 + C_3, \text{ etc.}$$

(*b*) Reactance.

$$X_{CT} = 1/X_{C1} + 1/X_{C2} + 1/X_{C3}, \text{ etc.}$$

or

$$\frac{1}{2\pi F C_T}$$

(5) Impedance of a capacitor.

$$Z = \sqrt{R^2 + X_C^2}$$

(6) Q of a capacitor.

$$Q = \frac{X_C}{R_C}$$

g. Resonance.

(1) Frequency of resonance.

$$fr = \frac{1}{2\pi\sqrt{LC}} = \frac{.159}{\sqrt{LC}}$$

fr = resonant frequency in cycles per second.
L = henrys
C = farads

(2) Capacitance required for resonance.

$$C = \frac{1}{4\pi^2 f^2 L}$$

(3) Inductance required for resonance.

$$L = \frac{1}{4\pi^2 f^2 C}$$

(4) Series resonant circuits.

$I = \frac{E}{R}$ at resonance.

$Z = R$ at resonance.

h. Meter Formulas.

(1) Resistance of meter movement.

$$R \ \underline{|\text{meter}|} = \frac{\text{voltage applied}}{\text{full scale } I \text{ of meter}}$$

(2) Sensitivity of meter movement.

$$\text{Ohms/volt} = \frac{1}{\text{full scale } I \text{ of meter}}$$

or

$$I \text{ for full scale deflection} = \frac{E}{R} \frac{\underline{|\text{meter}|}}{\underline{|\text{meter}|}}$$

(3) Ammeters.

$$R \text{ [of shunt]} = \frac{I \text{ [meter]} \quad R \text{ [meter]}}{I \text{ [shunt]}}$$

(4) Voltmeters.

$$R \text{ [multiplier]} = R \text{ [total]} - R \text{ [meter]}$$

$$R \text{ [total]} = \frac{E \text{ to be measured}}{I \text{ for full scale on the meter.}}$$

(5) Series type ohmmeters.

$$R \text{ [limiter]} = R \text{ [total]} - R \text{ [meter]}$$

$$R \text{ [total]} = \frac{E \text{ of battery used}}{I \text{ for full scale on the meter.}}$$

i. Alternating-Current Motors.

(1) $\text{Rpm} = \dfrac{f \times 120}{\text{No. of poles}}$

(2) $\text{No. of poles} = \dfrac{f \times 120}{\text{rpm}}$

(3) $\text{Efficiency (in percent)} = \dfrac{HP \times 746 \times 100}{E \times I}$

(4) $\text{Slip} = \dfrac{(\text{Synchronous speed-rotor speed}) \times 100}{\text{Synchronous speed}}$

(5) $\text{Torque} = \dfrac{HP \times 5250}{\text{rpm}}$

j. Alternating-Current Generators.

(1) $f = \dfrac{\text{Poles} \times \text{rpm}}{120}$

(2) $\text{No. of poles} = \dfrac{\text{f} \times 120}{\text{rpm}}$

(3) $\text{Rpm} = \dfrac{f \times 120}{\text{poles}}$

k. Vacuum Tube Constants.

(1) Amplification factor.

$\text{Mu} = \dfrac{\Delta E_p}{\Delta E_g}$ (with I_p constant).

(2) Dynamic plate resistance in ohms.

$r_p = \dfrac{\Delta E_p}{\Delta I_p}$ (with E_g constant).

(3) Mutual conductance in ohms.

$G_m = \dfrac{\Delta I_p}{\Delta E_g}$ (with E_p constant).

Δ (delta) = change or variation.
E_p = plate voltage.
E_g = grid voltage.
I_p = plate current.

l. Time Constants.

(1) *R-L* circuit.

$$t = \frac{L}{R}.$$

t = seconds.
L = henrys.
R = ohms.

(2) *R-C* circuits.

$t = RC$.
t = seconds.
C = microfarads.
R = megohms.

m. Mathematical Constants.

$\pi = 3.14$
$2\pi = 6.28$
$(2\pi)^2 = 39.5$
$4\pi = 12.6$
$\pi^2 = 9.87$
$\frac{\pi}{2} = 1.57$
$\frac{1}{\pi} = 0.318$
$\frac{1}{2\pi} = 0.159$
$\frac{1}{\pi^2} = 0.101$
$\frac{1}{\sqrt{\pi}} = 0.564$
$\sqrt{\pi} = 1.77$
$\sqrt{\frac{\pi}{2}} = 1.25$
$\sqrt{2} = 1.41$
$\sqrt{3} = 1.73$
$\frac{1}{\sqrt{2}} = 0.707$
$\frac{1}{\sqrt{3}} = 0.577$
$\log \pi = 0.497$
$\log \frac{\pi}{2} = 0.196$
$\log \pi^2 = 0.994$
$\log \sqrt{\pi} = 0.248$

n. Contents of Gas Cylinders.

$$\text{Contents in gallons} = \frac{C}{P1} \times \frac{70}{T} \times P2$$

Where: C = cylinder capacity in gallons.
$P1$ = pressure in psi of full cylinder at 70° F.
T = temperature in degrees Fahrenheit.
$P2$ = pressure in psi of cylinder being checked.

Note. Medical cylinders are filled to 2015 psi at 70° F.

The above formula is for the following *NONLIQUIFIED* gases only! Oxygen, helium, oxygen-helium mixtures, and oxygen-carbon dioxide mixtures.

o. *Miscellaneous Formulas.*

(1) Relative to a circle.

(*a*) To find circumference—multiply the diameter by 3.1416; or, divide diameter by 0.3183.

(*b*) To find diameter—multiply the circumference by 0.3183; or divide circumference by 3.1416.

(*c*) To find radius—multiply the circumference by 0.15915; or, divide circumference by 6.28318; or, divide diameter by 2.

(*d*) To find the side of a square to be inscribed in a circle—multiply diameter by 0.7071; or, multiply the circumference by 0.2251; or, divide the circumference by 4.4428.

(*e*) To find the side of a square to equal the area of a circle—multiply the diameter by 0.8862; or, divide diameter by 1.1284; or, multiply the circumference by 0.2821; or, divide circumference by 3.545.

(*f*) To find the area of a circle—multiply the circumference by one-quarter of the diameter; or, multiply the square of the diameter by 0.7854; or, multiply the square of the circumference by 0.7958; or, multiply the square of one-half the diameter by 3.1416.

(*g*) Doubling the diameter of a circle increases the area 4 times.

(2) Relative to a square.

(*a*) A side multiplied by 1.412 equals the diameter of a circle which will circumscribe the given square.

(*b*) A side multiplied by 4.443 equals the circumference of its circumscribing circle.

(*c*) A side multiplied by 1.1284 equals the diameter of a circle equal in area to that given square.

(*d*) A side multiplied by 3.545 equals circumference of an equal circle.

(*e*) To find the aera of an ellipse—multiply the product of its axes by .7854; or, multiply the product of its semi-axes by 3.14159.

(3) Relative to other geometrical forms.

(*a*) Contents of a cylinder = area of base X length.

(*b*) Surface of a cylinder = altitude X circumference of base plus area of both ends.

(*c*) Surface of a sphere = diameter squared X 3.1416; or, diameter X circumference.

(*d*) Contents of a sphere = diameter cubed X 0.5236

(*e*) Contents of a pyramid or cone, right or oblique, regular or irregular = area of base X one-third of the altitude.

(*f*) Area of a triangle = base X one-half the altitude.

(*g*) Area of a parallelogram = base X altitude.

(*h*) Area of a trapezoid = altitude X one-half the sum of parallel sides.

(4) To find the capacity of a tank in gallons.

(*a*) All measurements must be reduced to inches.

1. For rectangular tanks, multiply the length by the width by the depth.

2. For cylindrical tanks, multiply the length by the square of the diameter by .7854.

3. For elliptical section tanks, multiply the length by the short diameter by the long diameter by .0339.

(*b*) Divide the result of any of the above calculations by 231, which is the number of cubic inches in a gallon; the result is the capacity of the tank in gallons.

7. Conversion Factors and Tables

a. Common Factors.

To convert—	Into—	Multiply by—
Ampere-hours	Coulombs	3,600
Amperes per sq. cm	Amperes per sq. inch	6.452
Ampere turns	Gilberts	1.257
Ampere turns per cm	Ampere turns per inch	2.54
Btu	Foot-pounds	778.3
Btu	Joules	1,054.8
Btu	Kilogram-calories	.252
Btu	Horsepower-hours	3.929×10^{-4}
Centigrade	Fahrenheit	(C° x 9/5) + 32
Circular mils	Square centimeters	5.067×10^{-6}
Circular mils	Square mils	.7854
Cubic inches	Cubic centimeters	16.39
Cubic inches	Cubic feet	5.787×10^{-4}
Cubic inches	Cubic meters	1.639×10^{-5}
Cubic meters	Cubic feet	35.31
Cubic meters	Cubic yards	1.308
Degrees (angle)	Radians	1.745×10^{-2}
Dynes	Pounds	2.248×10^{-6}
Ergs	Foot-pounds	7.367×10^{-8}
Feet	Centimeters	30.48
Foot-pounds	Horsepower-hours	5.05×10^{-7}
Foot-pounds	Kilogram-meters	.1383
Foot-pounds	Kilowatt-hours	3.766×10^{-7}
Gauss	Lines per sq. inch	6.452
Grams	Dynes	980.7
Grams	Ounces (avoir)	3.527×10^{-2}
Grams per cm	Pounds per inch	5.6×10^{-3}
Grams per cubic cm	Pounds per cu. inch	3.613×10^{-2}
Grams per sq. cm	Pounds per sq. foot	2.0481
Horsepower	Foot-lb. per minute	3.3×10^{4}

To convert—	Into—	Multiply by—
Horsepower	Btu per minute	42.41
Horsepower	Kg-calories per min.	10.69
Inches	Centimeters	2.54
Inches	Mils	1,000
Joules	Foot-pounds	.7376
Joules	Ergs	10^7
Kilogram-calories	Kilojoules	4.186
Kilograms	Pounds (avoir)	2.205
Kg per sq. meter	Pounds per sq. foot	.2048
Kilometers	Feet	3,281
Kilowatt-hours	Btu	3,413
Kilowatt-hours	Foot-pounds	2.655×10^6
Kilowatt-hours	Joules	3.6×10^6
Kilowatt-hours	Kilogram-calories	860
Kilowatt-hours	Kilogram-meters	3.671×10^5
Liters	Cubic meters	.001
Liters	Cubic inches	61.02
Liters	Gallons (liq. US)	.2642
Liters	Pints (liq. US)	2.113
Meters	Yards	1.094
Meters per min	Feet per min	3.281
Meters per min	Kilometers per hr	.06
Miles (nautical)	Kilometers	1.853
Miles (statute)	Kilometers	1.609
Miles per hr	Kilometers per min.	2.682×10^{-2}
Miles per hr	Feet per minute	88
Miles per hr	Kilometers per hr	1.609
Poundals	Dynes	1.383×10^4
Poundals	Pounds (avoir)	3.108×10^{-2}
Sq inches	Circular mils	1.273×10^6
Sq inches	Sq centimeters	6.452
Sq feet	Sq meters	9.29×10^{-2}
Sq miles	Sq yards	3.098×10^6
Sq miles	Sq kilometers	2.59
Sq millimeters	Circular mils	1,973
Tons, short	Tonnes (1,000 Kg.)	.9072
Tons, long	Tonnes (1,000 Kg.)	1.016
Tons, long	Tons, short	1.120
Watts	Btu per min.	5.689×10^{-2}
Watts	Ergs per sec.	10^7
Watts	Ft.-lb. per min.	44.26
Watts	Horsepower	1.341×10^{-3}
Watts	Kg-calories per min.	1.433×10^{-3}

b. Metric Conversion Table.

Original value	Desired value						
	Mega	Kilo	Units	Deci	Centi	Milli	Micro
Mega		3→	6→	7→	8→	9→	12→
Kilo	←3		3→	4→	5→	6→	9→
Units	←6	←3		1→	2→	3→	6→
Deci	←7	←4	←1		1→	2→	5→
Centi	←8	←5	←2	←1		1→	4→
Milli	←9	←6	←3	←2	←1		3→
Micro	←12	←9	←6	←5	←4	←3	

The above metric conversion table provides a fast and automatic means of conversion from one metric notation to another. The notation "unit" represents the basic units of measurement, such as amperes, volts, ohms, watts, cycles, meters, grams, etc. To use the table, first locate the original or given value in the left-hand column. Now follow this line horizontally to the vertical column headed by the prefix of the desired value. The figure and arrow at this point indicates number of places and direction decimal point is to be moved.

Example: Convert 0.15 ampere to milliamperes. Starting at the "units" box in the left-hand column (since ampere is a basic unit of measure), move horizontally to the column headed by the prefix "milli", and read 3→. Thus 0.15 ampere is the equivalent of 150 milliamperes.

Example: Convert 50,000 kilocycles to megacycles. Read in the box horizontal to "kilo" and under "mega", the notation ←3, which means a shift of the decimal three places to the left. Thus 50,000 kilocycles is the equivalent of 50 megacycles.

c. Weights and Measures—Metric and English.

(1) Length.

1 Mil	=	.001	Inch
	=	.025400	Millimeter
	=	.0025400	Centimeter
1 Inch	=	1000	Mils
	=	25.400	Millimeters
	=	2.5400	Centimeters
1 Foot	=	30.480	Centimeters
	=	.30480	Meter
1 Yard	=	91.440	Centimeters
	=	.9144	Meter

1 Mile	=	1609.4	Meters
	=	1.6094	Kilometers
1 Millimeter	=	39.370	Mils
	=	.039370	Inch
1 Centimeter	=	.39370	Inch
	=	.032808	Foot
1 Meter	=	39.370	Inches
	=	3.2808	Feet
1 Kilometer	=	3280.8	Feet
	=	.62137	Mile

(2) Surface.

1 Circ. Mil	=	.78540	Sq. Mil
	=	.000001	Circ. Inch
	=	.00064516	Circ. Millimeter
1 Sq. Mil	=	1.2732	Circ. Mils
	=	.000001	Sq. Inch
	=	.00064516	Sq. Millimeter
1 Circ. Inch	=	1000000	Circ. Mils
	=	645.16	Circ. Millimeters
	=	6.4516	Circ. Centimeters
1 Square Inch	=	1000000	Sq. Mils
	=	1273240	Circ. Mils
	=	645.16	Sq. Millimeters
	=	6.4516	Sq. Centimeters
1 Square Foot	=	929.03	Sq. Centimeters
1 Circ. Millimeter	=	1550.0	Circ. Mils

(3) Volume.

1 Cubic Inch	=	16.387	Cubic Centimeters
1 Cubic Foot	=	28317	Cubic Centimeters
1 Cubic Centimeter	=	.061023	Cubic Inch
1 Cubic Inch of Water	=	.0361	Pound
1 Cubic Foot of Water	=	62.5	Pounds

(4) Weight.

1 Pound (Avoir)	=	453.59	Grams
1 Gram	=	.0022046	Pound (Avoir.)
1 Kilogram	=	2.2046	Pounds (Avoir.)

8. Specifications for Gas Cylinders Used in Army Medical Service

Gas	Type of cylinder	Capacity		Empty weight	PSI at 70° F.
		Gal.	lb-oz		
Nitrous oxide	D	250	4–0	14	900
	M	2000	31–4	75	900
Helium-oxygen	H	1240	0–3	110	1900
Oxygen	D	95	1–1	14	1900
	H	1650	20–0	110	1900
	M	750	8–8	75	1900

9. Temperature Comparison Chart

Centigrade—Fahrenheit

Water boils at..... 100 degrees Centigrade (C. or Cent.)
212 degrees Fahrenheit (F. or Fahr.)

Water freezes at..... 0 degrees Centigrade (C. or Cent.)
32 degrees Fahrenheit (F. or Fahr.)

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
0	32.0	24	75.2	48	118.4
1	33.8	25	77.0	49	120.2
2	35.6	26	78.8	50	122.0
3	37.4	27	80.6	51	123.8
4	39.2	28	82.4	52	125.6
5	41.0	29	84.2	53	127.4
6	42.8	30	86.0	54	129.2
7	44.6	31	87.8	55	131.0
8	46.4	32	89.6	56	132.8
9	48.2	33	91.4	57	134.6
10	50.0	34	93.2	58	136.4
11	51.8	35	95.0	59	138.2
12	53.6	36	96.8	60	140.0
13	55.4	37	98.6	61	141.8
14	57.2	38	100.4	62	143.6
15	59.0	39	102.2	63	145.4
16	60.8	40	104.0	64	147.2
17	62.6	41	105.8	65	149.0
18	64.4	42	107.6	66	150.8
19	66.2	43	109.4	67	152.6
20	68.0	44	111.2	68	154.4
21	69.8	45	113.0	69	156.2
22	71.6	46	114.8	70	158.0
23	63.4	47	116.6	71	159.8

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
72	161.6	82	179.6	92	197.6
73	163.4	83	181.4	93	199.4
74	165.2	84	183.2	94	201.2
75	167.0	85	185.0	95	203.0
76	168.8	86	186.8	96	204.8
77	170.6	87	188.6	97	206.6
78	172.4	88	190.4	98	208.4
79	174.2	89	192.2	99	210.2
80	176.0	90	194.0	100	212.0
81	177.8	91	195.8		

10. Steam Pressure and Temperature Chart

Steam pressure in pounds per sq. in.	Temperature in degrees fahrenheit
5	227.1
10	239.4
15	249.8
20	258.8
25	266.7
30	274.1
35	280.6
40	286.7
45	292.3
50	297.7
55	302.5
60	307.4
65	311.7
70	316.
75	320.
80	323.8
85	327.6
90	331.2
95	334.6
100	337.8

APPENDIX IV

CARE AND PRESERVATION, SPECIFIC MATERIAL

1. Batteries

a. Removal and Prevention of Corrosion. Batteries must be kept clean and dry to prevent slow discharging through dirt and moisture that may accumulate between the terminals. All terminals must be kept clean and free of corrosion. Corrosion on the terminals and brackets can be removed by scraping or by brushing with a stiff bristle brush. After removing corrosion, wash the parts with a solution of ammonia and water or bicarbonate of soda and water (one pound of soda to one gallon of water), rinse with clear water, dry, and apply a light coat of grease or vaseline to prevent further corrosion.

b. Specific Gravity. Wet cells should be operated at or near full charge. Recharge regularly and at a slow charging rate. (High charging rates will overheat the cells and may cause buckling of the plates.) The following specific gravity readings indicate the different charge values at 70° F.

1.280—full charge
1.225—half charge
1.150—discharged

Do not allow the specific gravity to drop below 1.225 or allow the battery to remain partially discharged for more than a few days.

c. Electrolyte Level. Electrolyte must be kept above the plates to prevent damage by overheating and to utilize the entire plate area.

d. Fire and Explosion Hazards. In use, and during charging, the battery gives off hydrogen and oxygen which, when combined, form an explosive mixture. Due to this, batteries should be kept away from open flames and sparks and charged in a well ventilated area.

e. Storage. All batteries should be stored in a cool, dry, well ventilated place. Wet cells should be kept fully charged and dry cells that have been in stock the longest should be used first as replacements.

f. Removal of Dry Cells When Discharged. When dry cells become discharged, they should be removed immediately. If left in the equipment, the cell case will swell and rupture. The swelling of the cell may make it impossible to remove the battery without damage to the equipment. The leaking electrolyte will cause extensive corrosion damage to the equipment in a short period of

time. Both dry and wet cells should be removed from equipment that is to be stored or remain out of service for an appreciable length of time.

2. Cables and Chains

a. Inspection. Cables and chains used in connection with counterweights and raising mechanisms must be inspected frequently. If one of these chains or cables breaks while in use, it is likely that the patient or operator will be injured and the equipment will be damaged. Inspection of cables may be facilitated by wearing cotton gloves and rubbing your fingers lightly along the cable. Any broken strands will snag the gloves. When broken strands are found, the cable should be replaced. Visual inspection for wear is the only practical method of inspection of chains. Pivot pins in that portion of the chain subjected to the greatest wear should receive special attention and, if necessary, replaced.

b. Lubrication. Cables and chains may be cleaned with kerosene or other solvents with a similar order of toxicity. If flammable solvents are used, percautions should be taken to eliminate the possibility of fire. After cleaning, cables and chains should be lubricated with a light oil. The oil should penetrate to the inner strands of cables since a rubbing action is imparted to the strands when the cable is flexed.

3. Stainless Steel and Chrome-Plated Surfaces

The following instructions indicate several methods of cleaning and maintaining stainless steel surfaces in serviceable and presentable conditions and should be used as applicable to local conditions. Chrome-plated surfaces can be handled by some of the methods as outlined for stainless steel but it must be remembered that the base metal may react with the cleaning agents and extreme care must be observed. These pitfalls are pointed out at the end of each method of cleaning.

a. In the vast majority of instances, the cleaning of stainless steel involves the removal of water marks left on the surface when water evaporates during the drying process. To remove these marks, use soap (with or without a detergent) and water applied with a soft cloth, fiber brush, or sponge. The cleaning action can be hastened by adding to the water either soda ash, borax, sodium perborate, or any of several nonabrasive commercial cleansers. After cleaning, the surface should be thoroughly flushed or washed with clear water and then dried. If the surface is not thoroughly cleaned by this method, one of the following should be employed, selecting the methods which are indicated by prevailing conditions.

This method of cleaning stainless steel with soap and water may also be used on chrome-finished surfaces.

b. Grease, oil, soot, fatty acids, and similar deposits which resist soapy water and ordinary dirt or product residue located in places which cannot readily be swabbed, may be removed with organic solvents. Due to the relatively high order of toxicity of carbon tetrachloride and benzene, these organic solvents should not be used for this purpose. The fire and explosion hazards associated with the use of gasoline, ether, and benzene are of such a degree that their use for the above purposes should be avoided. It it suggested that the solvents be limited to Stoddard solvent, kerosene, trichlorethylene, ethyl alcohol, acetone, or others of a similar order of toxicity. Even these solvents are sufficiently hazardous to necessitate adequate ventilation. In addition, good hygiene should be practiced along with appropriate personal protective measures to prevent skin contact. The items cleaned with these solvents should be thoroughly washed with hot soapy water followed by rinsing with clear water and drying before reuse. In cases where large numbers of pieces of equipment are cleaned with these solvents at one time, it may be necessary to provide mechanical ventilation to assure safe conditions instead of relying on natural ventilation. This method may also be used on chrome-finished surfaces.

c. By regular use of the procedures contained in *a* and *b* above, vats, drains, piping, filters, seals, and other restricted areas will be kept fairly clean; however, stronger measures may be required periodically. Good results have been obtained by using a five to fifteen percent caustic soda solution, either hot or cold, or by using a four to six percent solution of sodium pyrophosphate. If practicable, remove the part, clean separately and reassemble after completely drenching away the cleansing agent with clear water. These solutions are also effective removers of milkstone. This method may also be used on chrome-finished surfaces.

d. Difficult-to-remove deposits of organic or carbonaceous material, and rust picked up from associated carbon steel equipment or tools will yield to a ten or twenty percent nitric acid solution. This treatment will not harm stainless metal but will severely affect fittings or other equipment made of common steel, brass, bronze, copper, nickel, or other materials which dissolve in nitric acid. Always flush away all traces of nitric acid. If the part to be cleaned cannot be removed for separate treatment or isolated by plugs or dams, it is best to use a mechanical means of cleaning.

e. The above process (*d* above) is also useable on chrome providing the chrome finish is not marred or scratched. If the surface is marred or scratched, proper precautions must be taken. Immediately after application, marred or scratched area must be neutralized by rinsing in a water and baking soda solution.

f. In removing baked-on deposits, use the simplest method possible and the one which will have the least effect on the surface finish. The most common form of deposit calling for mechanical cleaning is "baked-on" splatter, spillover or condensation which fails to yield to chemical treatment or which is located in areas where strong solutions may not be used safely. In such cases, a gentle to vigorous polishing action will be required. A paste made with water and ammonia as the liquid base and magnesium oxide, grade FFF italian pumice, or french chalk as the gently abrasive solid may be tried first. Rub lightly with a soft damp cloth in the direction of the polishing marks on the steel. For extremely resistant deposits, stainless steel wool or stainless steel scouring pads may be needed. They may be used alone or in combination with one of the cleaners previously mentioned. This method may also be used with chrome-plated surfaces.

g. Scrapers, wire brushes, files, or other common steel or nonferrous tools may mar or imbed particles in the surfaces which may rust or open the way to corrosive electrolytic attack. Marred or pitted surfaces collect dirt rapidly, foster localized corrosion, become progressively more difficult to keep clean. Eventually, refinishing may be required.

h. When using tools to remove extremely stubborn scale, special care must be exercised to prevent deep scratches or gouges. Mechanical devices used by competent operators, or small stainless steel hand tools give the best results. Should marring occur, the stainless surface should be refinished before restoring the equipment to service.

i. The following commercial cleaners will not adversely affect stainless steel or chrome if used according to directions:

General Manual Kleanser
MC–3
No. 7 All Purpose Cleaner
G.L.X.
Kelvar
Dunmore
Solvay Farmdairy Cleaner
Oaklite General Cleaner
Peptex
Divo
Bryko
Solvay Cleaner 600
Kleer
HC6 Cleaner
All Purpose W Cleaner
Clipper Cleaner
Neutral W.

4. Painted or Lacquered Finishes

a. Smooth Finishes. Smooth finish paint or lacquer surfaces should be cleaned with a mild soap or detergent. Combination cleaner-polishes, such as used on automobile finishes, may be used to clean and restore original luster. Scouring powders or other types of abrasive cleaners should not be used.

b. Crinkle Finishes. Crinkle finishes may be washed with a mild soap or detergent. Abrasive type cleaners or cleaner-polishes

should not be used. Either of these will tend to smooth the surface resulting in a less attractive finish. Cleaners which dry to a white powder are almost impossible to remove completely. Light oil, such as mineral oil, applied sparingly with a cloth, will enhance the appearance of these finishes. Detergent type oil should not be used for this purpose.

5. Leather Goods

Unpolished leather goods, such as the diaphragm on some respirators should be treated once a year with neatsfoot oil. This will prevent the leather from drying and stiffening. Leather goods should be stored in a cool dry place.

6. Rubber Goods

a. Many items of medical equipment have components made of rubber, with which the maintenance technician must be concerned. Some examples are: insulation on low and high voltage electrical cables, door and port gaskets, bellows, face masks, breathing tubes, and rebreather bags.

b. Oxidation, oils, damage, and wear are factors in the deterioration of rubber. Excessive heat, light, and certain chemicals are the most common causes of oxidation, which is evidenced by hardening and cracking of the rubber. Oil, grease, and fats, both vegetable and mineral, with the exception of castor oils, cause rubber to swell and become tacky. Damage, generally a result of misuse, requires premature replacement of the rubber part. Some examples of misuse are sharp bending of tubing, creasing of flat rubber products, twisting of rubber insulated electrical cords, and contact with sharp edges or points. Wear probably accounts for less deterioration of rubber parts than any of the other factors above.

c. Conductive rubber, used on certain surgical items promotes safety by minimizing the build-up of static electrical charges. The conductivity of the rubber is due to the composition of the rubber. If foreign matter, such as wax, is allowed to accumulate on conductive rubber, it will act as an insulator and defeat the purpose of conductive rubber.

d. Rubber items should be thoroughly cleaned with mild soap and lukewarm water and air dried after each use. Rubber items should be stored in a cool dry place preferably in their original containers.

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By Order of *Wilber M. Brucker*, Secretary of the Army:

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For explanation of abbreviations used, see AR 320-50.

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