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NAVSHIPS 0967-000-0160

NON-REGISTERED

ELECTRONICS INSTALLATION AND MAINTENANCE BOOK

GENERAL MAINTENANCE

DEPARTMENT OF THE NAVY
NAVAL SHIP ENGINEERING CENTER

PUBLISHED: JUNE 1971

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BOX SCORE
GENERAL MAINTENANCE HANDBOOK
NAVSHIPS 0967-000-0160

EDITION	PUBLICATION DATE	STOCK NUMBER	LATEST EIB COVERED(1)
Basic	June 1971	0967-000-0160	798

NOTES

(1) The number listed in this column indicates that this handbook issue incorporates information from EIB issues up to and including the one shown. In addition to this column entry, effective with this change and in all succeeding changes, a source reference code will be inserted immediately following the last line of copy of pertinent articles picked up in EIMB handbooks. The following examples show the coding method used to identify origin of material used:

ORIGIN	CODE
EIB 674	(674)
EIB 13S (Shore Quarterly Supplement)	(13S)
Naval Ship Systems Command Technical News Vol 14, No. 6	(TN14-6)
CEIB 7 (Classified EIB)*	(C7)

*Only articles which have been revised to omit classified data but retain information of value and lasting interest.

This publication, dated June 1971, supersedes the Basic General Maintenance Handbook, dated August 1965; Change 1, dated February 1967; and Change 2, dated May 1967.

LIST OF EFFECTIVE PAGES

PAGE NUMBER	CHANGE IN EFFECT
Front Matter	
Title Page	Original
ii, Box Score	Original
iii, Effective Pages	Original
iv thru x, Table of Contents	Original
xi and xii, Preface	Original
A, Correction Page	Original
B, Notes Page	Original
Section 1 - Introduction	
1-1 and 1-2	Original
Section 2 - Maintenance Procedures	
2-1 thru 2-23	Original
Section 3 - Maintenance Concepts	
3-1 thru 3-29	Original
Section 4 - System Maintenance	
4-1	Original
Section 5 - Equipment Level Maintenance	
5-1 thru 5-43	Original
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6-1 thru 6-5	Original

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PREFACE

POLICY AND PURPOSE

The Electronics Installation and Maintenance Book (EIMB) has been established as the medium for collecting, publishing, and distributing, in one convenient documentation source, those subordinate maintenance and repair policies, installation practices, and overall electronics equipment and material-handling procedures required to implement the major policies set forth in Chapter 9670 of the Bureau of Ships Technical Manual. All data contained within the EIMB are authoritative, and derive their authority from Chapter 9670 of the Bureau of Ships Technical Manual, as established in accordance with Article 1201, U. S. Navy Regulations.

Since its inception, however, the EIMB has been expanded to include selected information of general interest to electronic installation and maintenance personnel. These items are such as would generally be contained in textbooks, periodicals, or technical papers, and form (along with the information cited above) a comprehensive, single-source reference document. In application, the EIMB is to be used for information and guidance by all military and civilian personnel involved in the installation, maintenance, and repair of electronic equipment under cognizance, or technical control, of the Naval Ship Systems Command (NAVSHIPS). All information, instructions, and procedures in the EIMB supplement such instructions and data supplied in equipment technical manuals and other approved maintenance publications.

ORGANIZATION

The EIMB is organized into a series of handbooks to afford maximum flexibility and ease in handling. The handbooks are stocked and issued as separate items so that activities requiring extra copies of any handbook may obtain them with relative ease.

The handbooks fall within two categories general information handbooks and equipment-oriented handbooks. The general information handbooks contain data which are of interest to all personnel involved in installation and maintenance, regardless of their equipment specialty. The titles of the various general information handbooks give only an overall idea of their data content; a more complete description of each handbook is provided in the General Handbook.

The equipment handbooks are devoted to information on a particular equipment class; they provide general test procedures, adjustments, general servicing information, and field change identification data.

The following table lists all handbooks of the series, together with their old and new NAVSHIPS numbers. (The old NAVSHIPS numbers are shown in parentheses.) The new NAVSHIPS numbers, although not presently imprinted on all handbooks of the EIMB series, serve also as the stock numbers which are to be used on any requisitions submitted.

HANDBOOK TITLE	NAVSHIPS NUMBER
(General Information Handbooks)	
General	0967-000-0100 (900,000.100)
Installation Standards	0967-000-0010 (900,000.101)
Electronic Circuits	0967-000-0120 (900,000.102)
Test Methods and Practices	0967-000-0130 (900,000.103)
Reference Data	0967-000-0140 (900,000.104)
EMI Reduction	0967-000-0150 (900,000.105)
General Maintenance	0967-000-0160
(Equipment-Oriented Handbooks)	
Communications	0967-000-0010 (900,000.1)
Radar	0967-000-0020 (900,000.2)
Sonar	0967-000-0030 (900,000.3)
Test Equipment	0967-000-0040 (900,000.4)
Radiac	0967-000-0050 (900,000.5)
Countermeasures	0967-000-0070 (900,000.7)

PREFACE

INFORMATION SOURCES

Periodic revision's are made to provide the best current data in the EIMB and keep abreast of new developments. In doing this, many source documents are researched to obtain pertinent information. Some of these sources include the Electronics Information Bulletin (EIB), the Naval Ship Systems Command Technical News, electronics and other textbooks, industry magazines and periodicals, and various military installation and maintenance-related publications. In certain cases, NAVSHIPS publications have been incorporated into the EIMB in their entirety and, as a result, have been cancelled. A list of the documents which have been superseded by the EIMB and are no longer available is given in Section 1 of the General Handbook.

SUGGESTIONS

NAVSHIPS recognizes that users of the EIMB will have occasion to offer comments or suggestions. To encourage more active participation, a self-addressed comment sheet is frequently provided in the back of each handbook change. Complete information should be given when preparing suggestions. It is most desirable that the suggestor include his name and mailing address on the form to facilitate direct correspondence in the event clarification is required and an immediate reply can be supplied regarding the suggestion. Any communication will be made through a personal letter to the individual concerned.

If a comment sheet is not available or correspondence is lengthy, suggestions should be directed to the following:

Commander, Naval Ship Engineering Center
Department of the Navy
Hyattsville, Maryland 20782
Attn: Technical Data and Publications Section
(SEC 6181C)

CORRECTIONS

Report all inaccuracies and deficiencies noted in all NAVSHIPS technical publications (including this manual, ship information books, equipment manuals, drawings, and such) by a "Planned Maintenance System (PMS) Feedback Report, OPNAV 4700.7 (REV. 5-65)" or superseding form. If PMS is not yet installed in this ship, report technical publication deficiencies by any convenient means.

DISTRIBUTION

The Electronics Installation and Maintenance Book is transmitted to using activities through automatic distribution procedures. activities not already on the EIMB distribution list and those requiring changes to the list should submit correspondence to the following:

Commander, Naval Ship Engineering Center
Department of the Navy
Hyattsville, Maryland 20782
Attn: Technical Data and Publications Section
(SEC 6181C)

Activities desiring extra copies of EIMB handbooks or binders should submit requisitions directly to Naval Supply Depot, Philadelphia, Pennsylvania. Complete instructions for ordering publications are given in the Navy Stock List of Forms and Publications, NAVSANDA Publication 2002.

RECORD OF CORRECTIONS MADE

CHANGE NO	DATE	CHANGES MADE	SIGNATURE

NOTES

SECTION 1

INTRODUCTION

1-1 PURPOSE

The purpose of the General Maintenance Handbook, NAVSHIPS 0967-000-0160, is to provide Naval personnel with an informative and comprehensive maintenance reference. This handbook contains general maintenance data that pertains to all electronic equipments and it can be used to supplement information contained in equipment technical manuals.

The satisfactory performance of modern electronic equipment depends to a great extent upon the maintenance procedures employed by the electronics technician. It further depends upon the skillful application of these procedures by the technician. Continued satisfactory performance is dependent upon the work done by the men who inspect, repair, and maintain electronic equipment.

The objectives of the General Maintenance Handbook are to aid in the maintenance effort by:

1. Preparing and assembling, in one handbook, the approved procedures and concepts to be employed in the maintenance of all electronic equipment.
2. Standardizing these procedures and concepts which, when used, will provide uniform and satisfactory electronic maintenance.
3. Indoctrinating all personnel engaged in maintenance with the importance of good workmanship.
4. Making all personnel involved in electronic maintenance aware of the importance of good maintenance techniques.
5. Preventing personnel injury and equipment damage by emphasizing safety precautions and by prohibiting unsafe maintenance practices.

1-2 SCOPE

Information for the General Maintenance Handbook has been collected from other EIMB handbooks, the EIB, the NAVSHIPS Technical News, and many other pertinent sources, both military and commercial.

The General Maintenance Handbook will be useful as a convenient reference book for three general categories of maintenance personnel:

1. Experienced Technician. The experienced technician has no great difficulty in coping with maintenance problems because of previous experience and well developed maintenance skills. This person will use the handbook as reference or review material. He will increase his knowledge of electronics maintenance as new concepts and procedures are added to this text.
2. Technician Out-of-School. This category of technician is representative of the individual who has completed Navy training courses, but has limited experience with the fleet. His experience will probably be limited to equipments covered in training courses and to equipments he has encountered in his brief tour of duty with the fleet. Consequently, this handbook will prove extremely valuable to him, especially as new equipments are confronted. The maintenance concepts in this handbook will help familiarize him with the new techniques involved in maintaining modern equipments.
3. Trainee. The trainee will find the information contained in the handbook to be useful as a reference while in training. Later, he will find that it serves as a source of review as well as reference. As a training aid, the individual sections might be recommended for suggested reading.

Information contained in this handbook is of lasting interest to all Naval personnel engaged in the maintenance of electronic equipment.

1-3 ORGANIZATION

Information in the General Maintenance Handbook, NAVSHIPS 0967-000-0160, is presented in six sections:

Section 1 - INTRODUCTION

This section explains the purpose, scope, and organization of the General Maintenance Handbook. It also describes the relationship of this handbook to other handbooks of the EIMB series.

Section 2 - MAINTENANCE CONCEPTS

This section presents the basic concepts to the technician. These concepts are the foundation of good electronic maintenance. Preventive maintenance programs (POMSEE and PMS) are explained and the procedures required for carrying out these programs are covered. Responsibilities of the operator and technician in carrying out the preventive maintenance program are defined. Troubleshooting and failure analysis are discussed. Types and classes of alterations, field changes, and the procedures to follow after accomplishment of each are also covered in detail in this section.

Section 3 - ROUTINE MAINTENANCE AND MAINTENANCE AIDS

This section reviews routine maintenance procedures such as cleaning; inspection; lubrication; use of maintenance aids, such as soldering tools and special hand tools; and soldering and splicing techniques. Emphasis is placed on the importance of these procedures in hopes of making the technician more aware of their value.

The importance of safety, not only to prevent injury to the technician, but to prolong the life of electronic equipment as well also are required. References are made to publications that cover personnel safety and equipment operation and maintenance safety procedures.

Section 4 - SYSTEM MAINTENANCE

Because of the complexity of today's modern electronic systems and the lack of documentation on the subject, an attempt has been made to acquaint the technician with some of the system test equipment that has been, and is being, designed to test these modern systems. When these new means of testing are not available, the technician is told how to use the resources at his disposal to cope with system maintenance problems.

Section 5 - EQUIPMENT MAINTENANCE

This section gives a practical approach to the problem of maintaining equipments. Maintenance information such as testing, troubleshooting, repair of subassemblies, modular components, and printed circuit boards is included in this section.

Section 6 - PARTS MAINTENANCE

This section is broken into a number of subsections, each of which deals with one type of component and its associated maintenance peculiarities. Information such as special tests, removal and replacement, and inspection are presented in detail for each of the major components discussed in this section.

1-4 CHANGES

Changes and revisions of the General Maintenance (and other EIMB publications) are announced and listed periodically in the EIB. Tabular lists in the EIB and Box Scores in the preface of the volumes themselves list the change numbers applicable, together with the effective date and NAVSHIPS number for ordering so that the technician may determine the status of his copy and keep the issues up to date.

1-5 ADDRESS FOR CORRESPONDENCE

Comments concerning corrections, additions, or changes should be addressed to:

Commander Naval Ship Engineering Center
Technical Support Branch
Technical Data and Publications Section
Department of the Navy
Prince George's Center
Hyattsville, Maryland 20782
Attention: SEC 6181C

SECTION 2

MAINTENANCE CONCEPTS

2-1 INTRODUCTION

In general, the concept of maintenance is that of work done to correct, prevent, or reduce failure and damage to equipment.

Maintenance of Navy electronic equipment is divided into two main categories, preventive maintenance and corrective maintenance. Preventive (routine) maintenance consists of checks to determine if equipment is functioning properly, visual inspections for damage, and lubrication. Corrective maintenance is the isolation of trouble, the replacement of defective components, and the realignment and readjustment of equipment to restore it to a satisfactory operating level. See figure 2-1.

2-2 PREVENTIVE MAINTENANCE PROGRAMS

An electronics preventive maintenance program consists of a schecule of inspections, tests, and routine maintenance procedures and a system of check-off lists to ensure that the schedule is carried out. The administration of such a program aboard ship requires that the preventive maintenance needs of every equipment be recognized, planned for, accomplished, and recorded. Two significant preventive

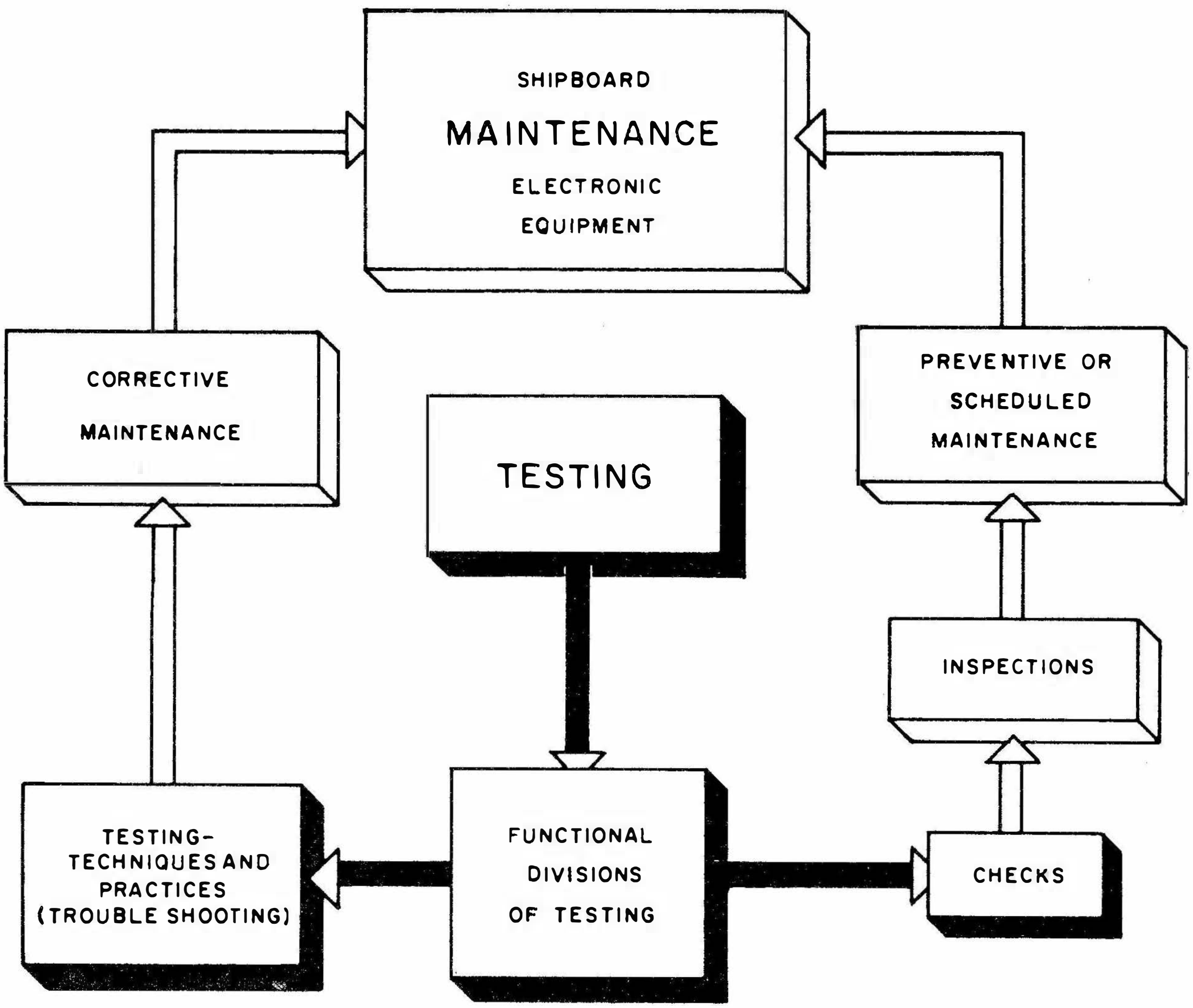

Figure 2-1. Electronic Maintenance, Functional Diagram

maintenance programs have been developed to accomplish these tasks: the Performance Operation and Maintenance System for Electronics Equipment (POMSEE) and the Planned Maintenance System (PMS). These programs, however, do not provide an efficient means for technicians to report certain maintenance problems. Such a system employing automatic data processing was then developed. This system, the Maintenance Data Collection System (MDCS), complements the PMS to form the basic Maintenance and Material Management (3-M) System. Each of these current maintenance programs (POMSEE, PMS, and 3-M System) are discussed subsequently.

a. POMSEE PROGRAM

The POMSEE program is designed to help operational and maintenance personnel determine and maintain proper performance of electronic equipment. The fundamental elements of POMSEE are the Reference Standards Tests, Reference Standards Summary Sheets, and Performance Standards Sheets. The Reference Standards Tests and Reference Standards Summary Sheets comprise Parts I and II, respectively, of the Reference Standards Book. The Reference Standard Summary Sheets, however, will be superseded when the PMS is implemented, either as a separate maintenance system or as a subsystem of the 3-M System. The requirements for establishing the Reference Standard Tests (Part I of the Reference Standards Book) for electronic equipment after installation, and for using these test procedures as a basis for equipment check-out after overhaul or restoration, remains in effect. A preliminary copy of the Reference Standards Book (Parts I and II) has been packed with each new electronic equipment. Upon its receipt, maintenance personnel should immediately perform the tests listed in the Reference Standards Tests (Part I) and forward the results recorded on the Reference Standard Summary Sheets (Part II) to NAVSHIPS for review. Final copies or changes are then published after NAVSHIPS evaluates the Reference Standards Summary Sheets.

POMSEE is a valid test document for equipment check-out after its installation or re-installation aboard ship, and after steps have been taken to ensure that the equipment is properly installed and operating satisfactory. It does not eliminate the necessity for making adjustments, alignments, checks, or other installation procedures described in the technical manual which are necessary to obtain satisfactory operation.

Before establishing the reference standards, the equipment must be completely checked out by qualified technical personnel to ensure optimum equipment operation. The qualified technical personnel should have received training in operation and maintenance of the equipment and have sufficient skill to tune, align, and peak the equipment until it is performing as near design characteristics as possible.

While there is no objection in having the installing activity perform operational tests in the shop prior to installation, NAVSHIPS requires that the POMSEE measurements be conducted on-board ship, and operating off Ship's power. Shop tests will not disclose the effect of poor installation, wiring errors, noise pickup, instability in ships power generating source, self generated and receiving interference, or the rough handling effects in transportation from shop to ship.

(1) Reference Standards Tests

The Reference Standards Tests, Part I of the Reference Standard Book, consist of a series of measurements made initially when the equipment is operating at peak performance. These measurements, containing upper and lower limits, provide maintenance personnel with standards against which subsequent measurements may be compared. The Reference Standards Tests are accompanied by blank spaces which are used by maintenance personnel to record the results of subsequent measurements. This allows maintenance personnel to develop a performance history of an equipment. The tests are scheduled on a routine basis such as daily, weekly, and monthly.

Daily tests are designed so that they can be performed in less than 10 minutes on a single-unit set. These tests are usually performed by the operator on watch and they consist mainly of a performance check using the equipment modes and features, and built-in test equipment.

Weekly tests are designed to monitor an equipment function where there is a definite likelihood that the interpretation of test results will reveal potential trouble. Examples typical of this type of test are: tests of regulated voltages to critical circuits; tests for accuracy, such as counter circuit outputs or servo tracking tests; and tests for component deterioration, such as magnetron spectrum, ripple voltage, or shaft backlash.

Monthly and quarterly tests consists of measurements that cannot normally be performed when the ship is underway. Examples typical of this test are: sonar beam pattern tests, sonar transducer maintenance, and cleaning and lubricating antennas.

In some instances, unscheduled tests are provided. These tests are not designed to detect impending failure but are performed upon completion of repair for check-out. They are also useful when maintenance personnel are troubleshooting or tracing a failure. Examples typical of this type of test are: tests of unregulated dc voltages, non-critical waveform amplitude tests, and motor input tests.

(2) Reference Standards Summary Sheets

The Reference Standards Summary Sheets, Part II of the Reference Standards Book, is basically a calendar with space provided for recording dates, measurements, and the initials of the person performing the tests. The test used are those in the Reference Standards Tests. Two identical Reference Standards Summary Sheets precede the front matter of a newly issued Reference Standards Book. After the sheets are filled in, one is retained in the book and the second is submitted to NAVSHIPS for evaluation (refer to Subsection 2-2a).

(3) Performance Standards Sheets

The Performance Standards Sheets list the operational characteristics of an equipment or system. The characteristics given include such parameters as meter readings, sensitivity values, output power, standing wave ratios, and all other measurable parameters that indicate the operational condition of the equipment. Performance Standards Sheets are used by maintenance personnel to determine the overall operation of an equipment by comparing its data with the test results recorded in the Reference Standards Book (Part II). This sheet is usually the first page in a newly issued Reference Standards Book. As part of the POMSEE program, this sheet should be removed from the Reference Standards Book and placed in a binder titled, "Electronic Equipment Performance Standard Sheets," NAVSHIPS 93000.

b. MAINTENANCE AND MATERIAL MANAGEMENT SYSTEM

The Maintenance and Material Management (3-M) System is an integrated management system which, when fully implemented and properly used, provides for orderly scheduling and accomplishment of maintenance and for reporting and disseminating significant maintenance related information. It is composed of two principle sub-systems; the Planned Maintenance System (PMS) and the Maintenance Data Collection System (MDCS). Together, PMS and MDCS form the nucleus of a shipboard maintenance program which can contribute significantly toward achieving improved fleet readiness with reduced expenditure of resources.

(1) Planned Maintenance System

The Planned Maintenance System (PMS) pertains to the planning, scheduling, and management of resources (men, material, and time) to perform those actions which contribute to the uninterrupted functioning of equipment within its' design characteristics. It defines uniform maintenance standards, based on engineering experience, and prescribes simplified procedures and management techniques for the accomplishment of maintenance.

The increasing complexity and quantity of equipment required for the operation of the modern Navy has necessitated the continuous updating of maintenance procedures and the refinement of maintenance management organization at all levels. These improved procedures are necessary for the assurance of equipment readiness, the key to operational readiness.

For this reason it is of utmost importance that all maintenance personnel be familiar with the proper use of the PMS documents and schedules for implementing and accomplishing planned maintenance. These tools of the PMS are explained in the following subsections.

(a) Departmental Master PMS Manual — The Departmental Master PMS Manual (OPNAV 43P1) contains reference pages identifying all of the available planned Maintenance Requirements for the equipments maintained by a specific department. This information is described by System, Sub-System and Component and each manual is "tailored" to reflect the requirements for a particular department of a specific ship. The Departmental Master Manual is further divided into work center sections, as appropriate, within the department. The Master Manual also contains information concerning the fundamentals of the PMS and is located in the departmental office for use by the Department Head in planning, scheduling and supervising the required planned maintenance.

(b) Group Maintenance PMS Manual — The Group Maintenance PMS Manual (OPNAV 43P1) also known as the Work Center Manual is that portion of the Master Manual that contains only the Planned Maintenance Requirements that are applicable to a particular maintenance group within a department. This manual provides a ready reference of Planned Maintenance requirements for the work center supervisor. This manual should be retained in the working area, near the Weekly Schedule and in the special hardware provided for its storage.

(c) Maintenance Index Page — The Maintenance Index Page (MIP), OPNAV Form 4700-3, is the basic reference document in the PMS. See Figure 2-2. It catalogues the maintenance requirements, skill levels considered qualified to perform the maintenance requirements, reference documents, and other reference data for all equipments listed in the Master manual. Each MIP contains a list of one set of Maintenance Requirement Cards. Specifically, the information listed is as follows:

1. The system, sub-system or component, by noun name, AN Nomenclature, Mark, Mod, etc.
2. Reference Publications pertaining to the specific system, sub-system or component.
3. The date of preparation of the MIP (month and year).
4. The System Command MRC Control Number to control library issue and identify specific MRC's as applicable to a certain MIP.
5. A brief description of each maintenance requirement.
6. The periodicity code of each maintenance requirement listed on the MIP.
7. The recommended skill level/s considered qualified to perform the maintenance requirement/s.
8. The average time required for each skill level listed to perform the maintenance requirements as listed. (This does not include "make ready" and "put away" time.)
9. Any related maintenance actions to be scheduled for simultaneous accomplishment.
10. Notations included as Management Aids when such information is available and needed for selective scheduling of a specific requirement. MIP's are a ready reference to be used in conjunction with the planning and scheduling of PMS. Each MIP indexes one complete set of MRC's which are applicable to a component or system.
11. A letter and a number indicating the Maintenance Group and the equipment concerned, for example F-1, (F) indicates the Fireroom maintenance group and the (1) indicate Boilers.

(d) Maintenance Requirement Card — The Maintenance Requirement Card (MRC) OPNAV Form 4700-1, is a 5- x 8-inch card which defines a specific preventive maintenance task in terms of step-by-step procedures. See Figure 2-3. It provides maintenance personnel with detailed guidance for performance of each specific PMS requirement. The MRC contains the following information and instructions:

1. The identification of the System, Subsystem, or Component involved in the maintenance action.
2. The MRC Code assigned to the card. This code is in two parts. The first part if the Equipment

SYSTEM, SUBSYSTEM, OR COMPONENT	REFERENCE PUBLICATIONS	DATE
Input Output Data Display Group AN/UYA-5(XN-1)(V)	NAVSHIPS 0967-306-4010 0967-306-4020	Nov 1970

SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN HOURS	RELATED MAINTENANCE
864376	Check output voltage of Power Supplies	W	ET3	.5	None
864377	Check memory drive current	M	ET3	.5	None

MAINTENANCE INDEX PAGE (MIP)
OPNAV 4700-3 (REV. 11/68)

SYSCOM MIP CONTROL NUMBER

Figure 2-2. Sample Maintenance Index Page

SYSTEM	COMPONENT	MRC CODE	
Input Output Data Display Group AN/UYA-5 (XN-1)(V)	Memory	E17 M-1	
SUBSYSTEM	**RELATED MAINTENANCE**	**RATES**	**M/H**
	None	ET3	0.5

MAINTENANCE REQUIREMENT DESCRIPTION

Check memory drive current

TOTAL M/H: 0.5

ELAPSED TIME: 0.5

SAFETY PRECAUTIONS

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Oscilloscope
Tuning Tool
Current Probe for oscilloscope

PROCEDURE

1. Check Memory Drive Current

   a. Place ON-LINE/OFF-LINE switch on maintenance panel to the off-line position.

   b. Set data toggles on maintenance panel to the 1 position.

   c. Connect current probe in turn to the following points:

      (1) J17-10
      (2) J17-20
      (3) J18-10
      (4) J18-20
      (5) J19-10
      (6) J19-20

   Oscilloscope should indicate 0.5V ±0.1V

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4376

M

LOCATION

DATE: 5 Nov 1970

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700-1 (C) (REV. 11/68)

Figure 2-3. Sample Maintenance Requirement Card

Code adapted from the first portion of the number identifying the MIP for that card set in the Departmental and Work Center PMS Manuals. The second part identifies the periodicity for the maintenance action, using a letter code for repetitive time element as follows:

D - Daily
W - Weekly
M - Monthly
Q - Quarterly
S - Semi-annual
A - Annual
C - Overhaul Cycle
R - Situation Requirement (100 hr., prefiring, prior to getting underway, etc.)

The periodicity code also includes a number for specific identity when more than one MRC of the same periodicity exists in the same MRC set. When two or more MRC's in the same set are prepared for the same periodicity, but for separate, distinct job requirements, the cards will be numbered consecutively, e.g., "D-1", "D-2", or "M-1", "M-2", etc.

3. When a single maintenance requirement has need for more than one periodicity they will be numbered as "Q-1R", "M-1R", "M-2R", etc.; the "R" in the case meaning "related," indicates a situation that is defined in an accompanying note. Related maintenance requirements are maintenance actions described on other MRC's within the same set which are most efficiently accomplished when they are done prior to, in conjunction with, or after a task described on the basic MRC. For example, if the equipment is opened for a maintenance action, that MRC may list and identify other MRC's which also require equipment opening and, therefore, can most logically and appropriately be accomplished at this same time. The intent of related maintenance is to take advantage of work effort and to avoid repetitious maintenance steps. If no related maintenance exists, the word "Non" will appear in this block.

4. Maintenance Requirement Description is a brief description of the PMS action to be performed.

5. Rate is the recommended skill level, identified by rate or Navy Enlisted Classification Code (NEC), designated to perform the described maintenance action. This information is provided as a management aid for workload assignment.

6. The average manhours required to accomplish the PMS task by each rate. The total manhours and total elapsed time are also listed. These times are expressed to the nearest tenth of an hour. "Make ready" and "put away" times are not included.

7. Safety Precautions direct attention to potential hazards to personnel or equipment while performing maintenance tasks. "Observe Standard Safety Precautions" is required in this block on every MRC. These are two specific categories of additional precautionary conditions. They are:

WARNING: Operating procedures, practices, etc., which may result in personnel injury or loss of life if not correctly followed.

CAUTION: Operating procedures, practices, etc., which if not strictly observed, may result in damage to the equipment.

WARNING and CAUTIONS are repeated immediately before the appropriate procedural step.

8. Safety of Ship. An MRC that has been identified on the MIP as a Safety of Ship Item will have "SAFETY OF SHIP" stamped in large outline letters across the face of the MRC and in such a manner to avoid interference with other printing on the MRC. If Safety of Ship Items are included on an associated Equipment Guide List, the MRC has both SAFETY OF SHIP and EQUIPMENT GUIDE LIST stamped on the face of card. Every effort has been made to indicate hazards in the safety precautions block and at appropriate steps in the procedures block, however, common sense, through safety indoctrination, and training of personnel maintaining and operating shipboard equipments are still required.

9. A list of specific tools, parts and materials required to properly perform the maintenance action is given.

10. Detailed step-by-step procedures to be followed to accomplish maintenance action are given. In some instances, cards will contain blanks which must be completed by ship's personnel in order to supply the date (e.g., limiting speeds, tolerances, and pressures) necessary for the proper execution of the work specified. These data readings will vary from ship to ship.

11. The System Command MRC Control Number in the lower right side is a Library Identification Code. This number must be referenced along with MRC codes, in all correspondence pertaining to specific MRC's.

12. A space is also provided for recording the location of a specific equipment aboard individual installation, or for alerting maintenance personnel to the existence of EGL's.

13. In most cases, the contents of the MRC is unclassified even though it may be applicable to classified equipment. In cases where classification of an individual MRC is required, due to content, the following entry is found in the "Procedure" block: "Maintenance Procedure with this requirement is CLASSIFIED. MRC is stowed in ________." (Ship will fill the blank in.) The complete classified MRC is printed on pink stock with the classification printed at top and bottom of each printed side and shall be handled in accordance with OPNAVINST 5510-1 series (Security Manual for Classification Information).

14. The date on the card is the Month and year when the MRC was prepared.

15. The MRC cards are to be used as follows:

a A complete working group of MRC's are to be located, in the holder provided, in the work center area.

b Maintenance personnel are to remove the assigned MRC's from the Work Center card container, obtain the required tools, parts, and materials listed on MRC, and perform the maintenance action as stated on MRC observing all safety precautions.

c When completed, maintenance personnel should then correct and/or report any deficiencies discovered during the performance of the maintenance action. Report the completion of the maintenance action to the Work Center Supervisor, who will update the Weekly Schedule.

d The MRC's should then be returned to the container after the job has been completed.

(e) Equipment Guide List — The Equipment Guide List (EGL) is a 5- x 8-inch card that accompanies specific MRC's to list identical-type equipment to which preventive maintenance task is to be performed. Identical-type equipments, such as radar repeaters, power supplies, etc., are listed to show their quantity and location. For example, a particular ship may have eight EN/SPA-4A Radar Repeaters; and each repeater requires the accomplishment of the same preventive maintenance task.

The EGL is actually an extension of the Cycle and Weekly Schedules. When EGL's are required, a Guide List Index (GLI) is also prepared listing each EGL along with its controlling MRC. The index is included at the end of the List of Effective Pages in the PMS Manual.

(f) Cycle Schedule — The Cycle Schedule (OPNAV Form 4700-4), shown in figure 2-4, is a visual display of the planned maintenance requirements that are to be performed by shipboard personnel between major overhauls of the ship. "Between overhauls" is defined as "the time between a departure after overhaul and through the completion of the next major overhaul." Most PMS requirements listed on the Cycle Schedule are within the capability of the ship's force. Occasions may arise where special test equipment, special tools, or outside assistance will be required in order to accomplish the required maintenance. The Cycle Schedule contains the name and hull number of ship involved, the work center concerned, the effective date of the schedule, the listings of the MIP's and their related systems, subsystems and components for which the PMS requirements are to be scheduled. It also contains the schedules of the Semi-annual, Annual, Cycle, and Situation Requirements. Cycle requirements are divided into "Quarters after Overhaul" for listing the Quarterly requirements, and Monthly requirements which have been scheduled in each quarter. Care and attention must be devoted to the preparation of the Cycle Schedule as it has a direct influence on the subsequent effectiveness of the long range PMS scheduling by maintenance personnel. The procedure for filling out the Cycle Schedule is as follows:

1. Type in the ship's name and hull number in the upper left block and enter the date of preparation in the upper right corner. When a new cycle schedule is prepared, the old schedule must be filed with its applicable quarterly schedule.

2. Type in the Maintenance Group Block, i.e., Radio ET's, Radar ET. Indicate sheet number (e.g., 1 of 3, 2 of 3, 3 of 3) when more than one schedule is required.

3. Starting with the first MIP in the Work Center Manual (43P1) list the Equipment Code in the first column titled "Equip Page" (that is, E-1, F-1, EL-4, A-1). When more than one of the same equipments are located in the same Work Center, each must be entered as a separate line item. For example, two power supplies are located in the same space, PS-1 will be entered twice, on separate lines.

4. From the MIP in the column titled "Component," list the noun name or AN nomenclature of each component. If more than one of the same type equipment is located in the same Work Center, each will be identified separately using the standard shipboard numbering system (i.e., Radio #1, Radio #2, ECM #1, ECM#2, and including equipment serial numbers). When a large number of similar equipments such as radar, power supplies, radar repeaters, etc., are to be maintained in accordance with the same MRC, it is advantageous to use the Equipment Guide List method of accountability.

The last line of the Cycle Schedule should be left blank so that space will be available on the matching Quarterly Schedule for the entry of the ships operational schedule, including space to make corrections without completely removing the previous operational schedule.

5. From the MIP, list each Maintenance Requirement for Monthly (M), Quarterly (Q), and Situation Requirement (R) in the column headed "Each Quarter." Situation Requirement requirements are listed here only as a reminder and will not be scheduled on a calendar basis. Daily (D) and Weekly (W) requirements are scheduled only on the Weekly Schedule and are not listed on the Cycle Schedule. Calendar requirements which may be modified by a situation, such as A-2R will appear in appropriate "Quarter After Overhaul" column.

Pay particular attention to the "Related Maintenance" column of the MIP. If any Semi-annual (S), Annual (A) or Cycle (C) requirements are related, they shall be scheduled in the same "Quarter After Overhaul" column.

6. From the MIP, list each Semi-annual (S) maintenance requirement in one of the four columns titled "Quarter After Overhaul," then list the same requirement to occur six months later. For example, an S-1 requirement scheduled to occur in the 1, 5 and 9 quarters shall also be scheduled to occur in the 3, 7 and 11 quarters. Requirements in these four columns should be staggered to ensure an even distribution of workload.

7. From the MIP, list each Annual (A) maintenance requirement in one of the four columns titled "Quarter After Overhaul."

8. From the MIP, list each Cycle (C) maintenance requirement, reviewing each to determine if a specific quarter after overhaul is indicated on the MIP. Ensure that all Cycle requirements have an appropriate quarter after overhaul indicated in parenthesis after each entry on the cycle schedule. As an example, C-1 (6), is a Cycle maintenance requirement scheduled to be accomplished in the 6th quarter after overhaul.

9. Cycle Schedules for ships with overhaul cycles extending beyond 12 quarters will be prepared for the entire overhaul cycle indicating 13, 14, etc., as necessary. Ships with overhaul cycles less than 12 quarters will schedule "Cycle Requirements" within the specified overhaul time frame. Ships encountering delays in entering overhaul shall extend their cycle scheduled by the addition of appropriate quarter numbers in the "Quarter After Overhaul" block. (Ensure cycle requirements required prior to entering overhaul are reviewed and rescheduled as necessary.)

10. The completed "Cycle Schedule" shall be signed by the Department Head over the words "Scheduled As Indicated."

(g) Quarterly Schedule — The Quarterly Schedule (OPNAV Form 4700-5), shown in Figure 2-5, is a visual display of the ship's tentative operational employment schedule in conjunction with the PMS requirements to be performed during a specific three month period. This schedule is a directive issued by the Department Head and as such may be changed only by him or his authority. It is updated weekly and provides a ready shipboard reference to the current status of PMS for each Work Center. The schedule provides space for entering "Work Centers, Year, Quarter After Overhaul," and the current

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USS Worcester

CLASS/HULL CL 144

MAINTENANCE GROUP

Computer ET

COMPONENT

EQUIP. PAGE	COMPONENT	SCHEDULE AS INDICATED — QUARTER AFTER OVERHAUL 1 5 9	2 6 10	3 7 11	4 8 12	EACH QUARTER
E1	AN/UYA5(XN-1)(V)	A1				M1 Q1
E2	AN/UYA6(XN-1)(V)		A1			M1 Q1
E3	RP-161/UYK			A1		M1 Q1
E4	RO-367(XN-1)/UYK				A1	M1 Q1

CYCLE SCHEDULE OPNAV FORM 4700-4 (3-68) S/N-0107-766-4001 C-2521[illegible]

★ U. S. GOVERNMENT PRINTING OFFICE : 1968—346-886/A-110

Figure 2-4. Sample Cycle Schedule

MAINTENANCE GROUP Computer Room	YEAR 1971	QUARTER AFTER OVERHAUL 2 Daniel Buckley
MONTH Jan	MONTH Feb	MONTH Mar

EMPLOYMENT SCHEDULE

4 Jan	11	18	25	1 Feb	8	15	22	1 Mar	8	15	22	29
M1, Q1				M1				M1				
A1, M1, Q1				M1				M1				
M1, Q1				M1				M1				
M1, Q1				M1				M1				
UPK	UPK	ASW	ASW	ASW	UPK	UPK	UPK	UPK	UPK	UPK	UPK	UPK

QUARTERLY MAINTENANCE SCHEDULE OPNAV FORM 4700-5 (4-64) C-40997

Figure 2-5. Sample Quarterly Maintenance Schedule months covered. Space must be reserved on the schedule for entering tentative ship's employment schedule. Thirteen columns, one for each week in the quarter, are available to enable scheduling of maintenance requirements on a weekly basis throughout the quarter. The procedure for filling out the Quarterly Schedule is given below.

1. Enter the name of Work Center concerned in the space provided on the schedule.

2. Enter the corresponding sheet number from cycle being scheduled (1 of 2, 2 of 2).

3. Enter the calendar months of the quarter to be scheduled, in accordance with one of the quarterly groupings shown below. Groupings other than those shown are not acceptable.

JAN	APR	JUL	OCT
FEB	MAY	AUG	NOV
MAR	JUN	SEP	DEC

4. Enter the number of the "Quarter After Overhaul" in the space provided. For example: A ship completing major overhaul during August 1969 will list the months of July, August, and September for the first Quarter after overhaul schedule. The second Quarter of the overhaul would then list the months of October, November, and December. While in overhaul, ships must continue PMS whenever possible. Ships departing major overhaul late in the quarter are not expected to complete all planned maintenance scheduled during that quarter, but should accomplish a proportionate share based on the time remaining in the quarter. When departure occurs within the last two weeks of the quarter, ships will complete that quarter to the maximum extent possible utilizing the current quarterly schedule. The first quarter after overhaul in this case will then begin with the next quarter.

5. Identify a date for the starting of each week. The main body of the Quarterly Schedule is divided into thirteen columns; each column represents a week. Each column is further divided into seven days by the use of check marks across the top of the columns. Write directly over the first check space of each week to identify the date of each Monday.

6. From the ship's operational employment schedule enter the following information:

a. Across the top of the columns lightly shade in the days that the ship expects to be underway.

b. Across the bottom line of the current Quarterly Schedule, write in the type of employment, corresponding to the dates indicated across the top columns. (Upkeep, ASW, ISE, TAV, etc.)

7. Place the new Quarterly Schedule next to the Cycle Schedule.

8. From the Cycle Schedule, select the "Quarter After Overhaul" column corresponding to the current quarter. Periodicity codes listed in this column and the column titled "Each Quarter" will be transcribed to the current quarterly schedule. The other columns on the Cycle Schedule will not affect the current quarter.

9. Refer to the MIP's for a brief description of the maintenance actions scheduled on the cycle schedule in order to determine if the action should be performed in port or at sea. Schedule the requirement on the Quarterly Schedule in the week most appropriate for accomplishment. Schedule all related maintenance together.

10. From the Cycle Schedule column titled "Each Quarter" schedule all monthly and quarterly requirements into appropriate weeks of the Quarterly Schedule. Next, from the "Quarter After Overhaul" column, schedule all annual and semi-annual requirements. The ultimate goal in scheduling the Quarterly PMS requirements is to ensure the completion of all necessary maintenance actions while maintaining a balanced work load within the framework of the ship's operating schedule. When there are changes in the ship's operating schedule, maintenance requirements may require rescheduling to fit the new operating schedule.

11. Schedule all cycle requirements for which the number in parenthesis matches the quarter after overhaul being scheduled.

12. The completed Quarterly Schedule shall be signed by the Department Head in the "Quarter After Overhaul" block. Fill in all header information for the next quarter on another Quarterly Schedule form and place it beside the current schedule in the holder. This provides continuity for scheduling and planning on a long-range basis.

This Quarterly Schedule serves as a directive for Work Center Supervisors for scheduling weekly maintenance. At the end of each work week, the Work Center Supervisor will cross-out (x) all maintenance requirements on the Quarterly Schedule that have been completed and will circle (O) all requirements that were not accomplished. The Department Head is responsible for the rescheduling of all circled requirements, if they remain within the same periodicity (i.e., a monthly can only be rescheduled in the same month, a quarterly can only be rescheduled within the same quarter, etc.).

Any requirement which cannot be accomplished during the current quarter, in addition to being circled, shall be identified on the back of the quarterly schedule with the reason it was not accomplished. Other unaccomplished requirements shall be rescheduled for accomplishment in the next quarter.

The completed Quarterly Schedule is removed from the holder after the close of each quarter and retained as a Planned Maintenance record. This record may be discarded by quarters, when the same number quarter after the next major overhaul has been completed, thereby providing a complete cycle of history.

Maintenance requirements shall not be scheduled or rescheduled on the subsequent Quarterly Schedule until the ship's employment schedule is known or until the last week of the current quarter, which ever comes first.

(h) Weekly Schedule — The Weekly Schedule (OPNAV Form 4700-6), shown in Figure 2-6, is a visual display of planned maintenance scheduled for accomplishment in a given Work Center during that week. The Weekly Schedule is posted in each Work Center and is used by the Work Center Supervisor to assign and monitor the accomplishment of the required PMS tasks by the Work Center personnel. It contains the name of the Work Center concerned, a listing of the systems, subsystems, and components assigned to the maintenance group of the Work Center, and the respective equipment codes. It lists the maintenance requirement to be performed in

Daniel Buckley

GROUP Computer Room **WORK SCHEDULE FOR WEEK OF** 4 Jan 1971 11/70

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN	OUTSTANDING REPAIRS AND P.M. CHECKS DUE IN NEXT 4 WEEKS
AN/UYA 5(XN-1)(V	Hanrahan	E1	D1W1	D1Q1	D1	D1	D1	D1	
AN/UYA 6(XN-1)(V	Urban	E2	W1M1	Q1	A1				
RP-161/UYK	Franck	E3	W1Q1						
RO-367(XN-1)/UYK	Nuzzo	E4	D1W1	D1Q1	D1	D1	D1	D1	

WEEKLY WORK SCHEDULE OPNAV FORM 4700/6 (9-65) S/N 0107-766-5600 A-20832 ★ U.S. GOVERNMENT PRINTING OFFICE: 1969-346-894/A-340

Figure 2-6. Sample Weekly Work Schedule

a specific week, the names of the personnel assigned to individual maintenance actions, and the outstanding repairs, PMS checks (Monthly and above), and known Situation Requirements due in the next four weeks. The procedure for filling out the Weekly Schedule is as follows:

1. Type in the following information from the current Cycle Schedule.

a. Work Center identification, e.g., Radio #1 and corresponding cycle schedule sheet number (e.g., 1 of 2, 2 of 2).

b. System, subsystem or component and MIP number, line for line to match the cycle schedule.

2. From the MIP's, enter the recurring weekly and daily requirements. Weekly requirements should be entered on Monday to provide ease of rescheduling. Daily requirements must appear each day.

3. Place clear plastic over the weekly schedule.

4. From the current Quarterly Schedule, the Work Center Supervisor transposes all PMS requirements and the date for the current week, to the Weekly Schedule. Exercise care to ensure a balanced workload, appropriate consideration of the week's operating schedule, and that all related maintenance actions are scheduled together. Review MIP's/MRC's and determine related maintenance requirements.

5. Using information from the Quarterly Schedule, fill in the "Outstanding Repairs Due" column (right column) with known corrective maintenance and all Monthly (and above) PMS requirements due in the next four weeks. This should include all PMS Situation Requirements which may be accomplished during that four-week period.

6. Assign maintenance personnel, by name, to specific maintenance tasks. Maintenance personnel will then obtain their PMS assignments from the Weekly Schedule, obtain the required MRC cards, tools or material, and perform the maintenance action. They must report all completed maintenance action to the Work Center Supervisor. The Work Center Supervisor will then cross off all completed requirements when reported and will circle the uncompleted requirement for rescheduling as the work load and ship's operations permit. At the end of each week, the Work Center Supervisor should bring the Quarterly Schedule up to date by comparing it to the weekly schedule, crossing out completed requirements and circling requirements not completed. The Weekly Schedule is then erased and the next weeks schedule prepared.

(i) Maintenance Control Board — The Maintenance Control Board is a prefabricated aluminum holder that contains a Cycle Schedule, a current Quarterly Schedule, and a subsequent quarterly maintenance schedule for each maintenance group. As its name implies, the Maintenance Control Board presents a readily available summary of the current and planned status of shipwide preventive maintenance for all interested personnel.

(2) Maintenance Data Collection System

The Maintenance Data Collection System (MDCS) provides a means for recording the expenditure of resources (men, material and time), associated with certain categories of maintenance actions. Maintenance personnel are provided a means to record, at the source, designated information pertaining to accomplishment of preventive or corrective maintenance actions. It also provides a system for processing significant maintenance and logistic information, and disseminates the results in the form of technical information for maintainability/reliability studies of operational equipment, and in the form of management information for improving workload planning and control. It incorporates the use of coded data elements, for data standardization and facilitating automatic data processing. Failure and corrective action information recorded on the maintenance action documents and the material usage information recorded on associated supply system issue documents, is retrievable through this system for use in engineering analysis and developing maintenance history.

The system makes it possible for reporting delays in the accomplishment of required maintenance actions (deferred actions) and indicating the principal reason for the delays. This information is also retrievable for use in maintenance problem and logistic support analysis and for developing a Current Ships Maintenance Project (CSMP) file which will assist in improving the planning and coordination of the ship's workload. For those maintenance actions which have been deferred because of a requirement for technical skills or special equipment not available on board ship, the MDCS makes provisions for documenting a work request to an appropriate repair activity. Follow-up reporting by these repair activities, upon completion of requested repair assistance, contributes significantly to the detail and depth maintenance information available for retrieval and subsequent use through MDCS.

The reports and forms used in MDCS are employed in the following subsections.

(a) PMS Feedback Report — The PMS Feedback Report (OPNAV Form 4700-7), shown in Figure 2-7, provides a direct line of communication, via the TYCOM, between the maintenance man and the Naval Material Command. The PMS Feedback is utilized to submit recommended modifications and revisions to PMS documentation and to request certain additional or replacement software and hardware. In addition, it is used to suggest changes to technical manuals and to report or inquire about other matters in connection with PMS. Instruction for completing and submitting reports are printed on the back of the last copy of this five-part form.

(b) Maintenance Data Form — The Maintenance Data Form (OPNAV Form 4790-2K), shown in Figure 2-8, is a multi-purpose form used to report the completion or deferral of a maintenance action or to request needed assistance. The data element that must be completed to report any one of the categories of maintenance information are grouped together in separate, clearly labeled sections on the form, to simplify data recording and to facilitate Automatic Data Processing (ADP). In addition to the standard data elements which are used for recording all reportable maintenance actions, this form provides special shaded sections for recording other necessary data elements for maintenance actions associated with specially identified systems or equipments, or reports completed under certain unique circumstances. This form supersedes OPNAV Forms 4700-2J, 4700-2B, 4700-2C, and 4700-2D.

(c) Supplemental Report Form — The Supplemental Report Form (OPNAV Form 4790-2L),

INSTRUCTIONS ON BACK OF GREEN PAGE

FROM: USS Worcester

SERIAL #: C-69

DATE 15 Nov 1970

TO: NAVY MAINTENANCE
MANAGEMENT FIELD OFFICE
Box 604 Hampton Roads Branch
Norfolk, Virginia 23511

VIA:

SUBJECT: PLANNED MAINTENANCE SYSTEM FEEDBACK REPORT

SYSTEM	COMPONENT
AN/UYA 5 (XN-1)(V)	Memory
SUB-SYSTEM	M. R. NUMBER E-17 M1
	CONTROL NO. 864376

DISCREPANCY:

☐ M. R. Description	☐ Equipment Change	☐ Typographical
☐ Safety Precautions	☐ Missing Maintenance Index Page (MIP)	☒ Technical Publications
☐ Tools, Etc.	☐ Technical	☐ Miscellaneous
☐ Missing Maintenance Requirement Card (MRC)	☐ Procedure	

Logic Diagrams in 0967-306-4020 are in error. Gate number 6D5A has output pin shown as 14. This pin should be 13.

Daniel Buckley
SIGNATURE

THIS COPY FOR:

OPNAV FORM 4700/7 (Rev. 8-66)

ADDRESSEE 1

Figure 2-7. Sample PMS Feedback Form

OPNAV FORM 4790/2K
(Rev. 1-70)

MAINTENANCE DATA FORM

MAINTENANCE ACTION — CHECK ONE: [X] COMPL. / DEFER / WORK REQ.

USS BUCK (DD761)
SHIP NAME/HULL NUMBER

SECTION I

JOB CONTROL NUMBER: 1. UNIT I.D. CODE	2. WORK CENTER	3. JOB SEQ. NO.	4. EQUIP I.D. CODE	AS DISCOVERED INFORMATION: 5. FIT	6. WD	7. WD DATE	8. STAT
Ø3861	OE Ø5	ØØ69	P3ØT9Ø3	B	PBC	Ø2202	2

9. IDENTIFICATION NUMBER	10. APL/AEL	11. ALTERATION (SHIP ALT, ORD ALT, FLD CHG, ETC.)
5C2221	582047 86	

SECTION II – COMPLETED ACTION

12. A/T	13. MAN HOURS	1/10	14. RATING/RATE	15. COMPLETION DATE YR DAY	16. STAT	17. CAUSE	TIME → METER	18. ACT. MAINT. TIME	1/10	19. TBL	20. EQUIP METER READING	21. MTR
C1	ØØ1	5	FTR2	Ø22Ø	1	6A		ØØØ8	7		ØØ587	

SECTION III – DEFERRAL ACTION PLANNING

22. A/T	23. MAN HOURS	1/10	24. RATING/RATE	25. DEFERRED DATE YR DAY	26. STAT	27. AVL	28. PRI	29. FPR	AND COUNTER → EQUIPMENT	30. ACT. MAINT. TIME	1/10	31. TBL ISL	32. EQUIP. METER READING	33. MTR

34. INIT. A/T	35. REPAIR W.C.	36. EST. MAN HOURS	37. ASS'T REPAIR W.C.	38. ASS'T EST. M/H	39. AVL	40. SCHED. START DATE YR DAY	41. SCHED. COMPL. DATE YR DAY	42. REPAIR ACTIVITY U.I.C.

SECTION IV – REMARKS / DESCRIPTION

INSURV BOARD USE: 44. TIME | 45. CLASSIFICATION NO. | 46. U/S | 47. M

43. NOUN NAME: AN-SPS4Ø

SWEEP GENERATOR TUBE SHORTED R
EPLACED WITH ONE DRAWN FROM SU
PPLY

S / T / V / W / X / Y / Z / CONT. SHEET / SHEET NO.

COMPARTMENT | DECK | FRAME | SIDE | INTEGRATED PRI.

1ST CONTACT/MAINT. MAN A.: L Riggs FTR 2 — 2ND CONTACT/SUPERVISOR NAME B.: J. Riddle FTC — CO SIGNATURE C.

SECTION V – FAILED PARTS/COMPONENT

48. EIC TO LOA	49. MFG. PART NO. / FSN	50. MFG. CODE	51. SERIAL NUMBER	52. F. PT. COND.	53. REF. SYMBOL	54. DIS
P3ØT9Ø3	597Ø 193 147Ø	Ø152Ø	——	2Ø9	V5Ø1	D
55.	56. MFG. PART NO. / FSN	57.	58.	59.	60.	61.
62.	63. MFG. PART NO. / FSN	64.	65.	66.	67.	68.

SECTION VI – SUPPLEMENTARY INFORMATION

69. BLUEPRINTS, TECH MANUALS, PLANS, ETC. — AVAILABLE ON BOARD: YES | NO

70. PREARRIVAL AND/OR ARRIVAL CONFERENCE ACTION- REMARKS

71. SCREENINGS ACTION: SHIP / SQD / TYCOM

SHOP
EST. M/H
DOC. M/H

LEAD PBE CODE | PLANNER I.D. | DATE OF ESTIMATE–ARRIVAL ± DAYS

TOTAL MANDAYS | M/D DOLLARS $ | MATERIAL $ | TOTAL COST $

JOB ORDER NUMBER

SQD SIG D. | TYCOM SIG./REPAIR OFFICER E. | COMPLETED BY F. | ACCEPTED BY G.

Figure 2-8. Sample Maintenance Data Form shown in Figure 2-9, is an MDCS feedback report used to inquire about, comment on, any subject related to maintenance accomplishment or maintenance action reporting. In this application, this report may be used individually or in conjunction with OPNAV Form 4790-2K. This form has been approved by CNO as the reporting form for limited duration data collection programs. This form permits collecting more detailed maintenance information than is available through routine MDCS reporting. Section I of this form is filled in the same way as on associated form 4790-2K if it is being used as a continuation sheet. Otherwise, only block 1, date and serial number are required. Section II is filled in with the voluntary information being reported. It should contain comments, sketches, technical data, etc. When required for mandatory submission, this section will be filled in as directed by appropriate authority. Section III is for signature use as indicated or as directed for special report use. Section IV is reserved for special reporting programs only and shall be filled in according to instructions. Section V is for addressing; use as indicated unless otherwise directed for special reporting.

(d) Work Supplement Card — The Work Supplement Card (OPNAV Form 4790-2F), shown in Figure 2-10, is a pre-punched pre-printed card supplied to the Lead Work Center and each assist work center included in the initial planning phase of the Work Request. This card is used primarily by repair work centers to report the daily progress (action taken, manhours expended, date) on a work request. This card may also be used to record remaining hours, report work delay/status and to request additional work supplement cards. The assist work center will use this same card to estimate their portion of the job. Information from these cards is used for Workload Planning and Control (WLP & C) reports.

1. Daily Progress. The Work Supplemental cards are used to document all manhours expended on each job in progress within the work center. The senior man actively engaged in the maintenance action is responsible for documenting the daily progress.

2. Remaining Hours. Whenever the remaining hours, as listed on the WLP & C reports, do not accurately reflect the scope of the job for this work center, this figure can be revised by entering the hours remaining for the job in block D of this form. The work center supervisor must concur with the new entry.

3. Work Delay. Work delays or work stoppage effecting satisfactory progress on the job is reported by using the Work Supplemental Card. The Lead Work Center or the Assist Work Center may use the Work Delay/Stoppage Codes, found on the reverse side of the card, in block G. There can be only one Work Delay/Stoppage Code effective at any one time for any specific work center. The latest delay code that is submitted will be reflected on WPL & C reports. The delay code 00 will be used to show the delay status from that work center WLP & C reports. The Work Center Supervisor must concur with assignment and removal of delay codes.

4. Replenishment. Request for replenishment of the supply of Work Supplemental cards can be accomplished by submitting a card for that specific purpose or in conjunction with the daily progress report by entering the number of cards desired (1 to9) in block H.

5. Assigning an Assist Work Center. When additional repair work centers are required to complete the requested work, the Lead Repair Work Center will provide to Assist Repair Work Center with two or more pre-punched/pre-printed work supplement cards. One is to establish the Assist Repair Work Center Job Planning Record, and the others are for reporting progress prior to receiving additional cards from Data Services. The Lead Repair Work Center will make the entries indicated on each card. The Lead Repair Work Center will provide sufficient description in the remarks section of the card to enable the Assist Work Center to scope the job.

6. Multiple Units. Multiple Unit work request on items such as binoculars, printing, photographing, placques, sound powered phones, clocks, etc., are permitted by using the words "various" or "miscell" in block 9 of the work request submitted on a 4790-2K form. Block 9 of the pre-punched 4790-2F card will always be blank when associated with this type work request. These multiple items will always be documented as a single maintenance action unless rejection of individually serialized items is involved. When individually serialized items are rejected, the Rejection Action Taken Code must be on a one-for-one basis for each item. For non-serialized items or whenever rejection is not involved, the Action Taken Code that best describes the overall effort will be recorded. Assist Work Centers will not reject individual units of a multiple unit work request. Multiple unit work requests on maintenance history significant items are not permitted.

7. Completion. Completion of a work request can be reported using the 4790-2F and entering the code "30" in block G. Assist Work Centers may also report completion of their portion of a job by using code "30" in block G on the 4790-2F. When code "30" is received by Lead Work Center, sheet 1 of the 4790-2K must be completed for the job to be closed out.

(e) Failed Parts/Components Card — The Failed Parts/Component Card (OPNAV Form 4790-2M), shown in Figure 2-11, is used to document a failed part or component only when block 29 on the OPNAV 4790-2K (Work Request) indicates this requirement with an entry. One pre-printed 4790-2M card is provided the Lead Work Center for this purpose. It is the Lead Work Center's responsibility to document failed parts/components including those discovered by Assist Work Centers. A maximum of three failed parts/components will be reported. When there are more than three, the Lead Work Center will determine and report the three most insignificant failures in the order of their importance.

(f) Single Line Item Requisition Document — This document (DD Form 1348), shown in Figure 2-12, is used for internal issue of material aboard ships that have automated (mechanical) supply records with Automatic Data Processing (APD) equipment. The procedure for filling out this document is as follows:

1. Enter the Job Control Number (JCN) in blocks L, M, and N. The JCN is made up from the Unit Identification Code (UIC), Work Center (WC), and the Job Sequence Number (JSN) contained in blocks 1, 2, and 3 of OPNAV Form 4790-2K pertaining to the maintenance action for which the item is requested.

OPNAV FORM 4790/2L
(REV. 1-70)
S/N-0107-770-3053

SUPPLEMENTAL REPORT FORM

CONTINUATION: 2K | 2L

USS BUCK (DD761)
SHIP NAME/HULL NUMBER

0EØ5-3
SERIAL NUMBER (OPTIONAL USE)

SECTION I

JOB CONTROL NUMBER				
1. UNIT I.D. CODE	2. WORK CENTER	3. JOB SEQ. NO.	4. EQUIP. I.D. CODE	YR DAY
Ø3861	ØEØ5	ØØ69	P3ØT9Ø3	Ø223

SECTION II - REMARKS/DESCRIPTION
(COMMENTS, REQUESTS, SKETCHES, ETC. – VOLUNTARY OR AS DIRECTED):

AN/SPS-4Ø SWEEP GENERATOR TUBE REPLACED. BELIEVE VIBRATION AND SHOCK TO THIS TUBE COULD BE REDUCED BY INSTALLING GUARD AROUND IT.

SECTION III - SIGNATURE

MAINTAINER REPORTING:	SUPERVISOR:
L Riggs ETR2 RANK/RATE	J Tiddle ETC RANK/RATE

SECTION IV - SUPPLEMENTARY INFORMATION (FOR USE ONLY WHEN DIRECTED BY REQUIRING ACTIVITY)

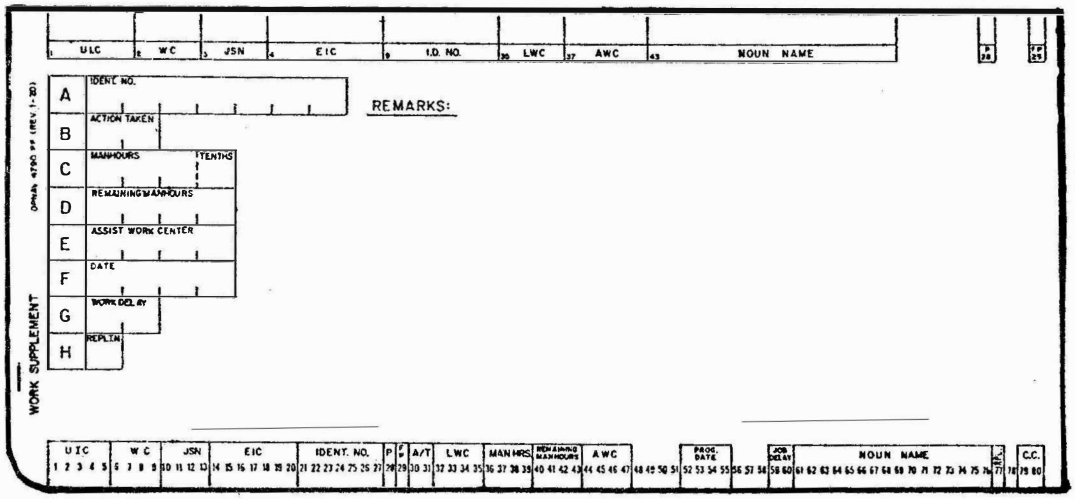
X
Y
Z

SECTION V - MAILING ADDRESS (FILL IN ACCORDING TO "DIRECTIONS" OR AS MODIFIED BY REQUIRING ACTIVITY)

TO:	VIA:
NMMDFO (E)	CCDL (COMCRUDESLANT)
CODE Ø411E BOX SECTION 6Ø4	US ATLANTIC FLEET
HAMPTON ROADS BRANCH	NEWPORT, R.I.
NORFOLK VA. 23511	

ADDRESSEE

Figure 2-9. Sample Supplemental Report Form



OPNAV Form 4790/2F Work Supplement Card (Front)

CODE — WORK NOT STARTED

11. Not Delivered to Work Center . . . . . . "NOT DELIVERED"
12. Insufficient Information . . . . . . "INSUFF INFO"
13. Awaiting Parts/Material . . . . . . "WAITG PARTS/MATL"
14. Lack of Manpower . . . . . . "LACK MANPOWER"
15. Work Center Equipment Unavailable . . . . . . "WC EQUIP UNAVAIL"

WORK STARTED BUT STOPPED

21. Priorty Changed . . . . . . "STP-PRIORITY CHANGE"
22. Insufficient Information . . . . . . "STP-INSUFF INFO"
23. Awaiting Parts/Material . . . . . . "STP-WAITG PARTS/MATL"
24. Awaiting Assist Work Center . . . . . . "STP-WAITG ASSIST WC"
25. Work Center Equipment Unavailable . . . . . . "STP-WC EQUIP UNAVAIL"

STATUS CODES

30. Completed–Not Signed Off . . . . . . "COMPL-NOT SIGNED OFF"
40. Re-Work Required . . . . . . "RE-WORK REQUIRED"
50-59. Special Purpose . . . . . . " SPECIAL STATUS"

OPNAV Form 4790/2F Work Supplement Card (Reverse) Work Delay and Status Codes

Figure 2-10. Sample Work Supplement Card

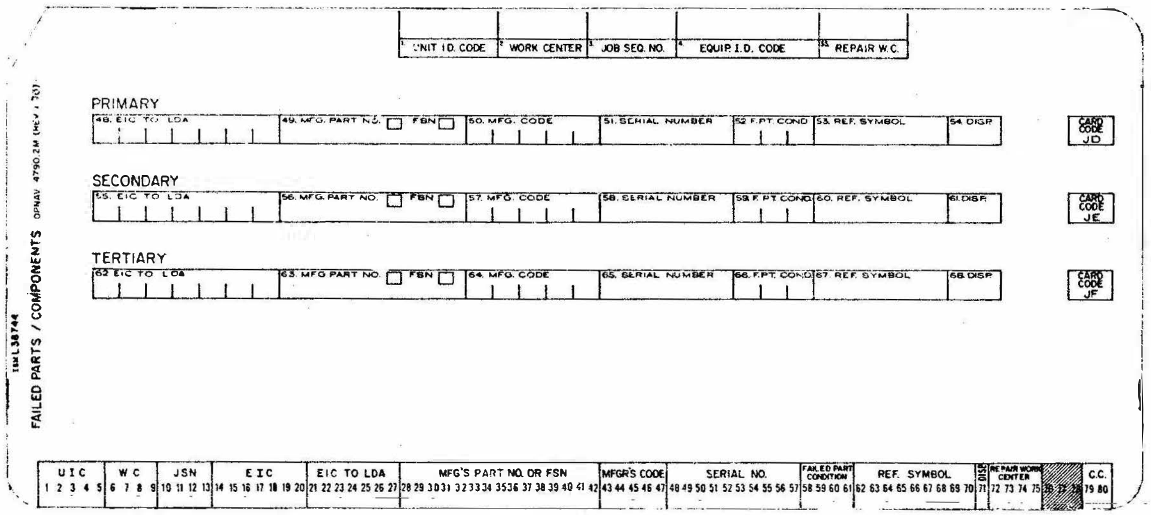


Figure 2-11. Sample Failed Parts/Components Card

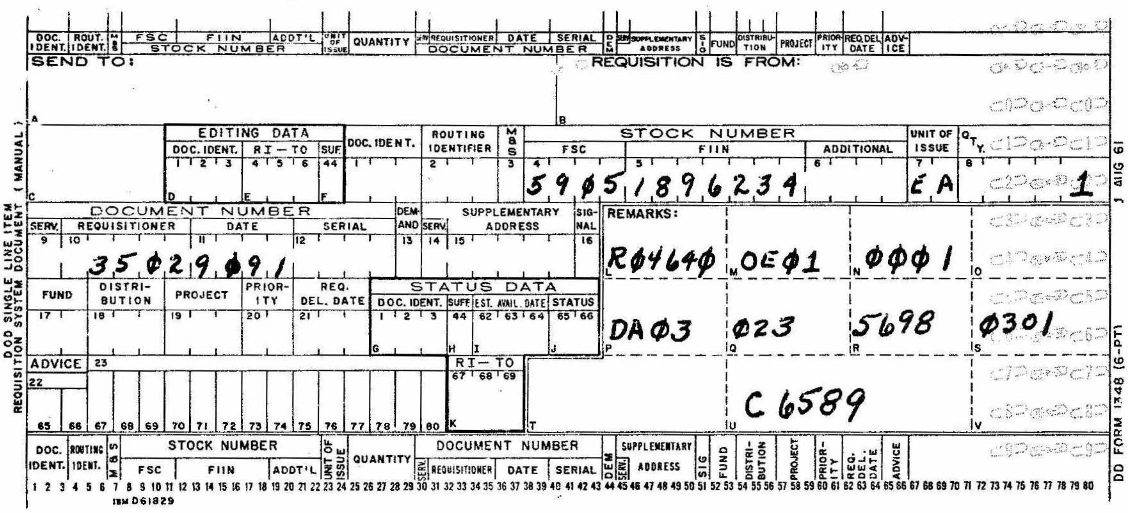


Figure 2-12. Sample DD Form 1348

Care must be exercised to ensure that the same JCN is used on all supply documents relating to the same maintenance action.

2. Enter the Federal Stock Number (FSN) in blocks 4, 5, and 6 for the item requested. The FSN is generally found in the Coordinated Shipboard Allowance List (COSAL) within the Allowance Parts List/ Allowance Equipage List (APL/AEL) for the equipment/component being worked on. When only the part number is known, the FSN may be obtained from the Master Cross Reference List (MCRL). When an item is identified only by the Manufacturer's Part Number for which no FSN has been assigned, the part number preceded by the Federal Supply Code of Manufacturers (FSCM) will be entered. When a requested item cannot be identified by a FSN or a Manufacturer's Part Number, the Noun Name and a brief description of the item will be provided in blocks 4, 5, and 6.

3. Enter the quantity of the item required in block 8. Provide the actual quantity required, consistent with the standard unit of issue, to complete the maintenance action.

4. Enter the Document Number in blocks 10 and 11. The document number contains two data elements. In block 10, enter the department/division serial number. In block 11 enter the Julian date of the day that the request for the item was placed with the Supply Department.

5. Enter the ~~urgency code in block 20~~. This code shall be a realistic code assigned by personnel designated by the Department Head.

6. When the item requested is Not In Stock (NIS) or Not Carried (NC) and it is imperative that the item be onboard by a certain date in order to complete the maintenance action to meet ships operations, enter the Required Delivery Date (RDD) in block 21. This date shall be a realistic date and assigned by personnel designated by the Department Head.

7. Enter the Equipment Identification Code (EIC) in blocks P and Q. The EIC code is obtained from the EIC Manual and should be the Lowest Designated Assembly (LDA) listed in the EIC Manual for the item requested. The EIC used here may not necessarily be identical to the EIC used on the 4790-2K.

8. Enter the APL and AEL code in blocks R and S. These codes are taken from the ship's COSAL. Exercise care to ensure that the APL/AEL is for the equipment/component actually being worked on. This entry may not necessarily be identical to the APL/AEL entry on the 4790-2K. In a case where the APL/AEL does not exist on board, enter "Not Listed."

9. Enter the Reference Circuit Symbol for the part or item in block U. This reference/circuit symbol may be found on schematics, circuit diagrams, and technical manuals.

Further documentation of the DD Form 1348 will be accomplished by the Supply Department. After appropriate action has been taken by supply, the maintenance technician will receive a copy of the DD Form 1348 with the material requested. In cases where the material is not available on board, the WC will be provided with a copy marked NIS or NC as appropriate for the WC's status information.

(g) Single Line Item Consumption/ Management Document — This document (NAVSUP Form 1250), shown in Figure 2-13, is used to request and issue ~~material internally aboard~~ ships that do not have automated (mechanized) supply records. A copy of this form is used to report all maintenance related material issues. The procedure for filling out this document is as follows:

1. Enter the material request date in block A. This entry will be the Julian date of the day that the request for the item is placed with the Supply Department.

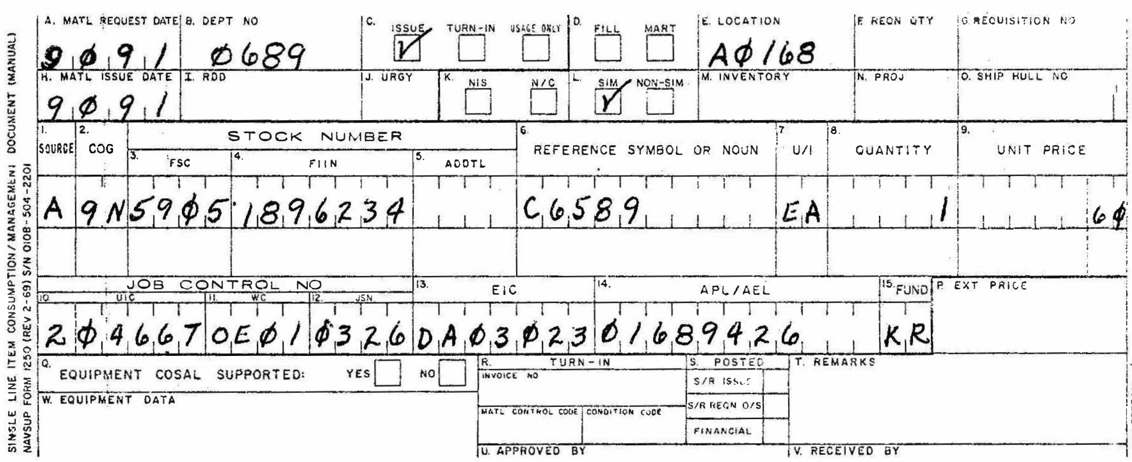


Figure 2-13. Sample NAVSUP Form 1250

2. Enter the Department Number in block B. This number is the next sequential number for each transaction of the department issuing the request.
3. Check the word "Issue" in block C to ensure proper reporting of the item used.
4. When the item requested is Not In Stock (NIS) or Not Carried (NC) and it is imperative that the item be on board by a certain date in order to complete the maintenance action to meet ships operations, enter the Required Delivery Date (RDD) in block I. This date shall be a realistic date and assigned by personnel designated by the Department Head.
5. Enter the Urgency code in block J. This code shall be a realistic code assigned by personnel designated by the Department Head.
6. Enter the Federal Stock Number (FSN) in blocks 3, 4, and 5 for the item requested. The FSN is generally found in the Coordinated Shipboard Allowance List (COSAL) within the Allowance Parts List/ Allowance Equipage List (APL/AEL) for the equipment/component being worked on. When only the part number is known, the FSN may be obtained from the Master Cross Reference List (MCRL). When an item is identified only by the Manufacturer's Part Number for which no FSN has been assigned, the part number preceded by the Federal Supply Code of Manufacturers (FSCM) will be entered. When a requested item cannot be identified by a FSN or a Manufacturer's Part Number, the Noun Name and a brief description of the item will be provided in blocks 3, 4, and 5.
7. Enter the Reference Circuit Symbol or Noun Name for the part or item in block 6. The reference symbol may be found on schematics, circuit diagrams, and technical manuals.
8. Enter the quantity of the item required in block 8. Provide the actual quantity required, consistent with the standard unit of issue, to complete the maintenance action.
9. Enter the Job Control Number (JCN) in blocks 10, 11, and 12. The JCN is made up from the Unit Identification Code (UIC), Work Center (WC), and the Job Sequence Number (JSN) contained in blocks 1, 2, and 3 of OPNAV Form 4790-2K pertaining to the maintenance action for which the item is requested. Care must be exercised to ensure that the same JCN is used on all supply documents relating to the same maintenance action.
10. Enter the Equipment Identification Code (EIC) in block 13. The EIC code is obtained from the EIC Manual and should be the Lowest Designated Assembly (LDA) listed in the EIC Manual for the item requested. The EIC used here may not necessarily be identical to the EIC used on the 4790-2K. In a case where the APL/AEL does not exist on board, enter "Not Listed."
11. The Approval Signature will be placed in block U. This block requires the signature of the Department Head or personnel designated by him.
12. When the item is issued by supply personnel, the maintenance technician receiving the item, will sign his name in block V as proof of delivery for the Supply Department.

Further documentation of the NAVSHP Form 1250 will be accomplished by supply personnel. After appropriate action has been taken by supply, the requesting maintenance technician will receive the yellow copy with the material. In cases where the material is not available on board, the maintenance technician will receive the yellow copy marked NIS or NC as appropriate.

2-3 OPERATIONAL MAINTENANCE

Operational maintenance consists of inspections, cleaning, servicing, preservation, lubrication, adjustment, and minor parts replacement not requiring a high degree of technical skill or knowledge.

a. OPERATOR RESPONSIBILITIES

Very often, a competent equipment operator can see or sense a malfunction in an equipment, which he can correct without the aid of a technician. He is qualified to make some adjustments and changes to an equipment, provided they do not require a high degree of technical skill. Further he may be required to perform the following duties:

1. Carry out routine maintenance such as lubrication and cleaning.
2. Maintain an adequate, up-to-date, and accessible list of replacement parts.
3. Log all the work performed on an equipment, including all significant measurements that are taken.
4. Perform "Operator Maintenance" (O. M.) as specified by the POMSEE handbook for the equipment.

b. TECHNICIAN RESPONSIBILITIES

A technician performs the tests, adjustments, and repairs that are beyond the ability of the operator. A technician must do maintenance work that involves internal alignment, disassembly, and critical adjustment. He must perform tests and follow procedures as required by the POMSEE book, PMS, the technical manual, and such.

2-4 TROUBLESHOOTING FOR CORRECTIVE MAINTENANCE

Corrective maintenance is the correction of equipment troubles, whether this be the repair of an equipment after a complete breakdown or the tuning and adjustment of an equipment necessary to restore it to an operating condition. Before corrective maintenance can be performed, operators and technicians must know that the trouble exists. Sounds like an erroneous statement? Numerous instances have occurred where obviously malfunctioning equipment were operating for hours, day, and even months without the symptom of the malfunction being recognized by either the operator or technician. Of course, no corrective actions were taken.

a. SYMPTOM RECOGNITION

Symptom recognition is the first step in troubleshooting, and is based on a complete knowledge and understanding of equipment operation and operational characteristics. In many cases, this is the responsibility of an operator even though he has no technical background. For an operator to recognize a symptom of malfunction, he must be thoroughly familiar with proper equipment operating techniques, and know the function of each mode and feature, even of those rarely used. Symptom recognition may be difficult under electronic countermeasures attack, but consider the probable consequences if corrective action was not taken, or the symptom was not reported to a technician. In many cases, a mode change or the adjustment of an operator's control is all that is needed.

Not all equipments produce symptoms that are easily recognized. This type of equipment trouble may then be discovered while performing preventive maintenance under a planned maintenance program, such as PMS and POMSEE. It is important that the "not so apparent" as well as the apparent troubles be recognized. Operators who are not technically qualified technicians on the equipment they operate are still responsible for reporting a malfunction or a symptom to the electronic technician.

b. SYMPTOM ELABORATION

After an equipment trouble has been recognized, all the available aids designed into the equipment should be used to further elaborate on the symptom. Use of front panel controls and other built-in indicating and testing aids should provide better identification of the symptom. The equipment operation section of technical manuals may serve as a guide.

c. LISTING PROBABLE FAULTY FUNCTIONS

The next step in troubleshooting is to formulate a number of logical choices as to the basic cause of the symptom, or what function is at fault. The logical choices should be mental decisions based on knowledge of equipment operation, a full identification of the symptom, and information contained in technical manuals. The overall functional description with associated block diagrams of technical manuals, and the Blocked Schematics with accompanying text of Symbolic Integrated Maintenance Manuals (SIMM) can help the electronics technician formulate logical choices.

d. LOCALIZING THE FAULTY FUNCTION

Localizing the faulty function is normally accomplished by using the Servicing Block Diagrams in technical manuals or the Precise Access Block Diagrams in SIMM's. For the greatest efficiency in localizing the trouble, the logical choices should be tested by following the signal flow of a function through the diagrams in an order that will require the least time. If one test does not prove that a particular function is at fault, the next choice should be tested, and so on, until the faulty function or basic cause of the symptom is located.

e. LOCALIZING TROUBLE TO THE CIRCUIT

Once the faulty function is determined, it may be necessary to make additional choices as to which circuit, or group of circuits is at fault. Again, the Servicing Block Diagrams supported with these parameters are used, along with schematics and other test location information that may be helpful in bracketing the faulty circuit. If the trouble is not immediately apparent, test methods are then necessary to further isolate the fault. Of the most common test methods are waveform analysis, voltage checks, resistance checks, tube testing, and semiconductor testing. Briefly, they are explained in the following subsections.

(1) Waveform Analysis

Waveform analyses are made by observing voltage and current variations with respect to time. The cathode-ray synchroscope is a device that accurately displays the voltage variations with respect to a time-base that is synchronized internally by its own circuits or externally by other synchronous signals. Numerous types of synchroscopes (commonly called oscilloscopes) are available, the required one being supplied with each equipment. The synchroscope required for particular types of tests is determined by characteristics such as the bandwidth of the input frequency, the input impedance, the sensitivity, the sweep rate (time base), and the methods of sweep control (synchronization).

(2) Voltage Checks

Voltage measurements, when compared with available voltage charts, provide a valuable aid in locating the trouble. However, the sensitivity of some test voltmeters differs from that of the voltmeter used to make the charts. In such cases, there will be a discrepancy in voltage readings, and they must then be evaluated before the true circuit conditions can be determined. A voltmeter of low sensitivity may disturb a circuit or even render it inoperative.

(3) Resistance Checks

Resistance changes are often the cause of a malfunction and degraded performance. The change in a resistance can then be detected by measuring the dc resistance with an ohmmeter between a given point and a reference (usually ground). Point-to-point resistance charts are provided in the technical manuals and SIMM's.

(4) Tube Testing

Electron tubes are more prone to failure than is any other electronic component. It is unwise, however, to attempt to make a general tube check in an equipment containing a large number of tubes. Before tube testing is attempted, the area of trouble should be localized as much as possible to avoid excessive tube tests. Only the tubes in a circuit judged to be faulty should be tested along with tubes associated with the faulty circuit.

When replacing a tube, equipment control settings should be noted before insertion of a new tube. A new tube should always be tested for gas or for shorts before insertion. If, with the new tube, the equipment performs abnormally and changing the control setting does not correct the trouble, the original tube should be reinserted, provided that it did not prove defective on a reliable checker. Tubes should not be swapped at ramdon, as the interelectrode capacitance of a tube is a factor in a tuned circuit, and indiscriminate swapping may detune certain circuits. Also, sockets and tube prongs are bound to be damaged from excessive swapping.

(5) Semiconductor Testing

Transistors, unlike vacuum tubes, are very rugged in that they can tolerate vibration and a rather large degree of shock, and under normal operating conditions will provide for a long period of dependable operation. However, transistors are subject to failure when subjected to excessive temperature and minor overloads.

To determine the condition of semiconductors, various test methods are available. In many cases it is possible to substitute a transistor of known good quality for a questionable one, and thus determine the condition of a suspected transistor. This method of test is highly accurate and sometimes expeditious for plug-in types. However, indiscriminate substitution of semiconductors in critical circuits is to be avoided. When transistors are soldered into equipment, this substitution becomes impracticable; it is generally desirable to test these transistors in their circuits.

Since certain fundamental characteristics are an indication of the condition of semiconductors, test equipment is available for testing these characteristics with the semiconductors both in and out of their circuits.

f. FAILURE ANALYSIS

After the faulty component, misalignment, etc., has been located, but prior to performing corrective action, the procedures followed up to this point should be reviewed to determine exactly why the fault affected the equipment in the manner it did. This review is usually necessary to make certain that the fault discovered is actually the cause of the malfunction, and not just the result of the malfunction.

2-5 ALTERATIONS

An alteration is any change in hull, machinery, fittings, or equipment which involves changes in design, materials, number, location, or relationship of the component parts of an assembly, regardless of whether undertaken separately or together with repairs. Changes in allowances of installed equipment are alterations and should be so handled.

The word "approve" in connection with an alteration indicates the Command's action on the proposed change. Command approval is promulgated in letters of technical instruction or SHIPALTS. Approval alone, however, does not constitute authority to proceed with the work. The word "authorize" is used to signify the Command's permission to proceed and the granting of funds for a particular ship during a particular availability.

Alterations which affect the military characteristics of a ship may be approved only by the Chief of Naval Operations, who also establishes their relative priority for accomplishment.

Alterations other than those affecting military characteristics are approved by the cognizant commands without reference to CNO. In general, alterations of this type concern matters of safety, efficiency, and economy of operation or upkeep (recorded in the Operational Improvement Plan) and health and comfort of personnel (recorded in the Habitability Improvement Plan). The command concerned is responsible for determining whether or not military characteristics are involved.

Alterations to vessels which are made necessary by changes in armament or by changes in equipment furnished by other commands are under the cognizance of the Naval Ship Systems Command.

a. SHIPALTS

Approved alterations to ships under the cognizance of the NAVSHIPS Command are known as SHIPALTS. Each quarter these are listed according to priorities (A, mandatory; B, essential; and C, desirable), are compiled as type priority lists, and are forwarded to cognizant Type Commanders for information. Type Commanders are requested to review outstanding approved alterations annually and initiate action to cancel those no longer considered essential.

Priority lists are also forwarded to the cognizant naval shipyards for guidance in advance planing; for proceeding with design, procurement, and installation work; and for resolving conflicting demands upon personnel and facilities.

In order to facilitate record keeping in the case of multiple building programs, alterations ordered in ships under construction which are also approved as SHIPALTS for ships already delivered are indicated by including the ships under construction in the applicable SHIPALT. This facilitates the orderly accomplishment of these alterations after delivery in case they are not completed during the construction period.

Items omitted from master lists are assigned appropriate priorities at the time work is authorized for applicable ships, or upon request.

The NAVSHIPS Command reviews outstanding SHIPALTS for an individual ship in advance of its scheduled overhaul period and issues, not later than 180 days before such overhaul, a list of the alterations authorized for accomplishment during the overhaul. The list is based upon available funds and equipment. The order of priority follows, as far as practicable, that of the type priority lists. The Type Commander and the commander of the overhauling naval shipyard are requested to comment upon this list. Upon receipt of their recommendations, the NAVSHIPS Command modifies, as considered desirable, the original list of authorized alterations.

SHIPALTS are issued on NAVSHIPS Form 4720/4 (formerly NAVSHIPS 99). Upon completion of an alteration, Section IV of the record must be returned to NAVSHIPS with an endorsement reporting its completion and a statement to the effect that the ship plans and technical manuals have been corrected to record the changes made.

b. ORDALTS

Ordnance Alterations (ORDALTS) provide the standard means by which naval activities are furnished plans, instructions, and material for accomplishment of alterations or modifications to naval ordnance material in service or in store.

An ORDALT instruction states the specific conditions of applicability of the ORDALT and the method by which the ORDALT is accomplished.

An ORDALT set provides the material necessary for the accomplishment of the ORDALT.

Whenever possible, ORDALTS will be prepared in such a fashion that they are unclassified, and can be accomplished by forces afloat without the assistance of contractor field engineers except as follows:

1. ORDALTS either too complex or too time consuming to be accomplished by forces afloat will be prepared, whenever possible, so that they are unclassified and can be accomplished by shipyard personnel during ship availability.

2. In certain situations, contractor personnel (field engineers and/or installation teams) may be assigned to provide technical assistance or to accomplish the ORDALT.

2-6 FIELD CHANGES

Electronic Field Changes provides operational, reliability, and maintainability improvements to existing electronic equipment. In addition, assistance is provided in the areas of installation, identification, and logistic support. These improvements, which overcome deficiencies in design and material, are accomplished after manufacture and delivery to the Navy. Prompt accomplishment of all applicable field changes is mandatory to the extent stated in the instructions that accompany the field changes.

a. CLASSES OF FIELD CHANGES

There are three class designations (A, B, and C) for field changes, one of which is assigned to each field change kit. They provide an abbreviated method of indicating the funding and installation responsibility.

A Class A field change requires no installation funding. These field changes are approved for accomplishment (installation) by forces afloat or station personnel on ship- or shore-installed equipment without further reference to the cognizant management command, under conditions stated in the field change instructions.

A Class B field change requires Fleet installation funding (not applicable to shore-installed equipment except at training activities). Changes to shipboard equipment are approved for accomplishment by naval shipyards or repair facilities without further reference to NAVSHIPS, under conditions stated in the field change instructions, when authorized by Type Commanders. Changes to equipment at training activities are approved for accomplishment and funded by the appropriate Systems Command.

The issuance of field changes which require Fleet funding for accomplishment is discontinued. Except for class B field changes presently under procurement, in the supply system, or in Fleet installation planning stage, this type of field change will no longer be issued.

A Class C field change normally requires industrial assistance for installation, and requires the appropriate Systems Command installation funding. This class of field change includes, but is not limited to, changes of an operational improvement nature which are to be authorized and accomplished by SHIPALT in the Modernization Plan. Changes to equipment at training activities are approved for accomplishment and funded by the appropriate Systems Command.

b. TYPES OF FIELD CHANGES

A Type I field change kit consists of the publications material (field change bulletins and publication corrections) and all parts, materials, and special tools required to accomplish the change to one equipment and to revise existing equipment nameplates, publications, and charts.

A Type II field change consists only of publications material required to accomplish the change to the equipment and to revise existing equipment publications and charts. The publications material may be promulgated in the form of the bulletins and correction material, or by means of a published article. Type II changes may require the parts be requisitioned from stock.

A Type III field change kit consists of the publications material (field change bulletins and publication corrections), and only a portion of the parts, materials, and special tools required to accomplish the change to one equipment and to revise existing nameplates, publications and charts.

A Type IV field change kit consists of only publications material required to accomplish the field change to the equipment and to revise existing equipment publications and charts. The Type IV field change information will be in the form of a publication package, but may be promulgated in advance by means of a published article such as in the Electronic Information Bulletin (EIB). Type IV field changes do not require the use of parts, materials, or special tools.

c. RECORDING ACCOMPLISHMENT OF FIELD CHANGES

The completion of all field changes, alterations, and modifications to electronic equipment authorized by NAVSHIPS shall be recorded on Field Change Record Card, NAVSHIPS 537. This card is part of the Current Ship Maintenance Project (CSMP) which is discussed in the General EIMB, NAVSHIPS 0967-000-0100.

d. REPORTING ACCOMPLISHMENT OF FIELD CHANGES

Except as required in Bureau of Ships Instruction 10550.1 Series, accomplishment of field changes should not be reported to NAVSHIPS. However, the performance and operational reports required on certain equipment should list the field changes that have not been accomplished. Refer to the General EIMB, NAVSHIPS 0967-000-0100 for information concerning the Electronic Performance and Operational Report.

SECTION 3

ROUTINE MAINTENANCE AND MAINTENANCE AIDS

3-1 SAFETY FIRST

Before attempting any repair or maintenance work on electronic equipment, be sure the equipment is disconnected from the power supply and that the main switch is properly tagged so that it cannot be inadvertently energized. If there is any doubt as to whether the supply circuits have been de-energized, they should be checked with a voltmeter or voltage tester. Make certain that the power supply filter capacitors are shorted and grounded using an approved grounding stick. Check the wiring diagram also to determine if there are any other capacitors that should be discharged by connecting their terminals to each other and to ground by use of a shorting stick. An exception to the rule for deenergizing the equipment may be made when it is necessary to observe operation. In this case, observe the safety precautions necessary to prevent shock or arcs which might start fires, ignite explosive vapors, or be injurious to the health of personnel. Refer to articles contained in EIMB General Handbook NAVSHIPS 0967-000-0100, Section 3, and the Naval Ships Technical Manual NAVSHIPS 0901-967-0000, Section V (formerly Chapter 67 of the Bureau of Ships Technical Manual), for general electronic safety precautions.

3-2 ROUTINE MAINTENANCE

Routine maintenance is the application of special procedures of inspection, cleaning, and lubrication of an equipment or system on a scheduled basis in order to keep an equipment or system at the most reliable and efficient operating level at all times.

a. CLEANING AND INSPECTION

A regular schedule of cleaning and inspection will go far toward ensuring trouble-free operation and the detection of incipient faults before they develop into a major source of difficulty. Cleaning procedures are given in most electronic equipment technical manuals and reference standards books. Where definite times for cleaning and inspection are not specified in the instructions given in the applicable technical manuals for the equipment, each ship should set up a schedule or periodic cleaning and inspection at intervals sufficiently short to keep the equipment ready for service. In setting up such a schedule, the following points should be considered:

1. All electronic equipment must be cleaned to assure good performance; such cleaning is not for appearance only.
2. Steel wool or emery in any form shall not be used on or near electronic equipment.
3. Sandpaper and files should not be used except as a result of competent advice.
4. A vacuum cleaner with a nonmetallic nozzle and adequate dust receiver should be used whenever practicable.
5. Solvents are to be used only when absolutely necessary and then only after proper safety precautions have been taken.
6. Care must be exercised when cleaning to avoid damaging components.

Dirt and foreign matter, if allowed to collect on heat dissipating components, acts as thermal insulators which prevent internally created heat from dissipating into the air. When this happens, the electronic components affected operate at abnormally high temperatures. This condition shortens the life of the component and thus precipitates a breakdown of the electronic equipment itself. Periodic cleaning of interior of radio transmitters or other equipments employing high voltage is particularly important. Potentials in excess of 3000 volts are often present in these equipments, and dust on insulators or other high voltage components forms a convenient path for arc-overs and consequent damage. In addition, a mixture of dust and lubricant forms an abrasive which can do considerable damage to moving of dust and lubricant forms an abrasive which can do considerable damage to moving of parts.

(1) Ultrasonic Cleaning

Ultrasonic cleaning is rapidly becoming the accepted method of cleaning various shipboard electrical and electronic hardware. Properly applied and intelligently used, ultrasonics will do a more thorough cleaning job than any other method presently known. For cleaning jobs, the utility of this tool is limited only by the size or weight of the part and ingenuity of the person using it. As with any new tool, attention must be given to understanding the tool—how it works and how to make it work for you.

Basically, two things are required for any efficient and satisfactory cleaning operation: the cleaning solution and the method. Cleaning solutions are either water-based solutions or solvents. The method is the way in which the solution is applied: hand scrubbing, soaking, spray washing or ultrasonic cleaning.

Ultrasonic cleaning utilizes both chemical and physical action. The proper solutions are selected first to loosen the chemically bonded material, then ultrasonic cavitation of the solution loosens the mechanically bonded material (dirt). Cavitation is a phenomenon in which vacuum bubbles are rapidly generated and violently collapsed in the solution. As these bubbles collapse, they exert a scrubbing force against the surface of the part placed in the solution.

Detergents play a large part in ultrasonic cleaning. Addition of a detergent to water decreases the amount of energy lost in cavitation. Addition of a wetting agent also accelerates degassing of the solution. Some of the initial energy is consumed in degassing air from the solution before maximum cavitation is achieved. The air bubbles formed during degassing act as an energy sink which reduces the energy generated by the ultrasonic transducer.

Detergents are of three basic types: alkaline, acidic, and solvent. Alkaline detergents generally consist of such alkalies as caustic phosphates, silicates, carbonates and surface active agents. Cleaning solutions onboard submarines must be limited to alkaline solutions to avoid atmospheric contamination. A satisfactory cleaning job can generally be done with alkaline detergents. Acids and solvents may be used in shipyard and repair ship ultrasonic cleaners if the material used for the cleaning tank, drain valves and piping is stainless steel or monel. Generally, the solution that is best for cleaning the part by conventional methods (soaking, flushing and rinsing) is also best when using ultrasonics.

To do a good cavitating job, cleaning solutions must meet the following conditions:

1. Their density must be about that of water or a little higher.
2. They must have a relatively low vapor pressure at the working temperature of the bath.
3. They must remain thin bodied and non-viscous at operating temperature.

These three characteristics—density, volatility, viscosity—are important from the standpoint of cavitation. Sonic energy levels are down to approximately one-sixth capacity in chlorinated solvents and one-tenth capacity in fluorinated solvents as compared to water-based solutions.

In addition, the following conditions also affect cleaning:

4. Length of time in ultrasonic cleaner (usually 15 minutes maximum).
5. Temperature of solution.
6. Height of solution.
7. Type of rinse (pressurized spray is preferred type).
8. Cleanliness of solution.
9. Types of cleaning fixtures used (baskets, subtanks, wire hangers, etc.).
10. Position of part (area to be cleaned should be completely submerged in solution).
11. Line voltage fluctuations.
12. State of cleaning solution (new or used).

For components saturated with oil, presoaking in a hot detergent solution in another tank is highly recommended. This method removes excess surface dirt and oils to lengthen the life of the ultrasonic cleaning solution and recirculation system filter.

When a cleaning job requires a stronger cleaning solution than is normally used, or a solution that is not compatible with materials used in the ultrasonic cleaner, a small subtank or container should be used. The subtank material should be compatible with the cleaning solution. The subtank with the solution should be suspended in the cleaning solution in the ultrasonic tank so that the bottom of the subtank is at least several inches away from the bottom of the ultrasonic cleaning tank (make certain that the top of the subtank remains above the weaker cleaning solution in which it is partially submerged). Glass breakers with cracks should not be used as a subtank because the ultrasonic method will break the cracked container. The loss in cleaning efficiency with a subtank is negligible if the wall thickness of the subtank is equivalent to the wall thickness of the ultrasonic tank. Due to the smaller amount of cleaning solution required, this method is less hazardous to operating personnel, and dumping the solution is less a problem.

Highly caustic cleaning solutions should not be kept in the ultrasonic cleaner beyond the time required for a particular cleaning job. After dumping the cleaning solution, the drain system of the ultrasonic cleaner should be flushed with fresh water. Copper drain pipe and brass drain valves will be eroded by any standing caustic cleaning solution. For the same reason, aluminum parts or components should not be cleaned in highly caustic solutions.

The amount of air trapped in the cleaning solution affects the intensity of cavitation and cleaning ability. Some of the initial energy will be consumed in degassing air from the solution before maximum cavitation is achieved. Ultrasonic agitation will effectively degas liquids; however, the bubbles formed during degassing act as an energy sink that may rob a transducer of energy. Therefore, a new or stagnant solution must be degassed before full ultrasonic cleaning efficiency is realized. The time normally required for degassing detergent solutions is approximately 15 minutes; fresh water may require as much as 30 minutes. Ability to recognize the degassed condition for the various cleaning solutions comes with experience.

Flushing or rinsing the cleaned part is extremely important in the overall ultrasonic cleaning process. The detergent keeps the particles of contamination suspended in the cleaning solution. When the cleaned part is removed from the ultrasonic tank, it is recontaminated by these suspended particles. Therefore, flushing or rinsing of the cleaned part is required to remove these loose particles. Rinsing should be in the direction opposite to the normal fluid flow through the filter. True cleaning is assured only by flushing or rinsing.

Ultrasonics alone is not the complete answer to cleaning problems, but it is one tool in the overall cleaning system. Since the type and degree of contamination vary even for the same application, no fixed process can be specified for all conditions.

(2) Ultrasonic Cleaning of Modular Assemblies

The choice of ultrasonic cleaning equipment should be governed not so much by the transducer type as by the intensity of cavitation needed to perform a given task, and the reliability of the equipment under conditions of rigorous field use. A typical ultrasonic cleaning unit is a unit in which the frequency of the ultrasonic oscillator is approximately 20,000 hertz. The amount of energy required by the transducers to reach this threshold of cavitation is naturally dependent on the efficiency of the transducers, as well as the acoustic properties of the liquid, the frequency, the temperature, the presence of standing waves, and other factors.

For example, a good rule of the thumb in selecting the proper generator is to multiply the capacity of the tank (number of gallons) by a quantity of 50 to 70, to derive the required power in watts.

After selection of the ultrasonic cleaner and solution (see table 3-1) for a particular cleaning task, follow the procedural steps below, in the sequence given.

1. Place the contaminated assembly or parts (in a wire-mesh basket or suspended on a wire hook) into the cleaning emulsion contained in the ultrasonic cleaning tank, and energize the equipment.

NOTE: Only baskets that are specifically designed for ultrasonic work should be used. Baskets are available from equipment manufacturers. Avoid the use of small mesh, which has the tendency to cut down on the amount of ultrasonics.

Table 3-1. General Guide for Ultrasonic Cleaning

PRINCIPAL USE	TYPICAL PRODUCTS	CLEANING CHEMICAL	BATH TEMPERATURE & IMMERSION TIME
General cleaning of water contaminants (finger prints, buffing compounds, shop dirt, blood, animal and vegetable oils, inks, milk residues, chemical salts and residues, carbohydrates, radioactive contaminants, food particles, dried soaps).	Surgical instruments and laboratory glassware, flasks, pertri dishes, syringes, ampullae, catheters, nursing bottles, eyeglasses and frames, pipettes, test tubes, microscope slides and covers, jewelry and precious stones, technical and optical glassware, dentures, plates, bridges, fossils, archeological specimens, styrene and methacrylate plastics, poly-plastics, hypo needles, plastic contact lenses, ceramics, precision metal products, quartz crystals.	Concentrated water base detergent, containing silicates, phosphates, synthetic detergent, wetting agent.	Room temp. to 200°F 15 sec to 5 min.
Same as No. 1, except to remove tartar, nicotine, hard soap deposits.	Same as No. 1, but is more effective on lab and optical glass, jewelry, dental appliances, eyeglasses, polishing and buffing compounds, surgical instruments.	Ammoniated concentrated water base detergent containing silicated, phosphates, wetting agents.	Room temp. to 200°F 15 sec to 5 min
General cleaning of solvent soluble contaminants (mineral oils, greases, pitch, shop soils, tar, paraffins, waxes, fats, fluxes, alkyd and polyvinyl printing inks, marking compounds, silicone oils and greases, methylmethacrylate and styrene).	Gears, bearing, electrical contacts, micromodule wafers, type faces, data film and tape, filters, semiconductor parts, mechanical devices, glass lenses, optical parts, gyros, electronic components, relays, tuning forks, bellows, electronics, ceramics, polyvinyl and polyethylene plastics, hermetic seals, precision metal products, screw machine products, connectors, technical and optical glass, electric motors, generators, armatures, machined parts, dressing tools and stones, precision stampings and castings, gas and water meters, cameras, microscopes, sight mechanisms, gages, measuring instruments, potentiometers, printed circuit boards, wax impressions.	Chlorinated hydrocarbon solvent.	Room temp. to 120°F 10 sec
General purpose pickling agent, and remover of tarnish, oxide, heat-treat scale, dried blood, milkstone.	Stained surgical instruments, chrome, cadmium, titanium, copper base alloy and steel, parts and instruments, aluminum, prepaint finishing, phosphatizing.	Concentrated water base phosphoric acid.	Room temp. to 150°F 1 to 10 min
Removes milkstone, investment plaster, temporary cement, zinc oxide, rust, oxides from cast iron and steel, heat-treat scale and smut from hardened steel.	Precision investment castings, brewery and dairy stainless steel valves and process apparatus. Temporary dental splints, gold, acrylic, chrome crowns, inlays. Can be used on copper and alloys, ferrous metals, chrome, molybdenum, tin.	Powdered and inhibited acid.	100° to 180°F 3 to 30 min

Table 3-1. General Guide for Ultrasonic Cleaning—Continued

PRINCIPAL USE	TYPICAL PRODUCTS	CLEANING CHEMICAL	BATH TEMPERATURE & IMMERSION TIME
Removal of corrosion or oxides on ferrous metals, salvaging engine parts (valves, bearings, pumps, etc.). Precleaning of heavy greases shop dirt, drawing and lubricating oils, prior to solvent cleaning.	Ferrous metals, bearings, mechanical parts, diamonds, orthodontic appliances. Not to be used on aluminum, magnesium or zinc.	Heavy duty alkaline soda ash, powder.	120° to 180°F 1 to 10 min
Carbon and lead deposit cleaner, heavy greases, and preservatives, buffing compounds, drawing and lubricating compounds, wax and paraffin, shop dirt.	Aircraft, marine and automotive engine parts, spark plugs, valves, pistons, cylinders, rings, filters, jet fuel nozzles.	Water base emulsion.	120° to 180°F 1 to 30 min
Copper cleaner, brightener and tarnish remover also clean shop dirt, chips, grinding and cutting coolants, light oils and greases.	Thermostats, relays, switches, jacks, connectors, brass and copper machinings and castings, copper sheet and laminates.	Water base moderately alkaline cleaner.	Room temp. to 140°F 1 to 5 min
Rust and heat-treat scale cleaner, oils, greases, buffing compounds, drawing lubricants, grinding oils, and coolants, cutting oils and coolants, printing and typewriter inks.	Filaments of vacuum tubes, tungsten, steel, drawn wire and rod, heat-treated metal parts.	Powdered alkaline.	100° to 180°F 1 to 15 min
Silver cleaner, brightener and tarnish remover.	Thermostats, relays, switches, jacks, connectors, silverware, sterling silver.	Water base acid cleaner.	Room temp. to 140°F 1 to 10 min.
All-purpose emulsion-solvent agent for one bath duo-cleaning of water soluble and solvent soluble contaminants. Heavy greases, oils, waxes, marking compounds, grinding, drawing, cutting oils, lubricants and coolant in any combination.	Pitch, ink, wax and paint marking compounds and grinding compounds from glass lenses, carburetors, engine parts.	Light brown organic and chlorinated hydrocarbon solvents.	Room temp. to 180°F 30 sec to 5 min

2. Leave the immersed assembly or parts in the cleaning solution for approximately 2 to 3 minutes (depending on the amount and type of contamination).

NOTE: Use immersion heaters to heat the solution to a suitable temperature, depending on the type of solution used.

3. Remove the assembly or parts being cleaned from the ultrasonic cleaning tank, and flush with fresh water (preferably warm or hot).

4. Drain the cleaning emulsion from the cleaning tank, and refill the tank with fresh water.

5. Place the assembly or parts (in a wire-mesh basket or suspended on a wire hook) into the tank of fresh water, to remove the remaining cleaning emulsion.

6. Remove the assembly or parts from the fresh water bath, and blow as much water as possible from the cleaned parts with dry, filtered air at no more than 50 lb/in^2 pressure.

7. Spray all surface areas with a water-displacing fluid.

8. After spraying, allow approximately 20 minutes for the water-displacing fluid to penetrate the crevices and combine with the remaining water.

9. Blow the residual mixture of water and water-displacing fluid from the assembly or parts with dry, heated air from a portable electric blower, or place into an air-drying circulating oven.

The electronic equipment can now be reinstalled and operated after drying and check-out of the units and components.

If the equipment cannot be returned to operational condition, it should be sprayed again with the water-displacing fluid, and the drying process repeated.

WARNING: Operating personnel should not immerse their hands in ultrasonic baths over long periods of time, since some burning of skin tissue may result.

Although ultrasonic cleaning is not a cure all for cleaning electronic assemblies, when properly employed for a specific application it is a very fast, efficient, and reliable way of removing contamination. Also, ultrasonic cleaning units provide a degree of cleanliness that could not be obtained previously by other techniques.

(3) Cleaning Solvent Hazards

The technician who smokes while using a volatile inflammable cleaning solvent is inviting disaster. Unfortunately, many such disasters have occurred. For this reason, the Navy does not permit the use of gasoline, benzine, ether, or like substances for cleaning purposes. Only non-volatile solvents shall be used to clean electrical or electronic equipment.

In addition to the potential hazard of accidental fire, many cleaning solvents are capable of damaging the human respiratory system in cases of prolonged inhalation. Inhibited methyl chloroform (1,1,1, trichloroethane) should be used where water compounds are not feasible. Methyl chloroform has a threshold of 500 parts per million (ppm) in air, whereas carbon tetrachloride has a threshold of 25 ppm. The threshold is the point above which the concentration in air becomes dangerous. Methyl chloroform is an effective cleaner and about as safe as can be expected when reasonable care is exercised. Care requires plenty of ventilation and observance of fire precautions. Avoid direct inhalation of the vapor. Inhibited methyl chloroform is not safe for use with a gas mask since the vapor displaces oxygen in the air.

The following list of "Dos" and "Don'ts" will serve as effective remainders to maintenance technicians who must use cleaning solvents.

1. Use a blower or canvas wind chute to blow air into a compartment in which a cleaning solvent is being used.
2. Open all usable port holes and place air scoops in them.
3. Don't work alone in a poorly ventilated compartment.
4. Place a fire extinguisher nearby and ready for use.
5. Don't use solvents in the presence of any open flame since this may lead to the formation of phosgene gas, which is very poisonous.
6. Don't use carbon tetrachloride as it is a highly toxic compound.
7. Don't apply solvents to warm or hot equipment as this increases the toxicity harzard.
8. Don't directly breathe the vapor of any cleaning solvent for a prolonged period.
9. Use water-based compounds in lieu of other solvents wherever feasible.
10. Wear rubber gloves to prevent coming into direct contact with the solvent.
11. Wear gloves when spraying solvent on permissible surfaces.
12. Hold the nozzle close to the object being sprayed.
13. Don't spray cleaning solvents on electrical windings or insulation.

For additional information on the safety precautions to be observed when using solvents, see the NAVSHIPS Technical Manual.

(4) Cleaning of Air Filters

Some air filters on naval electronic equipment are designed to be installed with a film of oil on the filter element. Filters of this type provide effective filtration with a minimum reduction of air flow. When this type of filter is used without an oil coating, as is done in many ships, the filter effectiveness is greatly reduced. The major disadvantage of the oiled filter is in cleaning. This drawback may be overcome by washing the filter element in a standard shipboard dishwashing machine (if an air filter cleaning room or area is not provided) as recommended in NAVSHIPS Technical Manual, Chapter 38, Paragraph 109 for air conditioning filters. No special procedures are necessary, although dirty filters may require two washings. The man-hours used in cleaning equipment air filters, and oiling when required, will be more than regained in improved reliability of the equipment.

Some of the commercial air filter adhesives (filter oils), to be used when required, authorized by the Navy are found in Table 3-2.

Table 3-2. Air Filter Adhesives

ADHESIVES DESIGNATION	SUPPLIER
Airsan 1-S	Air Filter Corporation Milwaukee, Wisconsin
Filterkote "M" or "W"	Air Maze Corporation Cleveland, Ohio
"NCC" Viscosine	American Air Filter Company Louisville, Kentucky
WS-4530	Esso Standard Division, Humble Oil & Refining Company New York, New York
Super Filter Coat	Research Products Corporation Madison, Wisconsin
Chevron Filter Coat (applied at 160°F)	Standard Oil of California San Francisco, California
EAC-2	Trion, Incorporated McKees Rocks, Pennsylvania

WARNING: Adhesives in the pressurized (aerosol) spray cans are not approved for use in the Navy due to the possibility of toxicity caused by by the decomposition of the released gas.

(5) Cleaning of Transistor Heat Sinks

As the complexity of electronic equipment increases, the available space for individual components has all but disappeared. Widespread use of transistors in equipment design means more heatwill be generated with less space in which it can be dissipated, thereby causing an ever-increasing environmental temperature in which the transistor must operate. The transistor is completely dependent upon its ability to absorb and dissipate the internally generated heat while operating at the increased temperature which it has generated. For this reason, heat dissipating devices, referred to as heat sinks, are being utilized to increase the heat dissipating capability of the transistor and to prevent transistor failures due to excessive heat.

Transistor heat sinks are designed to utilize the natural methods of conduction, convection, and radiation in order to reduce the transistor case and junction temperatures and thereby increase the overall reliability of the transistor. To obtain maximum transistor life, it is of utmost importance that the transistor temperature be kept within its design tolerance. Therefore, all transistorized equipments should be inspected on a routine basis to ensure that heat sinks are free of any accumulation of dust or dirt, that air filters are clean, and that proper air flow is maintained either from natural sources or forced air systems.

b. LUBRICATION

Electronic equipments which utilize moving mechanical parts require periodic lubrication. Failure to lubricate jeopardizes the useful life of the mechanical part and thus precipitates a breakdown of the electronic equipment. It is essential that maintenance personnel be thoroughly familiar with the lubrication requirements of the equipments for which they are responsible. Proper lubrication of the mechanical components in electronic equipment is emphasized in technical manuals and in reference standards books.

(1) Lubrication of Ball Bearings

Improper greasing procedures are a frequent cause of derangements to rotating electrical machinery provided with grease-lubricated ball bearings. The trouble is generally caused by forcing an excessive quantity of grease into the bearing housing, with either one or both of the following results:

1. Grease is forced through the bearing housing seals and onto the windings and, in the case of DC machines, onto the commutators where it causes deterioration of insulation and eventually results in grounds or short circuits.

2. The excessive quantity of pressure of grease in the bearing housing result in churning, increased temperatures, rapid deterioration of the grease, and ultimate destruction of the bearing.

The following instructions apply generally to all equipment except oil-lubricated bearings, synchros, and similar devices where friction must be maintained at an absolute minimum, and equipment for which approved lubrication charts or other specific instructions are furnished by the Navy.

(a) Grease Cups — Motors and generators provided with bearings that should be lubricated with grease are now normally delivered from the manufacturer with the grease cups removed from the bearing housings and replaced with pipe plugs. The grease cups are delivered with the onboard repair parts or special tools. It is recommended that grease cups be attached to electric motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole which remains should be plugged with a suitable pipe plug. When this procedure is used, the grease cups should remain in the custody of responsible maintenance personnel and can be stored in the workshop or toolroom. This procedure is particularly advantageous when the motors and generators maintained by a particular group of maintenance personnel need only relatively few different sizes of grease cups. This procedure should also be followed for motors and generators which have been supplied with grease cups attached to the machine.

NOTE: Care should be taken to make sure that a grease cup is clean before it is used to add grease to a bearing and that the pipe plug used to replace the grease cup after greasing is also clean.

A typical Grease Lubricated bearing is shown in Figure 3-1.

(b) Selection of Grease — The grease used for grease-lubricated ball bearings should be selected as follows:

1. Bearings which normally operate at a temperature of 194°F (90°C) or below should be lubricated with grease in accordance with Military Specification MIL-G-18709.

2. Bearings which normally operate at a temperature below 194°F (90°C) should be lubricated with a silicone grease in accordance with Military Specification MIL-L-15719A. Machines which require this special grease have a caution plate stating "USE HIGH TEMPERATURE GREASE" which is attached near the grease fitting by the manufacturer.

(c) Adding Grease — Bearings on new machines are properly lubricated when they leave the factory. The frequency with which grease must be added depends upon the service of the machine and the tightness of the housing seals, and should be determined for each machine by the engineer officer. Ordinarily, the addition of grease will not be necessary more often than once in six months. The use of excessive quantities of grease is to be avoided because it causes bearing failures. When a bearing housing is too full of lubricant, the churning of the grease generates heat which in turn causes deterioration of the grease. Under these conditions the grease separates into oil and minute abrasive particles, becomes increasingly sticky, and tends to seal the bearing against fresh lubricant until the resulting friction, heat, and wear cause failure of the bearing. To avoid the difficulties caused by an excessive amount of grease, add grease only when necessary, and, whengrease is added, it should be done as follows:

1. Wipe outside of grease fitting and drain plug free of all dirt.

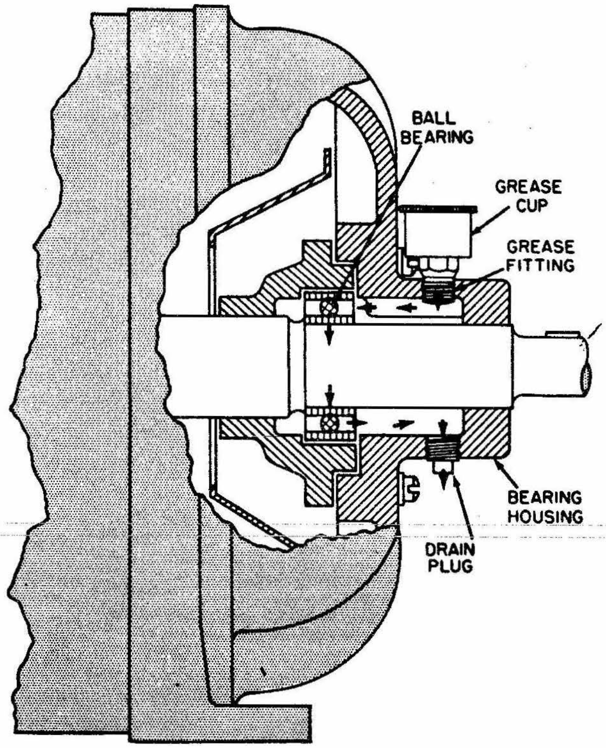


Figure 3-1. Grease-Lubricated Ball Bearings

2. Remove bearing drain plug, and make sure the passage is open by probing with a clean screwdriver or similar implements.

3. Remove pipe plug on top of grease pipe. Select proper grease cup and clean it thoroughly. Install bottom portion of grease cup on the grease pipe. Put in the top portion of the grease cup no more grease than will half fill it.

4. Empty and clean out the receptacles of the grease fitting down to the neck, then fill with clean grease.

5. Replace the grease cup and screw it down as far as it will go.

6. Run the machine and let grease run out of drain hole until drainage stops (normally about 30 minutes). Remove grease cup and replace pipe plug.

7. Replace the drain plug.

8. Do not use a grease gun to lubricate bearings unless there are no other means available. If a grease gun must be used, remove the drain plug in the bearing housing while greasing and use extreme care to avoid inserting too much grease or applying more than just enough pressure to get the grease into the housing.

(d) Renewal of Grease Without Disassembling the Bearing Housing — Removal of grease without at least partial disassembly of the bearing housing is not recommended. In any case, renewal of grease without at least partial disassembly of the bearing housing should not be attempted unless the following conditions apply.

1. The machine is horizontal. In vertical machines, there is no adequate means of protecting the windings against displaced lubricant.

2. A suitable fitting is provided for admitting grease. If a grease-gun fitting is provided, it should be replaced by a grease cup.

3. The drain hole on the bearing housing is accessible. Drain pipes do not permit satisfactory escape of displaced grease, and should be removed when renewing grease.

The machine must be capable of being run continuously while renewing grease. If the machine cannot be run continuously during the greasing period without injuring the driven auxiliary or endangering personnel, the bearing housing must be disassembled as described in paragraph (e) to renew grease.

If the above conditions apply, the grease may be renewed in assembled bearing housings by the following method:

1. Run the machine sufficiently to warm up the bearings.

2. Wipe any dirt away from the area around the grease fittings.

3. Remove the drain plug and drain pipes from the drain hole in the bearing housing.

4. With a clean wire, screwdriver, or similar implement, clear the drain hole of all hardened grease.

5. Remove the grease cup and clear the grease inlet hole of hardened grease.

6. Fill the grease cup with fresh clean grease, reinstall the cup and screw it down as far as it will go. Keep the machine running continuously.

7. Repeat steps (4) and (6) above until clean grease begins to emerge from the drain hole.

8. At this point it is important to stop inserting grease and allow the machine to run until no more grease comes out of the drain hole.

9. Clean any drain pipes which have been removed, and reinstall the pipes.

10. Install the drain plug.

Be careful to keep grease from reaching the electrical windings. The emergence of a large quantity of grease through the shaft extension end of the housing indicates excessive leakage inside the machine.

(e) Renewal of Grease with the Bearing Housing Disassembled — The extent of disassembly necessary will depend upon the construction of the bearing. For the usual construction which uses bearings with outer bearing caps, the following method should be used:

1. Remove the outer bearing cap after thoroughly wiping all exterior surfaces.

2. Remove old grease from all accessible portions of the housing and clean these parts thoroughly. Be careful not to introduce dirt or lint into the bearing housing.

3. Flush out the bearing cap with clean hot (about 120°F) kerosene, diesel fuel oil, or dry cleaning fluid (Federal Specification P-D-680). Follow this by flushing out with a light mineral oil (not heavier than SAE10, similar to diesel lubricating oil, N.D. Specification 14-0-13 symbol 9110).

4. Where practicable, plug all holes leading into the interior of the machine and flush out the complete housing with the outer bearing cap removed. Use the solvents and procedures described in the preceding paragraph. This should not be done on

equipment where the conditions are such that the cleaning fluids may leak into the windings. In such cases, omit this step.

5. Drain the mineral oil thoroughly; then pack housing half full with fresh, clean grease, and reinstall the outer bearing cap.

(f) Oil Lubricated Ball Bearings — Some electric motors and generators may be equipped with oil-lubricated ball bearings. Lubrication charts or special instructions are generally furnished for this type of bearing and should be carefully followed by personnel maintaining the equipment. In the absence of other instructions, the oil level inside the bearing housing should be maintained approximately level with the lowest point of the bearing inner oil ring. This will provide enough oil to lubricate the bearing for a considerable operating period, but not enough to cause churning or overheating.

One common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick, which also filters the oil and prevents leakage through the cup in the event that momentary pressure is built up within the housing. A typical wick-fed, oil lubricated ball bearing is shown in Figure 3-2.

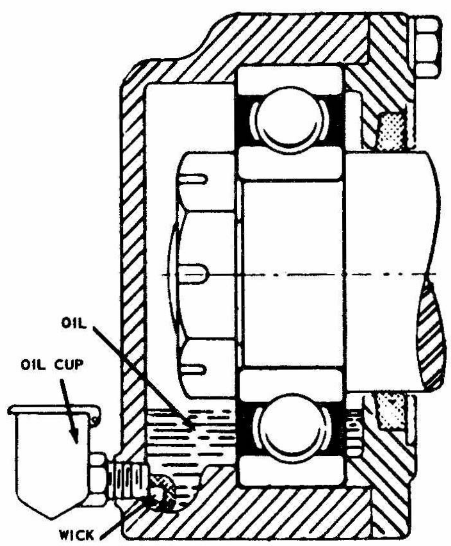


Figure 3-2. Wick-Fed Ball Bearing

(2) Lubrication of Sleeve Bearings

When lubricating sleeve bearings, proceed generally as follows:

1. Take every precaution to keep the oil and bearings clean and free from water or foreign particles.

2. Do not add oil while the machine is running. This affords an opportunity for oil mist or spray to escape from the bearing housing and be blown on the machine windings.

3. Bearings having an overflow gage should be filled until the oil is about one-sixteenth inch from the top of the gage. If the machine is equipped with an oil filler gage, the gage should be filled to the manufacturer's oil level mark, or (if no mark is available) the gage should be between two-thirds and three-quarters full at all times. Be sure that the gage glass and piping to the gage are clean or the glass will give false indications of the oil level. If the bearing has neither an overflow gage nor an oil filler gage, fill it to a level such that the oil ring dips into oil to a depth of about half the shaft diameter.

4. When the bearing and bearing housing are in good condition, there should be no loss of oil. If the proper oil level cannot be maintained without adding oil, it is probable that oil is leaking from the bearing. Be sure oil sight gage connection to bearing is tight. Much of the oil that leaks out of a bearing is drawn into the machine by the cooling air and sprayed onto the windings where it causes oil soaked dirt to collect. This condition tends to cause insulation failure. If oil leakage is suspected, carefully clean and chalk the shaft outside the bearing, the outside of the bearing housing, and the parts of the rotor adjacent to the bearing. If the machine is throwing oil, discoloration of the chalk will so indicate after a short run. This test is not dependable unless the chalked part is made perfectly clean at the beginning of the test. If leakage is found, the labyrinth seal in the bearing housing should be corrected to make it effective. Another possible source of leakage is from the vent with which some labyrinths are provided. Make sure that any such vent is not stopped up and that it vents into still air at atmospheric pressure, and where there is no current of air over the vent that will suck oil out of the bearing housing or oil vapor out of the vent into the machine. Such oil leakage is often due to overfilling the bearing or trying to fill the bearing through the vent.

5. Bearing oil should be renewed semiannually. Drain the oil off by removing the drain plug, then flush the bearing with clean oil until the drained oil flows clean.

(3) Types of Lubricants

The correct choice of a lubricant for electronic equipment is important, especially if the equipment is being operated under adverse conditions. To assist in the selection of the correct lubricant the following lubrication charts are provided.

Chart 1 (Table 3-3) lists all lubricants specified in MIL-L-17192D (SHIPS) (NAVY), Military specifications of lubricants, and lubrication information for electronic equipment. Many electronics technical manuals and their associated publications refer to many of these lubricants by Military Symbols. These symbols, where applicable, are added to the chart for cross referencing.

Chart 2 (Table 3-4) provides cross referencing between the old and new Military Specification designations assigned to lubricants as listed in Federal Supply Catalogues.

Chart 3 (Table 3-5) provides Military Specification designations and Federal Stock Numbers for those lubricants listed in electronics publications by the "Manufacturer's Designation."

Chart 4 (Table 3-6) provides a listing of those lubricants which are used in electronics equipments and are listed in electronics publications but not listed in MIL-L-17192D (SHIPS).

Table 3-3. Standard Navy Lubricants

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
VV-P-236 Petrolatum, Technical	8 oz. tube 1 lb. can 5 lb. can 35 lb. pail 120 lb. drum 400 lb. drum	9W9150-250-0931 9W9150-250-0926 9W9150-250-0933 9W9150-250-0928 9W9150-530-7368 9W9150-244-4869	PET	Amber Petrolatum U.S.P.	For use as a light grade of lubricating grease but not recommended for use as a lubricant in heavily loaded or hot running bearings. It may be used as a constituent in certain types of rust preventive compounds.
VV-I-530 Insulating Oil Electrical	1 qt. can 1 gal. can 1 gal. can 5 gal. pail 55 gal. drum	9W9160-685-0912 9W9160-611-2000 9W9160-082-2428 9W9160-685-0913 9W9160-685-0914			Dielectric strength 30,000 volts, with exception of 9W9160-082-2428 which is 40,000 volts. Used in oil-immersed transformers, oil switches, and oil circuit breakers.
P-D-680 Dry Cleaning Solvent	5 gal. pail 55 gal. drum	9W6850-274-5421 9W6850-285-1986	SD-2		For general cleaning of air filters electronic equipment, and other general purpose cleanup.
MIL-G-23827 Grease, Aircraft and Instrument	1 oz. tube 4 oz. tube 8 oz. tube 1 lb. can 5 lb. can 35 lb. pail	9W9150-985-7243 9W9150-985-7244 9W9150-985-7245 9W9150-985-7246 9W9150-985-7247 9W9150-985-7248	GIA		In ball, roller, needle bearings, gears and sliding and rolling surfaces of such equipment as instruments, cameras, electronic gear and aircraft control systems. Particularly suitable for equipment which must operate at both very low and very high temperatures for short periods. Does not contain extreme pressure or special antiwear additives. It is destructive to paint, natural rubber, and neoprene.
MIL-G-15793 Grease, Instrument	4 oz. tube 8 oz. tube	9W9150-235-5540 9W9150-235-5541			For lightly loaded bearings of fire control equipment and instruments, including the related components, such as synchros, gyros, and control mechanisms; also for gears bearings, sliding parts and other small precision instruments and devices.
MIL-G-16908 Grease, Ordnance	1 lb. can 5 lb. can 35 lb. pail	9W9150-184-9159 9W9150-235-5542 9W9150-272-7655		Grade I	For lubrication and protection against corrosion of plain ball, and roller bearings, and preservation of threads on ammunitions. Use in lieu of MIL-G-3278 when neoprene will be in contact with grease.
MIL-L-17331 Lubricating Oil Steam Turbine	5 gal. 55 gal.	9W9150-235-9061 9W9150-235-9062	2190 TEP		In main turbines and gears, auxiliary turbine installation, certain hydraulic equipment general mechanical lubrication, and air compressors.

Table 3-3. Standard Navy Lubricants—Continued

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
MIL-G-18709 Grease, Ball and Roller Bearing	8 oz. tube	9W9150-753-4650	BR	Andok B or Nebula EP-1 Grade III	For ball and roller bearings operating at medium speeds and temperature range 125°F to 200°F.
	1 lb. can	9W9150-526-4205			
	5 lb. can	9W9150-663-9795			
	35 lb. pail	9W9150-249-0908			
MIL-L-644 Lubricating Oil General Purpose	2 oz. can	9W9150-185-0629	PL-special		Lubrication and protection against corrosion of small arms, in lubrication of fuze mechanisms, and wherever a general purpose low temperature, lubrication oil is required.
	1 qt. can	9W9150-231-6689			
	5 gal. pail	9W9150-231-9062			
	55 gal. drum	9W9150-281-2060			
MIL-L-2105 Lubrication Oil Gear	5 gal.	9W9150-240-2242	GO-75	SAE 75	For lubrication of automotive gear units, heavy duty industrial-type enclosed gear units, steering gears, and fluid-lubricated universal joints of automotive equipment.
	5 gal.	9W9150-240-2246	GO-80	SAE 80	
	1 gal.	9W9150-754-2635	GO-90	SAE 90	
	55 gal.	9W9150-240-2244	GO-75	SAE 75	
	55 gal.	9W9150-240-2248	GO-80	SAE 80	
	55 gal.	9W9150-577-5845	GO-90	SAE 90	
MIL-L-6085 Lubricating Oil Instrument	1 1/2 oz. btl.	9W9150-664-6518	OAI		For aircraft instruments, electronic equipment, or where a low evaporation oil is required for both high and low temperature application, and where oxidation and corrosion resistance are desirable. Destructive to paint, neoprene and rubber.
	4 oz. can	9W9150-257-5449			
	1 qt.	9W9150-223-4129			
MIL-L-6086 Lubricating Oil Gear	1 gal. can	9W9150-265-9417	Grade L	-10 W-	For use under extremely low temperature, mild extreme pressure type oil with load carrying additive. General use in aircraft gear mechanisms, exclusive of engines.
	1 pt. can	9W9150-240-2235	Grade M	-20 W-	
	1 gal. can	9W9150-223-4130			
	5 gal. drum	9W9150-223-4116			
MIL-L-9000 Lubricating Oil Internal Combustion	5 gal.	9W9150-231-9037	9110	SAE 10	For internal-combustion engines operating under normal load and temperature conditions.
	55 gal.	9W9150-231-9030			
	5 gal.	9W9150-231-6649	9170	SAE 20	
	55 gal.	9W9150-231-6650			
	5 gal.	9W9150-231-6653	9250	SAE 30	
	55 gal.	9W9150-231-6654			
MIL-L-15016 Lubricating Oil General Purpose	1 pt.	9W9150-235-5575	2075	SAE 20W	For all applications which require other than special lubricants, and which are subject to normal variation between ambient and operating temperature. Use in lieu MIL-L-6085 when oil will be in contact with neoprene.
	5 gal.	9W9150-235-5571			
	5 gal.	9W9150-223-4137	2110	SAE 10	
	55 gal.	9W9150-235-5578			
	5 gal.	9W9150-231-6639	2190	SAE 30	
	55 gal.	9W9150-231-6641			
	5 gal.	9W9150-223-4131	3065	SAE 30W	
	55 gal.	9W9150-235-9077			

Table 3-4. Old and New Specification Designations

OLD MILITARY SPECIFICATION	NEW MILITARY SPECIFICATION	REFERENCE
14-P-1	VV-P-236	See Table 3-3
14-G-1	MIL-G-3278	See Table 3-3
14-L-2	VV-L-751a	See Table 3-3
14-L-3	MIL-G-18709	See Table 3-3
14-G-10	MIL-G-16908	See Table 3-3
14-L-11	VV-G-632	See Table 3-6
14-O-12	VV-I-530	See Table 3-3
14-O-13	MIL-L-9000	See Table 3-3
14-O-15	MIL-L-17331	See Table 3-3
14-O-20	MIL-L-6085	See Table 3-3
52-C-18	Cancelled	
AN-G-25	MIL-G-3278	See Table 3-3
AN-O-6a	MIL-L-7870	See Table 3-6
KS 7470	MIL-L-17672 MS2110 TH	See Table 3-6
KS 7471	MIL-G-3278	See Table 3-3
MIL-S-16067	P-D-680	See Table 3-3
VV-O-401	VV-I-530	See Table 3-3
P-S-661	P-D-680	See Table 3-3
MIL-G-3545	MIL-G-81322	See Table 3-6
MIL-G-3278	MIL-G-23827	See Table 3-3

Table 3-5. Manufacturer's Designations

MANUFACTURER DESIGNATION	MILITARY SPECIFICATION	UNIT OF ISSUE	STOCK NUMBER
Lubri-Plate No. 105	None	2 oz.	9W9150-291-9088
Lubri-Plate No. 110	None	1 lb.	9W9150-334-7948
AIRO Lubri-Plate	None	2 oz.	9W9150-030-0451
Molykote "G"	None	1 lb.	9W9150-985-7317
Molykote M-77	None	1 lb.	9W9150-985-7317
Stoddard Solvent 140-F	P-D-680 P-D-680		See Table 2-3 See Table 2-3
MOS, Lube-Powder	MIL-L-7866	10 oz.	9W6810-893-9373
Beacon Lube No. 325	MIL-G-3278		See Table 2-3
GE 10C	VV-I-530		See Table 2-3
GE SS4005	MIL-I-8660	1 oz.	9W5970-159-1598
Dow-Corning DC-4	MIL-I-8660	1 oz.	9W5970-159-1598
McLube MOS_2-210 (formerly MOS_2-200)	None	As Requested	*
McLube MOS_2-1118	None	As Requested	*
Thermotex øøø	None	1 lb.	9W9150-082-2650

*Must be ordered from McGee Chemical Co. Inc., 8000 West Chester Pike, Upper Darby, Pa.

Table 3-6. Lubricants Used in Electronics Equipments But Not Listed in MIL-L-17192D (Navy) (Lubrication Information of Electronic Equipment)

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
51-F-23 Hydraulic Fluid	5 gal. 55 gal.	9W9150-261-8315 9W9150-261-8316			Used in connection with the hydraulic transmission of power. For use with synthetic seal.
VV-K-211 Kerosene	5 gal. 55 gal.	9W9140-242-6749 9W9140-273-2394	K		General uses such as a cleaner for machinery or tools.
MIL-L-7870a Lubrication Oil General Purpose	4 oz. 1 qt. 1 gal.	9W9150-542-1430 9W9150-263-3490 9W9150-273-2397	OGP		Specially designed for use where an oil of low evaporation, possessing rust-protective properties is desired.
VV-G-632 General Purpose Grease	35 lb. 100 lb.	9W9150-272-7656 9W9150-235-5551	CG-1		Automotive chassis, suitable for lubrication of mach. equipped with pressure grease fitting.
MIL-G-7421 Grease Aircraft	1 oz. 1 lb.	9W9150-754-4611 9W9150-190-0883	GAI		Used in rolling and sliding surfaces having very low motivating power.
MIL-G-81322 Grease Aircraft	8 oz. 1 lb.	9W9150-273-2390 9W9150-223-4003	GH		Used in antifriction bearings operating at high speeds and high temperatures.
MIL-S-11090 Cleaning Compound	5 gal. 55 gal.	9W6850-224-6665 9W6850-224-6666			Used as a solvent for cleaning grease and oils.
MIL-L-17672 Lubrication Oil General Purpose	1 gal. 55 gal.	9W9150-753-4799 9W9150-582-5480	2110-H		Used in steam turbines, hydraulic systems, water generators and hydraulic turbine governors.
VV-L-751a Lubrication Oil	35 lb. 35 lb. 35 lb.	9W9150-246-3262 9W9150-246-3267 9W9150-246-3271	CW-1A CW-1B CW-1C		Cold weather. Warm weather. Hot weather. Used for lubricating chain wire rope exposed gears.

c. ENVIRONMENTAL EFFECTS ON ELECTRONIC EQUIPMENT

It is beyond the scope of this subsection to present all the problems encountered from environmental conditions, because individual methods of installation and stowage of electronic equipments differ from ship to ship, and from one Naval shore station to another. However, some of the preventive and corrective measures that should be taken under adverse environmental conditions, and the effects on the equipment subjected to these conditions, are given in the following paragraphs.

(1) Temperature

The cooling or heating of air spaces surrounding the components of electronic equipment is generally accomplished and controlled by blowers, fans, hot oil and water coolers, etc., either to dissipate the heat generated by the equipment components, or to heat or cool the surrounding ambient air. Regardless of the method employed for the cooling or heating of spaces, if maintenance personnel neglect to keep the screens, filters, fans, ducts, surface area of coolers, and equipment free from foreign matter, the heating or cooling will be greatly affected, which may result in equipment damage or malfunction caused by improper temperature control.

Extremely low temperature may cause brittleness in certain types of metals, and loss of flexibility in rubber, insulation, and similar materials.

Extremely high temperature may cause deformation and deterioration of terminal boards, seals, insulation, and heat sensitive devices.

Rapid changes of temperature may be especially damaging to certain types of electronic components.

(2) Humidity

High humidity, the "arch enemy" of electronic equipment, with its resultant damage to equipment components from condensation and fungus growth, under conditions of both high salt-laden moist air and high temperature, is normally found in tropical climates. In this case, adequate ventilation of the equipment is of the utmost importance to protect the equipment components from entrapped moisture and extremely high operating temperatures. To overcome any adverse effects on electronic equipments, maximum and minimum temperature gradients should be controlled by one of the cooling or heating mediums provided.

In many cases, critical electronic components are encapsulated, potted, or sealed to protect them from the detrimental effects of moisture and temperature variations. However, sealing the component does not completely eliminate the problem of high-humidity conditions because the seals sometimes must be broken for maintenance or repair work. There is also the possibility that the maintenance technician will not always have the suitable sealing compounds on hand to repair or replace sealed components. Where this condition exists, except in cases of emergency, the repair or replacement of sealed components should not be performed in the field.

(3) Storage

When electronic equipment and component parts are to be stored, or when they must remain in an inoperative condition for a considerable length of time, additional preventive measures must be taken to prevent detrimental effects from environmental conditions. New or repaired modular assemblies and parts are received in accordance with the applicable packaging specification. When the outer bulky casing (crate or carton with its Kimpak, Reliso-Pak or similar material) is removed, the unit (or units) remains packaged in a water-vaporproof bag. This package should be stored intact until drawn for use as a replacement item by the maintenance technician.

(4) Standby Equipment

Equipment that is to remain idle and deenergized for a considerable length of time should have their space heaters (if provided) turned ON to keep the insulation and equipment dry. If space heaters are not provided for the equipment, electric lamp bulbs or a portable electric heater as a temporary measure can be placed within or near the equipment. This is especially important in humid or cold climates.

(5) Corrosive Atmosphere

The effect of a corrosive atmosphere on metal parts, insulation, etc., can cause serious damage to unprotected electronic equipment. For this reason, the maintenance technician should be cognizant of the harmful effects of all corrosive elements. He must be especially aware of the effects produced by salt spray or salt-unpregnated air. To prevent corrosive effects, a regular periodic cleaning schedule should be established. This schedule should include dusting and cleaning, lubrication of moving parts, and the application of approved solvents or wetting agents to remove any accumulation of foreign matter, such as soil, dust, dirt, oil film, salt-impregnation, etc. In addition, all access doors and panels should be fastened securely and in place when no maintenance work is being performed on the equipment.

(6) Barometric Pressure Effects

Electronic equipment installed in aircraft or submarines is often subjected to severe changes in barometric pressure. To overcome any adverse effects on the equipment, pressurization of individual components by use of pressurized chambers is often employed. These components are hermetically sealed to prevent variations in barometric pressure, and are generally classified as throwaway or non-repairable items. Therefore, the maintenance technician should not attempt to repair such items.

(7) Vibration and Shock

Vibration effects are directly related to the resonant mechanical frequency of the equipment concerned. Vibration caused by loosening of parts or relative motion between parts, can produce objectionable operating conditions such as noise, intermittent circuit malfunctions, short circuits, component electrical overload or burnout, and equipment failure. Mechanical shock caused by impacts or high acceleration or deceleration can result in extensive damage to, or derangement of, the electrical equipment. In order to maintain and minimize the detrimental effects from shock or vibration, shock-mounting and anti-vibration devices of various types and sizes are being employed in shipboard installations to isolate the components and equipments from their mountings. Each device has its own place in the field of isolation; the selection of isolators depends upon specialized requirements and tolerance to the environmental conditions in which they must operate.

Shock-mount and anti-vibration devices are relatively simple in their design and construction and require little maintenance. Conditions of service and age and the condition of the equipment differ from ship-to-ship. Consequently, it is impracticable to provide a rigid schedule of inspections and tests. However, certain general requirements and precautions must be taken and observed to ensure that the mounting clips, shock-mounts, ground straps, and associated hardware are secured and are in place. Precautions must be taken to ensure that paint, oil, solvents, and other types of organic material are not applied to or allowed to come in contact with the resilient surface area of a shock-mount. If allowed to do so, this will result in loss of resiliency, deterioration, and premature failure of the resilient member of the shock-mount.

3-3 MAINTENANCE AIDS

Proper care and maintenance of electronics equipment are dependent on the quality and condition of the tools with which the electronics technician performs his duties. It is important that the technician knows the capabilities of each of his tools and the techniques by which each tool may be used. It is also important that the technician be familiar with methods for the care of his tools. Good workmanship depends not only on the skill of the technician but on the quality of his tools; good clean tools make good, clean work. This section will deal with the tools most likely to be used in electronic maintenance and repair; their various usages will be discussed with regard to safety of personnel and proper maintenance and stowage of the tools.

a. SOLDERING TOOLS

There are three groups of soldering tools used in electronic maintenance. Each group is designed to be used for the particular job at hand such as heavy duty, light or general duty, and intricate soldering on such items as semiconductors, printed circuit boards, and modular assemblies used in electronic equipment.

(1) Soldering Irons

Soldering irons are used for heavy duty types of electronic work such as unsoldering heavy connections and tining surfaces. There are two types of irons; a plug tip and a thermostatically controlled screw-in tip. These irons are shown in Figure 3-3 and the tips used with each type iron are given in Table 3-7.

Table 3-7. Soldering Iron Tips
(Standard Plug Tip Soldering Iron)

DIAMETER (INCH) A ±2 PERCENT	LENGTH EXTENDING FROM SHELL (INCH) B (min)	HEATING TIME (MINUTES) (max)
1/4	1-1/4	2-1/2
3/8	2	4
1/2	2	4-1/2
5/8	2-1/4	5
7/8	2-1/4	6

(2) Pencil Irons

Pencil irons are used for general or light duty work or for intricate work. There are two styles of pencil irons; a plug tip and a screw-in tip with a self contained heat element. The pencil irons are shown in Figure 3-3 and the tips for each style are given in Table 3-8.

Table 3-8. Pencil Iron Tips
(Type III, Style "A", Pencil Plug Tip Iron)

DIAMETER A ±2 PERCENT	LENGTH EXTENDING FROM SHELL (INCH) B (min)	SHELL ASSEMBLY DIAMETER (INCH) C (max)	HEATING TIME (MINUTES) (max)
1/8	7/8	3/8	1-1/2
1/4	1-1/4	1/2	2

(3) Soldering Guns

Soldering guns are used for general purpose or light work when instantaneous heat is required for just a short time. There are two types of guns. Type I utilizes a transformer and a solid copper wire tip and Type II does not have the transformer and uses a straight, solid copper, screw-in tip. The two types of guns are shown in Figure 3-4 and the tips for each type gun are given in Table 3-9.

b. SPECIAL HAND TOOLS

For successful installation, repair, and maintenance of electronic equipment the electronics technician must have not only a high degree of mechanical skill and dexterity, but also a thorough knowledge of the proper selection and use of tools. Most faults in electronic maintenance cannot be corrected without the use of tools. The ease with which a repair can be made is often a direct function of the tool selected to perform a given task. In the performance of their duties, maintenance personnel should be provided with, or have access to, at least one each of the basic tools listed in the Electronics Tool Allowance List and also have access to the special hand tools discussed in the following subsections.

(1) Punches

Punches (shown in Figure 3-5) are often useful in electronics work. The punches usually found in the electronics shop are the center punch, starting punch, pin punch, aligning punch, gasket punch, and various types of chassis punches.

The center punch is used to make a punch mark for starting a drill. The point of this punch is carefully ground to an angle of 60 degrees which is the same as the angle of a standard twist drill. Drills will start more quickly and have less tendency to wander if they are started in a punched hole.

The starting punch is used to knock out rivets after the heads have been cut off. It is also used to start driving out straight and tapered pins because it can withstand the heavy hammer blows necessary to break the pin loose and start it moving. This punch is made with a long gentle taper extending from the tip to the body of the punch.

The pin punch is made with a straight shank and is used to follow-up on the job requiring a starting punch. After a pin has been partially driven out with a starting punch, which is limited in use because of its increasing taper, the pin punch with its slim shank is used to finish the job. The pin punch should never be used as a starting punch because a hard blow may cause the slim shank to bend or break. The largest size starting the pin punches that will fit into the hole should always be used. The pin punch should never be struck with a glancing blow as it may break the punch and; pin punches may be difficult to remove from the hole.

The aligning punch is from 12 to 16 inches in length and has a long taper. This punch is used for moving or shifting plates or parts so that corresponding holes will line up. It should never be used as a pry bar.

The hollow shank gasket punch is used for cutting holes in gaskets and similar materials. The cutting end is tapered to a sharp cutting edge to make clean, uniform holes. The material to be cut should be placed on a soft background such as lead or hardwood so that the cutting edge will not be damaged.

The scratch awl, or metal scribe, is also in this category of tools. It is used to mark soft metals and can serve as an alignment tool.

Punches are made of tool steel, tempered and hardened at the point. A punch should never be used to work on extremely hard metals or remove bolts by force because its point will be dulled.

The chassis punch provides a quick method of cutting round, round-keyed, square, or "D" shaped holes in steel up to 16-gauge in thickness. These punches are made of tool steel and are operated by screw action to provide clean cut holes. The round chassis punches are available in sizes ranging from 1/2 to 3 inches in diameter. To use the chassis punch, a hole slightly larger than the punch screw size must be drilled in the material at the center of the hole to be cut. The punch must then be disassembled. The cutter section has two cutting edges located symmetrically for balance and is threaded to

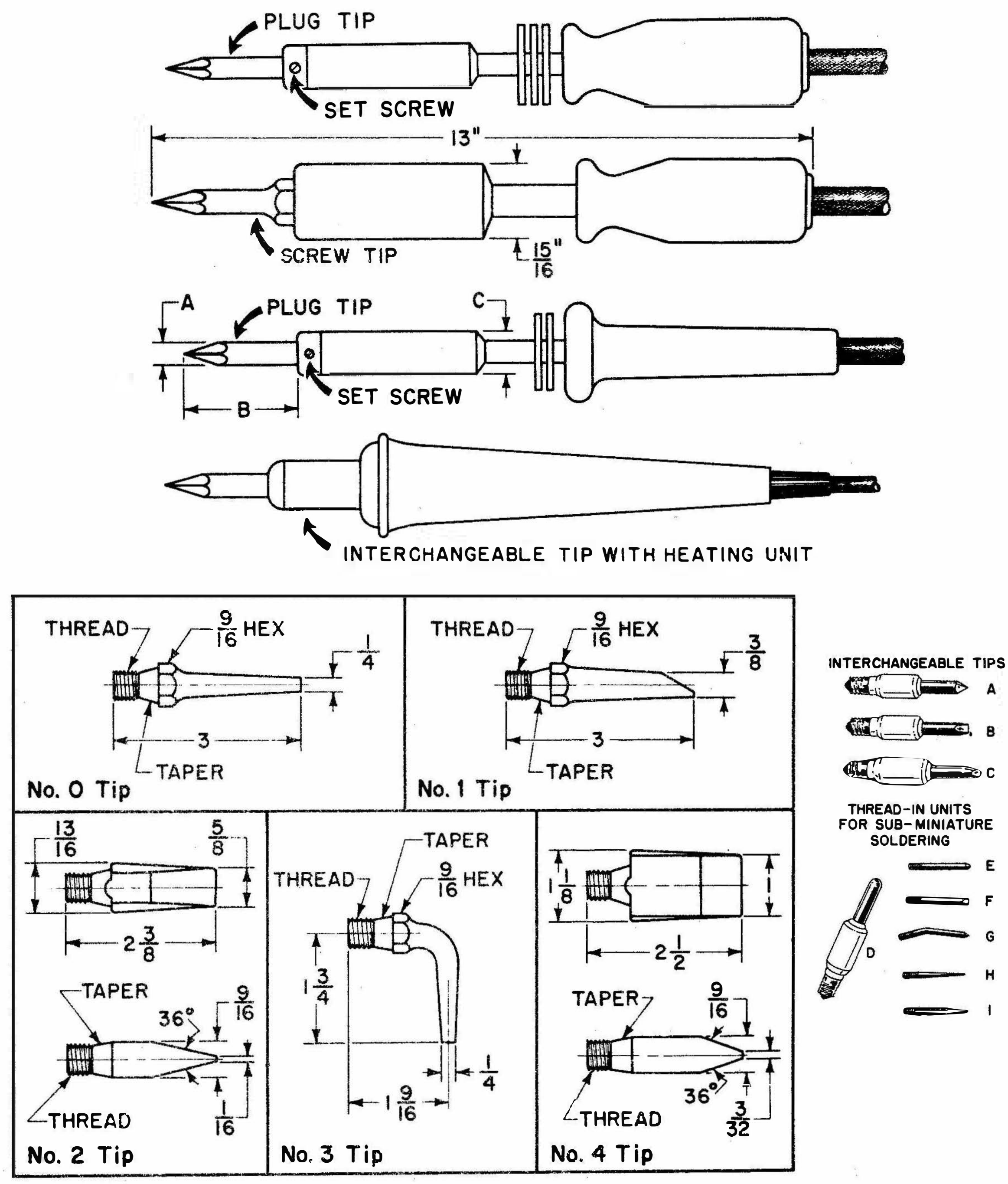


Figure 3-3. Types of Soldering Irons and Tips

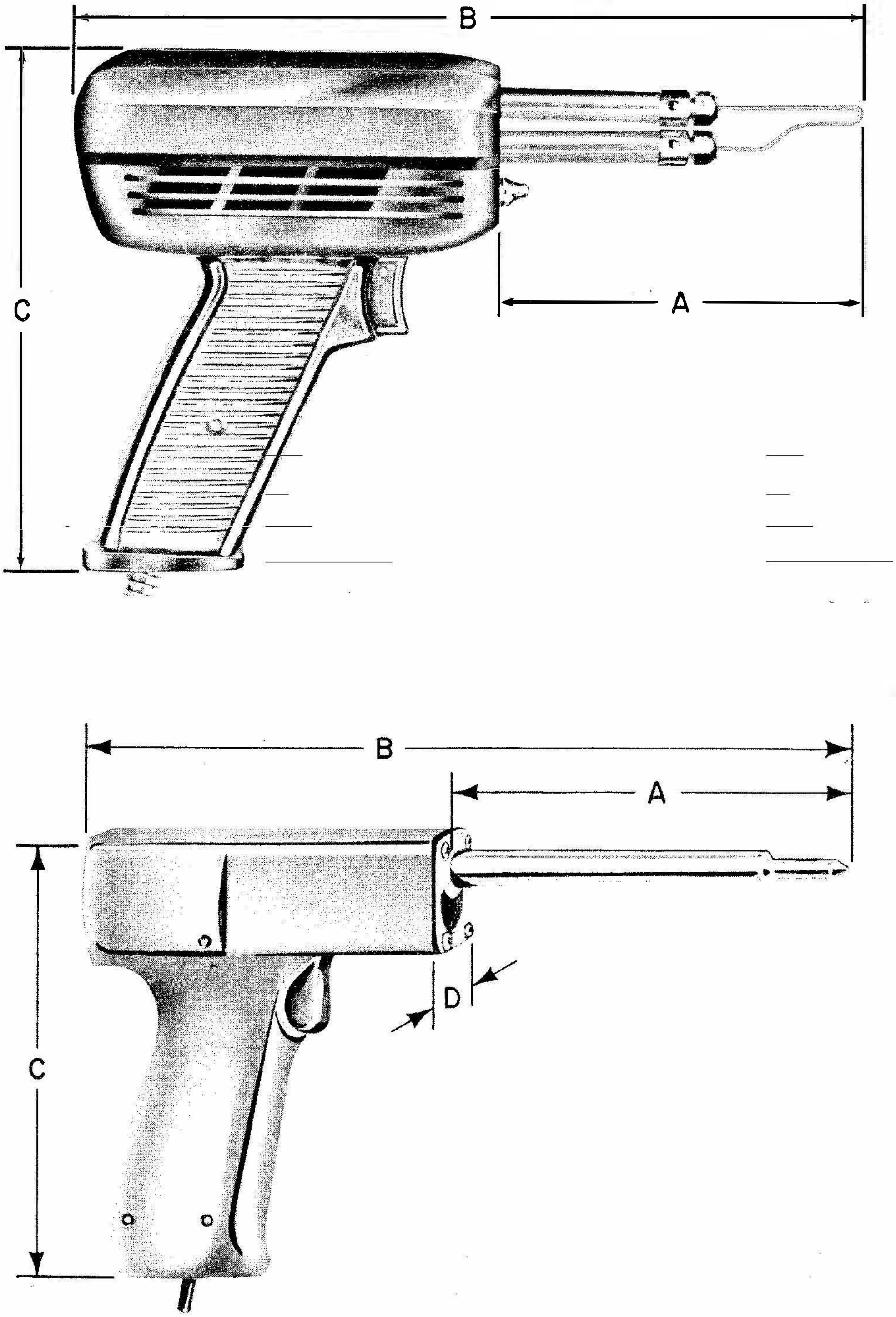


Figure 3-4. Soldering Guns

Table 3-9. Soldering Gun Tips

CLASS	DUTY	WEIGHT WITHOUT CORD (OUNCES)	A TIP LENGTH (INCHES)	B OVERALL LENGTH (INCHES)	C LENGTH (INCHES)	D WIDTH (INCHES)
(Type I Soldering Guns)						
1	Heavy	50	5-7/8	12	7	3
2	Medium	48	5-3/8	12	7	3
3	Light	40	5-3/8	12	7	3
(Type II Soldering Guns)						
1	Heavy	50	6-1/2	12	6	1-1/2
2	Medium	16	6	10	5-1/2	1-3/8
3	Light	10	5	9	5	1-1/4

receive the bolt (punch screw). The bolt is placed through the die section and then through the drilled hole in the material. The bolt is then screwed into the cutter until it is "finger tight." A wrench of the proper size to fit the bolt head is then used to turn the bolt clockwise until the cutter has completely cut through the material. After the hole is made, the punch must be disassembled again and the metal removed from the die. The edge of the hole in the material should be smoothed and deburred with a half-round file.

(2) Taps, Dies, and Reamers

(a) Taps — The tap is a tool used for cutting threads to receive a machine screw. These threads are cut into the sides of a hole which has been drilled for the root (minor diameter) of the screw. The tap is numbered the same as the screw; if a No. 5-40 screw is to be used, a No. 5-40 tap is used to cut the threads in the sides of the hole. There are three styles of taps; the taper, the plug, and the bottoming tap. All three styles will cut the same size thread required but the style selected is determined by the situation and/or depth requirement. The taper tap diameter gradually increase in size and may be used when the work permits the tap to be run entirely through the hole. The plug tap, whose first few threads are chamfered, will produce threads almost to the bottom of a hole. When threads are required to the very bottom of a hole, the plug tap is used and then removed and the bottoming tap is used since it will cut through to the bottom of the hole. The tap is held in a special holder known as the tap wrench. There is the straight handle type and the T-handle type wrench. The three styles of taps and the two types of tap wrenches are shown in Figure 3-6.

(b) Dies — The die is a thread-cutting device used to cut threads on outside surfaces, whereas taps are used to cut threads on inside surfaces. Dies are made to cut right-hand or left-hand threads and are found in a variety of forms. There are adjustable round split dies for screw and bolt threading; square solid dies for hose fittings; hexagon solid dies for dressing over bruised or rusty threads; and various types for pipe threading. The die holder is called a die stock. A die and die stock are shown in Figure 3-6.

(c) Reamers — A reamer is used to make a true circular hole, or for enlarging a hole. Unless a hole has been drilled perfectly true, the resulting hole will be slightly eccentric or slightly oversize. There are various styles of reamers such as the solid spiral, solid straight and the tapered hand reamer used in sheet metal work for enlarging small holes to the desired size. The various styles and types of reamers are shown in Figure 3-6.

(d) Countersinks — A countersink is a reamer which is used to bevel the edges of a hole. It is generally used in the electronics maintenance shop to countersink screw holes so that flat head machine screws will be flush with the chassis surface. The countersink is found in many angles and the one selected should have the same angle as the head of the flat head machine screw being used. In an emergency, a drill twice the diameter of the screw hole may be used. A countersink is shown in Figure 3-6.

(3) Rotary Cutting Tools

Rotary cutting tools commonly used in electronics work and shown in Figure 3-7, are the circle cutter, rotary hacksaw, and the carbide cutter. These tools are used to cut large circular holes from 1 to 5-1/2 inches in diameter in material up to 1 inch in thickness.

(a) Circle Cutter — The circle cutter (commonly called a "Fly-cutter") is used in a drill press to cut large holes. It consists of a body provided with a square tapered bitstock shank, fitted with a replaceable 1/4-inch straight diameter shank twist drill and an adjustable round bar carrying a renewable cutter bit. To use the circle cutter, determine the size of hole to be cut and use the following procedure:

1. Adjust the round cross arm so that the distance from the point of the guide bit to the tip of the cutter bit is one-half the diameter of the hole to be cut. Securely tighten the cross arm locking screw in the cutter body.
2. Adjust the guide bit so that it extends approximately 1/2-inch beyond the tip of the cutter bit and then tighten the guide bit locking screw in the cutter body.
3. Place the shank of the circle cutter in the chuck of the drill press.

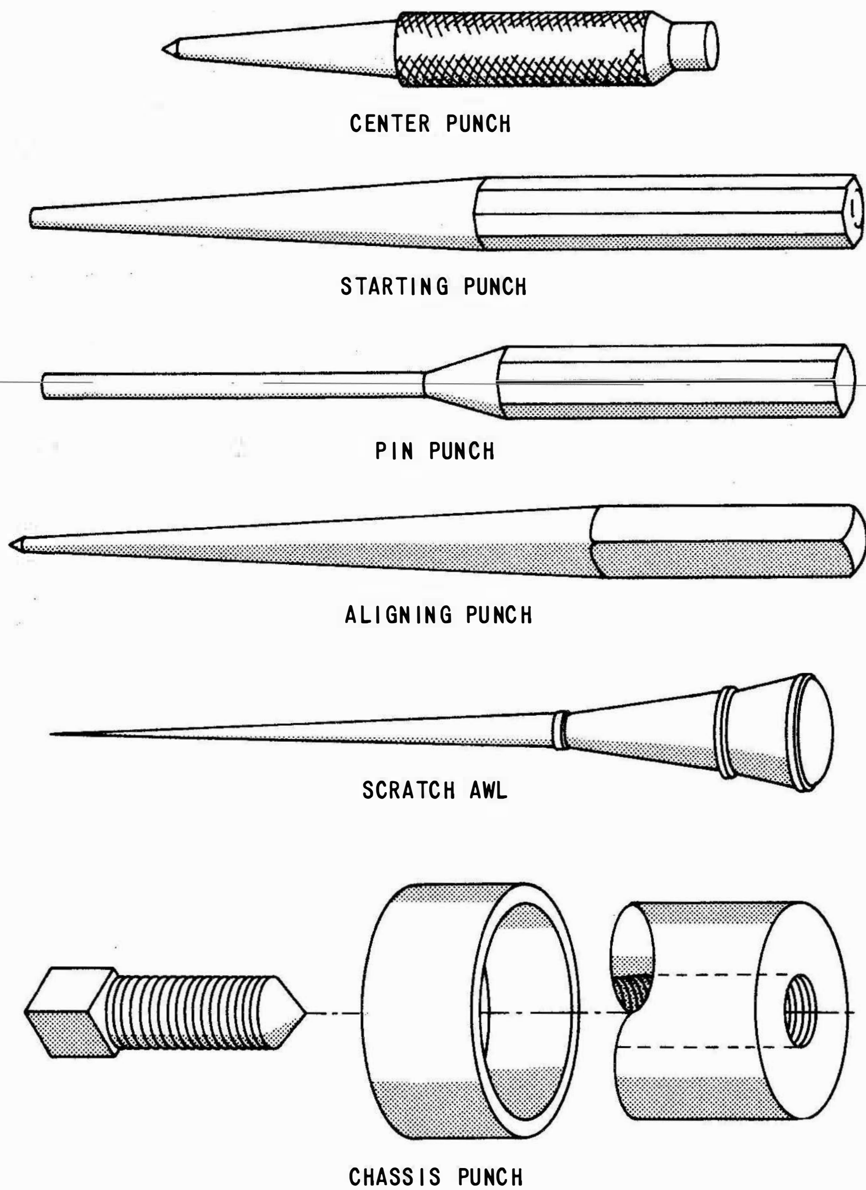


Figure 3-5. Punches

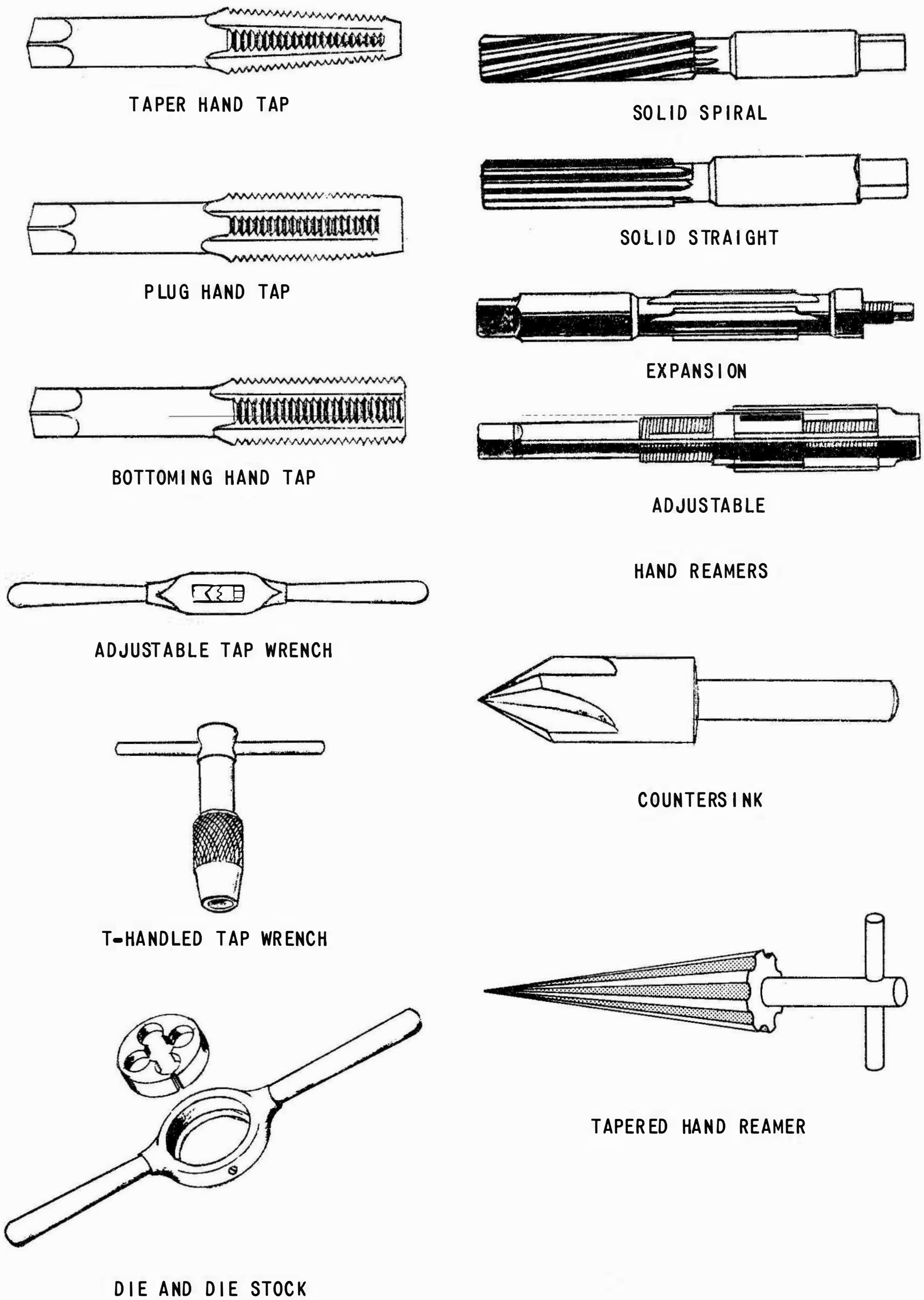
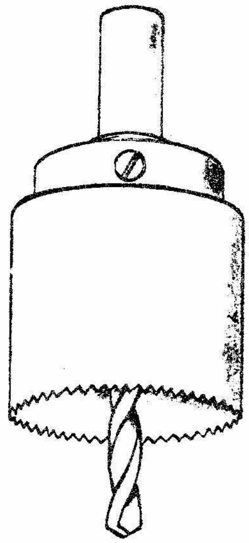
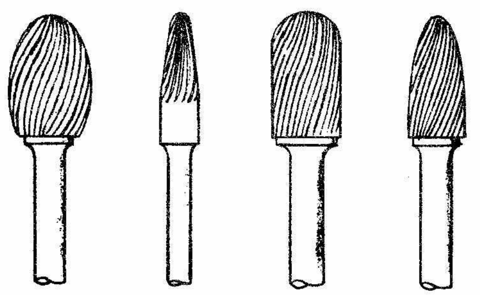


Figure 3-6. Taps, Dies, and Reamers



ROTARY HACKSAW



CARBIDE ROTARY CUTTERS

Figure 3-7. Rotary Cutting Tools

4. Clamp the work on a wooden block which will support the entire area of the circle to be cut. Tighten the clamps to ensure that work will not rotate with the cutter.

5. Center punch the center of the circle to be cut.

6. Place the tip of the guide bit on the punch mark and commence drilling the hole.

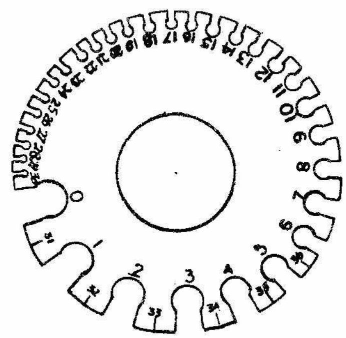
7. Continually apply pressure until the cutter bit has cut through the material.

(b) Hacksaws — The rotary hacksaw shown in Figure 3-7, can be used to cut large holes through any machinable material up to 1 inch in thickness. The rotary hacksaw is for use in drill presses or portable electric hand drills. It has a high speed steel cutting edge which is electrically welded to a tough, alloy steel body; it has a high speed steel pilot drill, heavy hexagonal shanked arbors and a sufficient set for deep drilling. Rotary hacksaws are self-aligning as the larger diameter saws float on their arbors and are driven by double drive pins. The material should be center punched for the pilot drill and clamped in a vise or on the drill press table. When using an electric hand drill, the drill should have a no-load speed of not more than 1500 r/min.

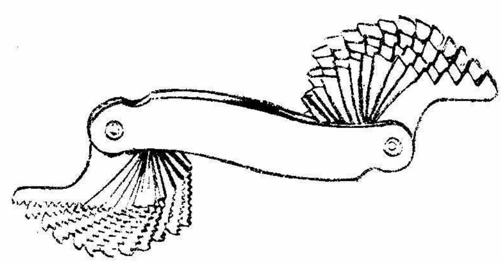
(c) Carbide Cutters — Carbide cutters shown in Figure 3-7, are rotary cutting tools made of solid carbide and are used in drill presses, portable electric hand drills, and flexible shaft tools for grinding, filing, burring, countersinking and cutting metal. They are available in various lengths and sizes with both 1/8- and 1/4-inch diameter shanks.

(4) Wire and Thread Gauges

Wire and thread gauges are used to determine the size of wire and the number of threads per inch on a screw respectively. There are various types and styles of wire and thread gauges in use today. The most common type of these gauges are shown in Figure 3-8.



WIRE GAUGE



SCREW THREAD GAUGE

Figure 3-8. Wire and Thread Gauges

(a) Wire gauges — The wire gauge is used to determine the size of a wire. It is usually a circular in shape with notches around its edge and a number along side. To use this gauge, insert the wire into the smallest notch that will accept it and note the corresponding number.

(b) Thread Gauges — The thread gauge is used to determine the number of threads per inch of a screw. It consists of a number of leaves attached to a handle. The leaves are accurately machined on one edge to conform to the standards of the cross-sectional shape of the screw threads they are made to measure. The threads per inch of a screw are determined by placing the screw against each leaf of the gauge until the threads of the screw exactly match those of the leaf. The markings of this leaf indicate the number of threads per inch.

(5) Wire Strippers

When preparing wires for terminations and connections, the removal of the insulation without damaging the conductor is of prime importance. It has been established by experience that the only practical way of preventing damage to conductors when removing insulation from wires is by using tools designed for this purpose. Two types of wire strippers are shown in Figure 3-9. The first type is the simpler of the two, and is especially useful for stripping insulation in tight quarters. To use it, you place the end of the lead into the cutting groove of the stripper; hold the wire in one hand, the stripper in the other hand and pull downwards, away from the cutting edges of the groove. The second type is used when stripping many wires. When using this type of wire stripper, you must place the wire into the correct groove to avoid cutting the end off the conductor instead of stripping off the insulation.

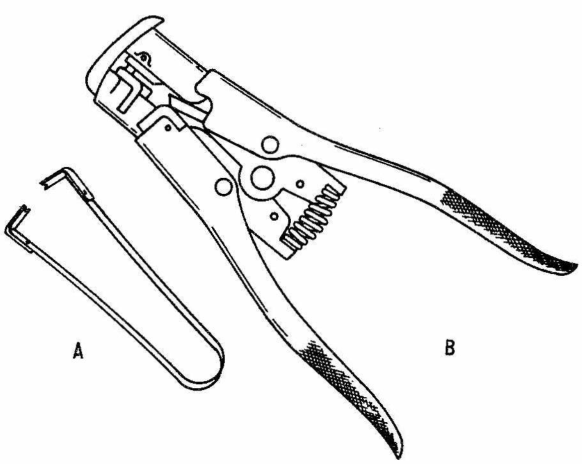


Figure 3-9. Wire Strippers

(6) Tube Puller

The tube puller shown in Figure 3-10 is used to pull a hot tube without waiting for it to cool down. The puller holds on to the tube by suction. To use it, you push the button, seat the puller on the tube, release the button, and pull the tube.

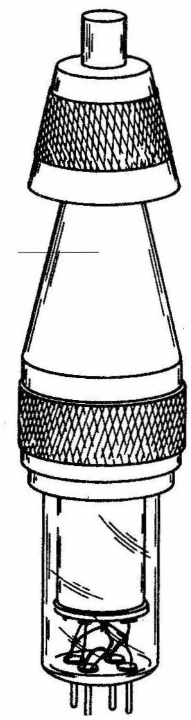


Figure 3-10. Tube Puller

c. REFERENCE PUBLICATIONS

Various publications, some of which are discussed below, are available for guidance in maintenance work, or for reference and study by electronics personnel. Some of these publications are as vital to intelligent maintenance as is test equipment.

In general, publications are available from the Naval Supply Depot, Philadelphia. However, before requisitioning such material, consideration should be given to the equipment installed, the mission of the ship or activity, the purpose of and distribution policy for the individual publications, and the available stowage space.

Because it is essential that reference material be as current and accurate as possible, publication changes and corrections should be entered as they become available. For example, if the current issue of the EIB corrects information in an earlier issue, the earlier issue should be changed. If the change affects other publications (technical manual, field change bulletin, and parts allowance list, for instance), these also must be corrected. The changes must be legible and accurate. If no page is furnished for recording completed changes, some method for recording these changes should be devised. One method is to make notes in the margin of the new material to indicate the publications in which the change has been entered.

By assigning to specific individuals the responsibility for making all changes in designated publications, and by checking their entries from time to time, the Electronics Officer will do much toward eliminating the possibility of his crew using incorrect repair information.

In order that an activity's file of publications may be kept up to date, current issues of the NAVSHIPS Technical News, the EIB, and the Index of Forms and Publications (NAVSUP 2002) should be examined for information on the availability of handbooks, final technical manuals, revision supplements, and changes pertaining to the equipment on board.

(1) NAVSHIPS Technical Manual

NAVSHIPS Technical Manual (NAVSHIPS 0901-960-0000), issued in three volumes, is the most complete and authoritative reference available on NAVSHIPS equipment. This handbook is issued as an informative and comprehensive guidance to Naval personnel, afloat and ashore, who are responsible for, or engaged in, the installation, operation, maintenance, and repair of equipment under cognizance of the Naval Ship Systems Command.

(a) Scope — This manual contains administrative and technical instructions not included in the U.S. Navy Regulations or other publications of higher authority but which are deemed necessary for a clear understanding of the requirements of the technical work and equipment under the cognizance of the Naval Ship Systems Command.

The date and instructions in the handbook are in accordance with what is considered the best engineering practices for operation, maintenance, testing, and reliability of the equipment and for the safety of the personnel concerned. Chapter 9670 of the Manual, titled "Electronics" is required reading for electronics personnel. This chapter also lists other chapters containing information of value to electronics personnel.

The instructions and data contained in this handbook do not intrude on or interfere with the internal organization of a ship or with perogatives of the operational commander.

In order to make the instructions clear, brief descriptions and illustrations of type units or outstanding examples of subtypes in the same class have been included. However, for complete information of design details, operation, adjustment, and care of equipment, the manufacturer's Technical manuals must be consulted.

(b) Distribution — Each chapter of the manual is prepared as a separate pamphlet so that individual chapters may be issued to Naval vessels or other Naval activities for use in the instruction of Naval personnel. Copies of individual chapters shall be requisitioned directly from the U.S. Naval Publications and Forms Center, Philadelphia, Pa. 19120, in accordance with NAVSUP Publication 2002, using DD Form 1348 (NAVSTRIP). Requests from U.S. Naval Activities for the complete manual (Volume I, II, and III) are no longer required. Requisitions from other Departments of Defense, other Government agencies, and foreign nationals for the subject manual, still require Command approval and are to be forwarded to the Naval Ship Systems Command. This manual, including the binder, is the property of the Naval Ship Systems Command. It shall be returned to the Command when no longer required.

(2) Equipment Technical Manual

The equipment technical manual (TM), which is presently prepared to specification MIL-M-15071G provides information on a particular equipment.

(a) Scope — The information provided in the TM is a functional description, installation procedures and directions, theory of operation, operation, troubleshooting, maintenance and repair, and spare parts. These categories are grouped into eight chapters; the content of which is described below.

CHAPTER 1 — GENERAL INFORMATION

This chapter provides a functional description of the equipment for command personnel, supervisory personnel, and others seeking a general understanding. The functional description is non-technical and explains the intended use, the physical and functional operational capabilities, the purpose, limitations, and the relationship of units that comprise the equipment. Illustrations of each unit are provided for physical identification and to show the basic interconnections and relative sizes. A tabular listing of all equipment, accessories, and documents supplied including any government furnished items, overall dimensions, weight, and volume is also included.

CHAPTER 2 — OPERATION

This chapter contains all the procedures necessary to enable operating personnel to efficiently and effectively use the equipment. These include routine and emergency operating instructions, safety precautions, operating limits, transfer between automatic and manual operating conditions (when applicable), complete starting (turn-on) and stopping (turn-off) procedures, including emergency turn-off, and any instructions required by the operator to prepare the equipment for use. Where operating procedures are to be performed to a specific sequence, step-by-step procedures are given, initial safety requirements and connections of accessory equipment are also given. Tables and charts are provided for the presentation of operating instructions for different modes of operation. Warnings and cautions for conditions that may create hazards are located appropriately. Instruction for operators maintenance and the use of test equipment incorporated in the equipment is also included. Illustrations which show the location of controls, check points, and adjustments (with normal indications listed) are included to facilitate use and understanding of the procedures.

CHAPTER 3 — FUNCTIONAL DESCRIPTION

This chapter contains a brief description of how the equipment operates in simple technical languages, and it is supported by line illustrations. The building block technique is used to describe the functional operation of the equipment as follows:

Pictorial line diagrams of the major units are shown in a composite group, units are identified, and a simple description is included. Interaction of major parts is, likewise, illustrated and mentioned, and detailed electrical and mechanical descriptions are included with supporting illustrations. Overall block diagrams, simplified functional block diagrams, and simplified schematic diagrams are used with simple technical descriptions of functional operation. Mechanical diagrams are likewise included, and integrated circuits are explained in simplified form. Digital devices are described using conventional symbols and notations, with adequate flow charts and functional operating descriptions for complete understanding.

CHAPTER 4 — SCHEDULED MAINTENANCE

This chapter contains preventive maintenance procedures and performance test instructions required on a scheduled basis for preventive maintenance. The maintenance and repair data are presented on a unit-by-unit basis. Where the procedures required for maintenance or repair are the same for more than one unit, the procedures will be given for only one unit and references will be made to that unit for the other units that require these same procedures. The procedures given in the Planned Maintenance cards are usually also repeated in this technical manual.

All preventive maintenance procedures and test inspections are included in this section although some procedures may be supplied in a separate Reference Standard Book (POMSEE) or on separate MRC's of the PMS. When the reference standards information is incorporated in the technical manual, maintenance checks and routine maintenance procedures are provided. Typical tests and periodic checks include, at least the following: safety, electrical and mechanical items, cleaning, inspection, and lubrication. Each of the procedures for the preceding items are usually illustrated and include the minimum rating of the technician who can perform the test. The acceptable limits of performance for the applicable procedures have been established and included within the procedure chart. In general, the maintenance procedures indicate what is to be done, when it is to be done, how to do it, and the expected results and inspection procedures. Lubrication instructions include the manufacturer's recommendations on the type of lubricant to use and the time interval between lubrications. Lubricants are identified by military specification numbers or commercial designations, as applicable. The repair instructions provide for the removal, repair, adjustment, and replacement of all items which are within the ability of the electronics technician to perform.

CHAPTER 5 — TROUBLESHOOTING

This chapter contains information to aid the electronic technician in locating the cause of the equipment malfunction. It contains troubleshooting guides such as troubleshooting dependency diagrams which give a logical procedure for the isolation of faults by observing meters, checking fuses and circuit breakers, and following a block diagram type of branch chart which shows the interdependency of troubles and tests and how they branch out from unit to unit. Complete instructions are given for signal tracing of electrical circuits including the use of special test instruments and any special servicing techniques. Troubleshooting diagrams are included which give the details of mechanical and electrical assemblies and their relationships. These diagrams include block diagram, signal flow diagrams, control diagrams, power distribution diagrams, logic diagrams, maintenance schematic diagrams, and trouble dependency diagrams as necessary to support the troubleshooting procedures.

All input-output signals and connectors in the signal path are shown and identified on the functional diagrams showing lead numbers and terminal identifiers. All built in monitoring devices and controls are shown, external test equipment and data is separately referenced. Hull grounds, power grounds, chassis grounds and equipment grounds are specifically indicated. The leads of motors, generators and synchros are identified. Switches and terminals, panel markings, and switch positions are also clearly shown. Mechanical coupling to controls, switches, potentiometers, synchros and other devices are shown and the signal path is indicated by weighted lines and arrowheads. References are made for appropriate corrective actions and functional descriptions. Control diagrams are grouped by control function, energizing voltage, mode of operation and the physical limits of cabinet or assembly. All relay energizing circuits are shown with tie points, terminals and with the switches and relays in their starting position, and lamps and indicators showing the control or functional status are shown.

Power distribution diagrams are usually prepared for each voltage level used within the equipment and show and identify motors, transformers, regulators, power supplies and assemblies, subassemblies, and modules. Fuses, circuit breakers, switches and relay contacts are shown and located. All connections and plugs and jacks and terminal boards in the distribution path are shown and identified. All metering and indicator circuits are shown and all grounds, common, and neutral return lines are marked and indicated. The functional names of the controls and indicators are shown as marked on the equipment.

Maintenance Schematic Diagrams include unit to unit connections, interunit connection diagrams, assembly and subassembly diagrams which includes all circuit elements and allows circuit tracing from unit to unit. An alphanumeric coordinate table is placed on the apron so that circuit elements can be located by zones, so that when a twin tube or relay is drawn in separate sections at different locations, it is easily located by the coordinate system. Major and minor signal paths are identified by different line weights on the diagrams and arrowheads show the signal flow path. All significant voltages at buses, tube pins, and transistor elements are indicated except where this data is better represented by a separate table. Resistance and voltage charts for the diagram are supplied on the apron of the schematic for quick reference. Schematic diagrams are found in alpha-numeric order corresponding to the reference designation of the unit, subassembly, etc. Control cycle diagrams and timing circuit diagrams show the exact cycle and timing relationship together with the origin of all timing signals both conventional and digital. Module logic diagrams are provided for each type of module with flow charts and test programs, and with coding instruction sheets for all digital test programs to support the troubleshooting data.

Troubleshooting dependency diagrams illustrate the functional dependency of one test point upon another test point or circuit. They are arranged in pyramidal fashion which depicts the continuity of each signal level path through successive dependency levels. The box at the top or apex of the chart represents an acceptable condition of all boxes below it. However, if any characteristic of the apex box is out of tolerance, then one or more of the characteristics in boxes below the apex is found unacceptable. Each functional dependency box contains the location and identification of the test point and references specific notes contained on the apron of the diagram. The chain begins at the top level and follows in ascending numerical order the logical test point from top to bottom to determine the location of the faulty circuit.

Fault logic diagrams are based on a fault observed during troubleshooting, and progressively requires a series of yes or no answers which progressively narrows the fault to a particular functional area. Tolerance values are given if a specific yes or no cannot be supplied. Each diagram includes or references the information necessary to complete the fault isolation or repair and to establish the test of operating conditions required to start the fault isolation procedure. The single line block contains questions which can be answered from observation without changing the test setup and which require special setups or external equipment. Double line boxes are conclusion boxes which list the functional area within an equipment that is the probable source of the malfunction and shall reference another diagram for further isolation or correction of a fault.

The troubleshooting matrix chart shows the functional dependency of the output signals or indication upon circuit elements, circuits modules, etc. These charts are illustrated in grid form with a vertical column representing a circuit element module, etc., while the horizontal line represents the procedural step which results in the observable output or indication. Use of this type of chart is explained fully in the manual.

CHAPTER 6 — CORRECTIVE MAINTENANCE

This chapter contains instructions required to adjust, and align the equipment, remove, repair and reinstall and align all repairable parts and modules, subassemblies and assemblies. These instructions identify the action to be accomplished, safety precautions to be observed, tools, parts, and test equipment and materials required. It lists preliminary control settings, test equipment set-up instruction, and step by step instructions with supporting illustrations to accomplish the maintenance task.

CHAPTER 7 — PARTS LIST

The parts list itemizes all shipboard, tender, and shore-based parts including attaching hardware. It includes the parts list, a list of common item descriptions, a list of manufacturers, attaching hardware, and parts location illustrations arranged by item number or using a grid coordinate type system to facilitate easy location of parts from a location table. Exploded views, line drawings and photographs are used for illustrations.

CHAPTER 8 — INSTALLATION

This chapter contains drawings and information pertaining to site selection, special tools and material requirements, unpacking and handling, preparation of foundations, mechanical assembly procedures for mounting instructions, bolting diagrams, safety precautions, clearance for access and ventilation, fluid cooling requirements, clearances for motion under shock and recommendations for reducing of electric and magnetic interference. In addition tests and test procedures required to demonstrate that the equipment is capable after installation of satisfying all operational requirements.

APPENDIX — Where used contains supplementary information.

INDEX — All manuals containing more than 100 pages have a detailed subject index at the back of the book.

(b) Distribution — Two copies of the TM for a particular equipment are supplied with the equipment. In addition, the Command supplies file copies to activities concerned with the installation and maintenance of the equipments or with Training of electronics personnel. Supplies of manuals remaining after initial distribution are stored at the Naval Supply Depot, Philadelphia, for issue to individual activities. When the supply of manuals is extremely limited, special justification may be required to obtain copies. Manuals for instruction and study can be issued only to Navy and Marine Corps schools, and then only in quantities consistent with the available stock.

Advance, preliminary, or temporary technical manuals may be furnished where a delay in completing the final manuals is anticipated. As a general rule, return postcards are included under the front covers of the manuals. These cards provide a ready means for informing Contractors of where the completed final manuals are to be sent. To ensure receipt of the final manuals, the postcards should be filled in and returned promptly. Advance, temporary, and preliminary publications are to be destroyed upon receipt of final technical manuals, as indicated in the promulgating letter in the final books. If the manuals to be destroyed are classified, disposal must be in accordance with existing regulations covering the destruction of classified material. The instructions which accompany changes to technical manuals indicate the desired disposition of material removed from the basic publications.

(3) Symbolic Integrated Maintenance Manual

The Symbolic Integrated Maintenance Manual (SIMM) provides information on a particular equipment and contains functional description, installation procedures and directions, theory of operation, troubleshooting, maintenance and repair, and spare parts.

This manual is similar in content to the equipment technical manuals previously discussed, but is written in a more concise form designed to aid both the experienced and the inexperienced technician in the maintenance, alignment, and repair of the equipment as expeditiously as possible. Its main superiority is that it contains a detailed troubleshooting chart. The data content and its method of presentation is discussed below.

Section 1. GENERAL INFORMATION

The general information consists of reference data on the equipment. This information is for use of command level personnel and others requiring a general summary of the equipment, its performance, advantages and limitations, and the relationships of the units.

Section 2. THEORY OF OPERATION

The theory of operation is presented by blocked schematic, precise-access block diagrams, and blocked text. These presentations are described in the following paragraphs.

(a) Blocked Schematic. The blocked schematic diagrams are schematics of hardware items arranged in block form. Blue and gray shaded areas are used to denote the functional and physical location of the circuit elements. The blue and gray shadings denote the following:

Each area of blue denotes a functional entity, which comprises all circuit elements included in accomplishing a circuit function. Each functional entity is identified by a circuit-identifier code that indicates the active element, the circuit functions, and the numeric occurrence of the same type of functional entity on the schematic. The functional entity is enclosed in the lightest blue shade. Subfunctional entities are one shade darker than the shade of the grouping of sub-functional entities to which they belong.

The gray-shaded areas denote the physical location of the circuit elements. The first level of physical location is shown by the lightest shade of gray. Subordinate locations are shown by increasing densities of gray-shading.

(b) Precise-Access Block Diagram. The precise-access block diagram shows all the functional entities within a unit, signal flow within the unit, and all cabling and wiring within the unit. Each functional entity shown by symbols, is identified by the circuit-identifier code and blue shading used on the block schematic diagram. Gray shading, showing physical location of the functional entities, is also used on the precise-access block diagrams.

(c) Blocked Text. Blocked text is presented on a page facing the blocked schematic diagrams and the precise-access block diagrams. The arrangement of the blocked text is identical to that of the associated diagram. Terse text of high information content, pertaining only to the functional entity being described, is substituted for the circuit elements or symbol in the respective blue-shaded area. The circuit-identifier code is included with text to aid in identification.

Section 3. MAINTENANCE INFORMATION

Maintenance information is divided into two categories: checkout and trouble isolation; and alignment, adjustment, and repair data. Checkout and trouble isolation is presented on maintenance dependency charts, and alignment, adjustment, and repair data is presented on the assembly maintenance data pages. The data presented by both of these methods is as follows:

(a) Maintenance Dependency Chart. The maintenance dependency chart displays the sequence of power or signal flow in the equipment. Each horizontal line displays an event such as a lamp lighting, a relay energizing, or an availability of a signal or voltage. Symbols on the event lines indicate the functional entities, circuit elements, or previous events that the event is dependent on. The symbols are located within the vertical columns, which identify the functional entities and circuit elements. When an event or signal availability is not present, the previous events, signal availabilities, functional entities, and circuit elements on which the event is dependent can be readily ascertained. Three different types of symbols are used to indicate the accessibility of the point where the event or signal may be measured or observed. The three symbols and what each symbol indicates are as follows:

A black box with white letters — the event can be recognized from outside the equipment.

A gray box with black letters — the event can be recognized or measured at a readily accessible point within the equipment.

A white box with black letters — a circuit point at which an event or signal availability may be measured. This circuit point is not necessarily readily available.

The circuit identifier codes and all symbols used on the diagrams and maintenance dependency charts are shown in tabular form with an explanation of their meanings in each manual. In order to use diagrams and maintenance dependency charts effectively, the technician must familiarize himself with symbols used and their meanings.

(b) Assembly Maintenance Data. The assembly maintenance data pages contain data necessary to align, adjust, remove, replace, disassemble, reassembly, and test the unit and components of the unit.

Section 4. PARTS LISTING DATA

Parts listing data is only provided for parts that may be replaced during maintenance of the equipment. The parts listing data arrangement is explained in the following paragraphs.

(a) Assembly Location and Description. The assembly location and description page provides photographs that identify the equipment and the locations of the subassemblies. A tabular listing provides the name, manufacturer, and part number of the equipment and subassemblies.

(b) Electronic Parts List. The electronic parts list comprises a photograph or line drawing with a superimposed blue grid and a tabular listing. The tabular listing provides the reference designation of the part, grid coordinates of the parts location, description of the part, name of manufacturer, and part number.

(c) Mechanical Parts List. Except that there is no reference designator, the mechanical parts list is identical to the electronic parts list.

(4) Electronics Installation and Information Books

The Electronics Installation and Information Books (EIMB) is a series of authoritative publications which provide field activities with information on the installation and maintenance of electronics equipment under the technical control of the Naval Ship Systems Command.

The EIMB consists of thirteen separate volumes or handbooks in order to ensure coverage of all naval electronics equipment. The following is a list of each handbook by title and NAVSHIPS number, which is also the ordering stock number.

Title	NAVSHIPS No.
The Complete EIMB Series	0967-000-0000
General Handbook	0967-000-0100
Installation Practices Handbook	0967-000-0110
Electronic Circuits Handbook	0967-000-0120
Test Methods and Practices Handbook	0967-000-0130
Reference Data Handbook	0967-000-0140
RFI Reduction Handbook	0967-000-0150
General Maintenance Handbook	0967-000-0160
Communications Handbook	0967-000-0010
Radar Handbook	0967-000-0020
Sonar Handbook	0967-000-0030
Test Equipment Handbook	0967-000-0040
Radiac Handbook	0967-000-0050
Countermeasures	0967-000-0070
Tabular Separators (Equipment Books Only)	0967-000-0009

The information contained in the EIMB series is supplemental to equipment technical manuals and related publications.

(a) Scope — The handbooks of the EIMB series are divided into two categories; general information handbooks and equipment oriented handbooks. The general information handbooks contain data of interest to all personnel involved in installation and maintenance, regardless of their equipment specialty. The equipment handbooks are devoted to information on a particular equipment class; they provide specific equipment test procedures, important adjustments, circuit applications, general servicing information, and field change identification data. The technician, by using the EIMB, will tend to reduce time consuming research, and obtain supplementary information helpful in servicing and maintaining his equipment.

(b) Distribution — The distribution of the EIMB handbooks and handbook changes is a joint effort by the Naval Ship Engineering Center, Washington, D.C., and the Naval Supply Depot, Philadelphia. Distribution policy is established by NAVSEC 6181C. Activities not already on the EIMB distribution list and those requiring changes to the list should submit correspondence to:

Commander, Naval Ship Engineering Center
Department of the Navy
Prince George's Center
Hyattsville, Maryland 20782
Attention SEC 6181C

(5) Electronics Information Bulletin

The Electronics Information Bulletin (EIB), NAVSHIPS 0967-001-3XXX, is an authoritative publication, published bi-weekly, and forwarded to all naval ships and to naval electronics installation and maintenance activities.

The EIB contains advance information of field changes, installation techniques, maintenance notes, beneficial suggestions adopted by various yards and bases, notification of technical manual and EIMB revision and changes with the latest applicable data and stock numbers.

Unless otherwise indicated, the maintenance requirements prescribed in the various issues of the EIB's are consistent with those contained in the Planned Maintenance System.

All articles, including those under the cognizance of Naval Electronic Systems Command (NAVELEX), have been authenticated and are authoritative in nature. Accordingly, reference may be made to a particular issue of the authority for adoption of ideas contained therein. Nothing in the EIB publication authorizes interface changes between equipment and systems, or between equipment and ship.

Articles of lasting interest are later transcribed into the EIMB except for field changes and corrections to publications.

As issues are received, they are to be filed in a folder or notebook in consecutive order. An EIB Index is provided as a ready reference to all articles contained in the EIB's. The Index is arranged in functional sections parallel to the sections of the EIB such as General, Communications, and Countermeasures. The General articles are listed by subject matter and the equipment articles are listed by type number. A column is provided to give the location of articles transcribed to the EIMB handbooks.

Confidential issues of the EIB are published when sufficient classified data warrants.

(6) Other Publications

Other publications of value to electronics personnel are:

1. Elements of Electricity and Radio NAVSHIPS 0967-188-4010 (formerly NAVSHIPS 900,012).
2. Radar Electronics Fundamentals (NAVSHIPS 900,016).
3. Radar System Fundamentals (NAVSHIPS 900,017).
4. Microwave and Wave Guide (NAVSHIPS 903-5).
5. U.S. Navy Synchros (Ordnance Pamphlet No. 1303, published jointly by the Bureau of Naval Weapons and the Bureau of Ships).
6. Radio Frequency Transmission Lines NAVSHIPS 0967-108-3010 (formerly NAVSHIPS 900,008).
7. Shipboard Antenna Details (NAVSHIPS 900,121(A)).
8. Microelectronics Maintenance Manual NAVSHIPS 0967-311-5010.

As the titles indicate, many of these publications offer information on the theories and principles that are basic to a fuller understanding of electronic equipment.

3-4 SOLDERING TECHNIQUES

The efficiency of electronics equipment is dependent, to a very large degree, upon the quality of workmanship employed and the type of materials used in the soldering of its electrical connections. An appreciable portion of equipment failure can be traced directly to poorly soldered connections or joints. Electronic equipments aboard ship are subjected to continual vibration and frequent shock. Therefore, it is imperative that all soldering be done with the utmost care. The following sub-paragraphs give the procedures for prepration of connections, type of solder to use, and how to tell a good connection from a bad connection. Special techniques are used for soldering printed circuit boards and microelectronic applications which are covered in Section 5 of this handbook.

a. JOINT PREPARATION

Before any connection or joint can be soldered, it must be absolutely clean. Clean it free from oxide, corrosion, dirt, and grease. Do this by scraping, filing, or rubbing the joint with sandpaper until the metals to be joined present a bright, clean appearance. During this cleaning process, especially when removing insulation from wire, take care to avoid making cuts or nicks in the conductor. Cuts or nicks greatly reduce the mechanical strength of the conductor, especially under conditions of vibration.

After the parts or conductors have been cleaned, they are mechanically joined, and made secure in order to ensure a good electrical connection. The type of connection made or the method used to secure the parts will depend on the size and shape of the individual or number of conductors to be soldered. When making a mechanical connection to a connector or lug, wrap the wire around the lug or connector for at least one turn. Be sure the connector and wire cannot move. If a wire can move during soldering, it will, and this will result in a bad connection. Wrapping a wire all the way around a connector or lug will make a very secure mechanical connection, but presents a problem later if the wire or part must be removed. The solder joint itself provides a secure mechanical bond, often stronger than the wire itself, but the initial turn of the wire provides the mechanical immobility needed before applying solder.

b. SOLDER AND FLUX

Soldering is the bonding together of two similar (or dissimilar) metals by the means of a third metal which has a much lower melting point than the first two. This third metal is called solder and is usually an alloy of lead and tin. Soft solder is universally used in electronics work and is specified by the percentage of each constituent, with that of tin appearing first; i.e., 40-60 or 50-50. In military equipment or when rapid soldering is necessary, a 60-40 solder is recommended.

Metal, when exposed to the atmosphere, usually oxidizes; that is, a surface film forms on the metal. This oxidation, if not removed, prevents solder from adhering to the metal and making a good electrical bond. To remove this oxide layer, flux is used before soldering.

The most common flux used in electronics is made of rosin, a dark-brown, butterlike paste which works well with tin- or solder-dipped metals commonly used for wires, lugs, and connectors. Most electronic solder, in wire form, is made with one or more cores of rosin flux so that you do not have to use an external flux. When the joint or connection is heated and the wire soldering is applied to the joint (not the iron), the flux flows on the surface of the joint and removes the oxide. Then, providing you have sufficient heat, the solder flows and displaces the flux. If you don't have sufficient heat, the solder will never displace the flux and a poor connection will result.

Soldering paste, acid, or "killed acid" flux should never be used when soldering electronic or electrical conductors. Unavoidable penetration of this paste or acid into the insulation always leads to a reduction of the insulation resistance and to current leakage which will cause corrosion and noise. When acid flux has inadvertently been used, all traces of the acid must be removed by washing thoroughly with alcohol and dried. If acid flux has been allowed to come in contact with insulating material such as phenolic resins, used where high resistance is necessary (as in terminal boards), it may be necessary to replace the contaminated insulating material.

c. APPLICATION OF SOLDER

Before applying solder the joint or connection must be heated. This joint must be heated to a temperature greater than 361 degrees F. This is the temperature at which solder will re-solidify. If the temperature of the joint never goes higher than the liquid of the solder, a bad solder joint will result. Apply the tip of the soldering tool (iron or gun) underneath the joint, if possible. If it is not possible for the tip to contact all wires and terminals in the joint or connection, make sure it touches and heats the largest piece of metal involved. An experienced technician knows about how long it takes to heat a joint to a point where the joint (not the iron or gun tip) melts the solder. Do not overheat the joint or the solder itself will oxidize and result in a bad solder joint.

Apply the solder, letting it flow by gravity and capillary action between the parts to be joined. If the joint will not melt the solder, wait until it will. Do not feed the solder into the opposite side of the joint from the iron as this will require more heat on the joint thereby overheating the joint and possibly cause damage to nearby components. Apply enough, but only enough, solder to make a smooth, globular joint, with solder filling all spaces and crevices. Too much solder is as bad as too little. It is also a bad practice if the solder does not flow freely on all elements of the joint. Ideally, when solder is applied to a hot joint, the solder should shrink inward toward the center of the mass of the joint by capillary action.

After applying the solder, allow the joint to cool without disturbing it. Do not pull on the wires, move the chassis, or allow any vibration to shake the work table or bench. Vibration or movement of the wires or parts during the cooling period ususually produces a bad solder joint.

When making a critical connection, clean the joint after it has cooled by brushing it with isopropyl alcohol. This removes flux residue without leaving any contamination.

d. TYPES OF JOINTS

By using proper soldering procedures and precautions it is possible to make solder joints free of defects. When procedures are not followed and precautions are relaxed, defective joints are invariably encountered.

(1) Good Solder Joint

A good well-bonded connection or joint is clean, shiny, smooth and round, and approximately outlines the wire and terminal. The wire and terminal are completely covered and the solder adheres firmly. The insulation is close, but not in the hole or slot; it is approximately 1/8-inch from the terminal. It is not charred, burned, nicked, or covered with rosin. A film of rosin may remain on the joint and need not be removed unless the joint is in a high-frequency circuit or unless fungus proofing is anticipated. The connection should be free of enamel and other impurities, and nothing should remain trapped within the solder. The wire is cut off slightly beyond the edge of the terminal (approximately 1/16-inch) without disturbing the solder connection.

(2) Bad Solder Joints

Bad or improperly made solder joints are particularly annoying because they usually cause intermittent troubles which are difficult to track down. Solder joints may be defective for a variety of reasons such as the one discussed in the following subparagraphs.

(a) Cold-Solder Joint — A cold-solder connection has a dull appearance and crystallized texture. The surface is often jagged and granular. Solder does not adhere positively and can sometimes be picked with a finger nail or by using a sharp pointed instrument such as a machinest scribe or test probe. Because of the poor union between the wire and terminal, the joint will, in time, develop high resistance as the mating metals oxidize. This type of joint results from insufficient heating of the terminal and wire being joined. This may be due to one of the following factors: poor contact (low thermal conductivity) between the hot iron and the joint; soldering iron being too cold; dirt or oxide film on the terminal or wire, or to rapid dissipation of heat due to large conductors or terminals. A cold-soldered joint can be made secure by reheating it with a hot iron. However, if dirt or oxide covers the terminal or wire, it may be necessary to take the joint apart, clean the surfaces, and re-solder.

(b) Rosin Joint — The rosin joint is so named because the wire is held by rosin rather than by solder. The flux is spread over the terminal and instead of bonding with the terminal, the solder settles on the top of the rosin. The solder may not cover all parts. The solder does not feather out but forms round edges. A rosin joint occurs when using a "cold" iron or one that is too small. It may also be caused by using too much flux. If the temperature of the joint is not high enough, the flux will not evaporate and will remain on the joint or become embedded in the solder. A rosin joint may have all the appearances of a good solder joint and any joint having excessive solder should be suspected. In many cases, merely applying a hot iron will clear up a rosin joint. If this fails, it is then necessary to take the joint apart, clean off the rosin and re-solder.

(c) Disturbed-Solder Joint — A disturbed-solder connection is one in which the wire moved before the solder fully set. This type of joint has an irregular or crystallized appearance and is the result of a poor mechanical connection in which the wire has moved. A disturbed-solder joint may appear good but can loosen later in service. It may become the same as a cold-solder joint and introduce high resistance into the circuit. To correct this type of joint, the same procedure should be used as for a cold-solder joint.

(d) No-Solder Joint — An unsoldered joint may not cause trouble in service until the metals have oxidized and noise is introduced into the circuit. If a good mechanical connection was made, vibration tests may not bring out the fault, but the equipment may break down later.

Applying solder to a no-solder joint is not enough, it must also be cleaned. The joint may have stood awhile and a heavy film of oxide may have developed. Care must be taken to see that the joint is clean and well wet with solder.

(e) Excessive-Solder Joint — When more solder than necessary is used for good electrical bonding or when the contour of the connected elements is obscured, there is excessive solder on the connection. Excessive solder presents a potential short circuit hazard. It may spread into a tube socket or bridge across adjacent terminals. A joint with solder overhanging or too close to other terminals may not cause an immediate short, but after vibration it can result in a short; also, small particles may wedge between adjacent conductors. This type of joint is often difficult or impossible to determine if the solder has properly alloyed with the wire and terminal. Excessive solder may be removed with a clean iron. Wipe the iron clean of any extra solder before applying it to the joint so that it will attract solder to its face.

(f) Insufficient-Solder Joint — When not enough solder has been applied to insure a secure connection it is termed an insufficient-solder joint. This type of joint is usually caused by removing the solder from the joint before enough has melted. Such joints can introduce high resistance and, as current flows, undesirable heat. Insufficient-solder joints may loosen and cause an intermittent or fully open connection depending upon the oxide present. Safety factors to compensate for possible corrosion and crystallization require that the solder quantity be more than the bare minimum required to carry the current.

(g) Excessive-Rosin Joint — Roson on the surface does not alone denote a defective joint unless there is so much that it has spread to adjacent terminals or into socket holes.

Excessive-rosin joints can occur with the excessive use of rosin-core solder. The solder melts, adheres to the terminal and floats the rosin to the surface. There may be flaking or peeling which will interfere with electrical contacts in sockets, jacks, plugs, etc. Excessive rosin over solder may conceal a poor connection. It may also interfere with the electrical action in high frequency circuits. If a film of rosin coats a joint, moisture and fungus proofing coatings will not adhere properly.

(h) Insufficient-Flux Joint — This fault displays the same characteristics as a cold-solder joint, i.e., there is insufficient flux to clean the metals and the solder will not adhere. Insufficient-flux joints may occur from using core solder having voids along its length.

(i) Loose Solder — Loose solder is not directly a connection defect, but is the result of using an excessive amount of solder and allowing it to drip on the chassis. It forms balls and rolls about, lodging between terminals, adjacent connectors, capacitor plates and crevices. Loose solder may also attach itself to wire insulation as it may drip off the connection. Remove all loose solder with a suction cup, pick, or pliers to avoid inadvertent short circuits or grounds caused by the unwanted pieces of solder.

3-5 SPLICING TECHNIQUES

Splicing is the process of joining two or more conductors at a common point. Joining or bonding of the wires with solder only is not enough. The wires or conductors must be mechanically joined in order to provide a secure joint as solder itself has very little mechanical strength. Figure 3-11 shows the two basic types of splices used in electronic maintenance. Both in the "Western Union" splice and the simple tap joint, the strain, between the conductors, is taken up by the wire itself and not by the solder.

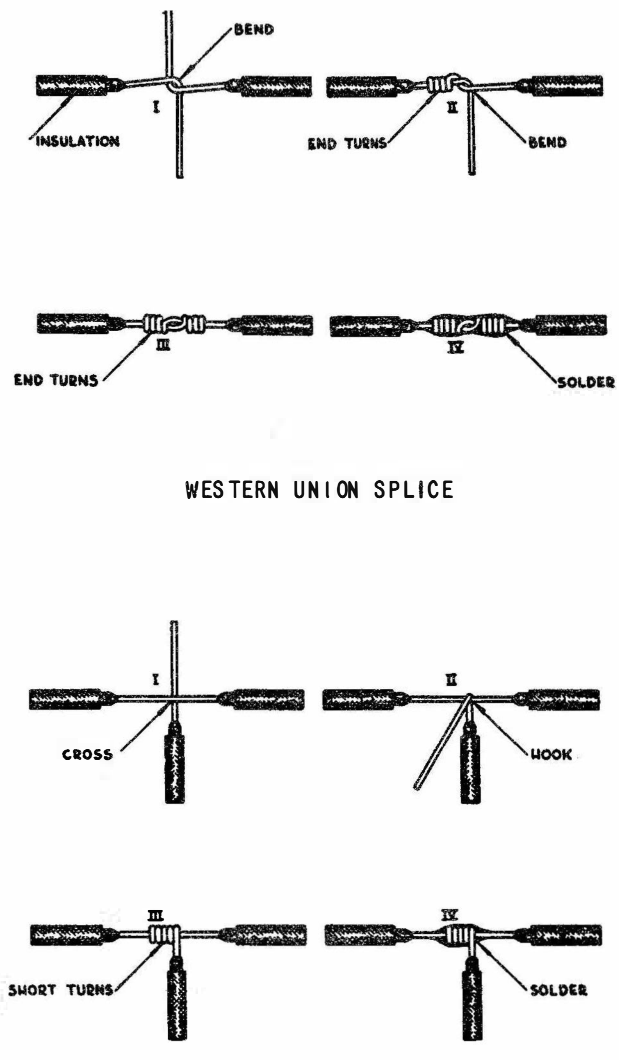


Figure 3-11. Types of Splices

SECTION 4

SYSTEM MAINTENANCE

4-1 AUTOMATED TESTING

Any electronic system can be completely checked-out with general purpose test equipment, but the time required to individually test the components in one of today's very complex systems could greatly exceed the design of the system. Obviously, corresponding improvements in system testing procedures are necessary.

One improvement in system testing has been realized by designing systems that testing can be performed at various functional levels, allowing groups of components to be tested as a whole, thus reducing the time required to test components individually. One advantage of this method is that complete test plans can be written to provide optimum sequencing of tests and wave shapes or voltage outputs for each functional level.

This method of testing has led to the development of special support equipment or test sets capable of simulating operating conditions of the system under test. Appropriate signal voltages are applied by the test equipment to the various fundamental levels of the system and the output of each level is monitored. The testing sequences are prewritten and the steps are manually switched. The limits for each functional level are preprogrammed to give a go/no-go indication.

If a no-go indication is observed for a particular function, the localized area of the system in which the malfunction occurs is then tested by using general purpose test equipment and troubleshooting manuals. This type of semiautomatic testing has led to the development of both on-line and off-line automatic test systems. The on-line systems are designed to continually monitor performance, and to automatically isolate faults to removable assemblies. Off-line systems automatically check-out the removable assemblies and isolate faults to the component part level. Two on-line systems, the Test Evaluation and Monitoring System (TEAMS) and the Centralized Automatic Test System (CATS) are presently in production or under development by the Navy.

a. TEAMS

TEAMS is an on-line system that continuously monitors the performance of electronic systems and isolates faults to removable assemblies. This system is stimulated by a central processor that is controlled by a test program on perforated tape.

Displays are used to present the status of the equipment and provide data with instructions for fault localization. Lights are used to indicate which equipments are under test and also an out-of-tolerance condition. A printer provides a record copy of the test results to be used by the technician for isolating the fault in a removable assembly to a replaceable part.

b. CATS

CATS is an on-line system that continuously monitors the performance of electronic systems, predicts system performance trends, and isolates faults or removable assemblies. CATS is computer controlled, with the instructions preprogrammed in the computer memory.

The status of the electronic system being monitored by CATS is presented in various forms. Information concerning a failed module is presented on a status-and-fault-isolation indicator to alert the technician of the need for a replacement module.

4-2 OTHER TESTING

When no automatic means of accomplishing fault isolation is available, general purpose test equipment and effective troubleshooting procedures must be employed, but such fault diagnosis should be attempted only by experienced technicians.

Each suspect device or component lead must be checked manually. Special care must be exercised when testing integrated circuits since these circuits may be easily damaged by excessive voltages or currents and leads may be physically damaged.

Precautions concerning the use of test equipment for troubleshooting equipments containing integrated circuits are similar to those that must be observed when troubleshooting equipments containing semiconductor devices. See Section 5 of this handbook for these precautions.

SECTION 5

EQUIPMENT MAINTENANCE

5-1 APPLICATION OF EQUIPMENT MAINTENANCE

Maintenance of electronic equipment is divided into preventive maintenance and corrective maintenance. Preventive maintenance consists of operational checks, performance checks, inspections, cleaning, adjustment, lubrication, and such types of checks, to maintain an equipment in an operating condition. Corrective maintenance involves the repair of equipment to restore it to an operating condition.

a. PREVENTIVE MAINTENANCE

Preventive maintenance must be performed on a planned systematic basis. When accomplished in a haphazard manner, preventive maintenance may jeopardize an equipment rather than prolong its life. The Planned Maintenance System (PMS) is designed to provide the technician with a planned and orderly routine for carrying out preventive maintenance for an equipment. Refer to Section 2 of this manual for details. When PMS is not implemented, POMSEE will continue in effect for the scheduling and performance of all testing. Performance testing will provide the technician with a set of reference standards and specific parameters with which he can evaluate the condition of the equipment. This will allow him to foresee probable troubles, and perform preventive maintenance to prevent equipment failures. In most cases, the performance tests are provided. They are included in POMSEE as reference standards tests and in technical manuals.

The following subsections outline the responsibilities of both the equipment operator and the technician for conducting preventive maintenance.

(1) Operator

Preventive maintenance performed by the operator normally consists of general cleaning, inspection, daily reference standards tests, lubrication, and other similar procedures as detailed in POMSEE requirements. Daily operational tests performed by the operator as required by POMSEE are designed so that they can be performed in about ten minutes. Mainly, these tests consists of checking equipment performance with built-in test equipment. By this method, the operator can give a daily operational status report to the technician.

(2) Technician

The primary concern of the technician in preventive maintenance is the performance test required by POMSEE or PMS utilizing the MRC's. Upon completion of these tests, the results are recorded for equipment history, and can be evaluated by the technician for symptoms of degradation or impending failure of the equipment.

b. CORRECTIVE MAINTENANCE

The objective of corrective maintenance is to repair the equipment to restore it to a fully operational status as quickly and expeditiously as possible. When equipment historical data is insufficient or nonexistent, the technician may be required to use troubleshooting procedures, as explained in Section 2 of this manual, to aid him in locating the malfunction or faulty component.

5-2 ANTENNA MAINTENANCE

Antennas are located in the most exposed locations possible aboard a ship in order to provide for efficient radiation and reception, but it complicates routine antenna maintenance. Because personnel have a natural reluctance to climb masts or stacks, the antenna system is occasionally neglected until a major casualty develops.

The major enemies of the antenna system are corrosion caused by salt spray and stack gages, and paint on insulators.

Constant whipping of all types of antennas caused by the wind or ship motion contributes much towards broken strands, parted couplings, and broken mounting brackets.

a. GENERAL CLEANING AND INSPECTION PROCEDURES FOR ANTENNAS

The procedures given in the following subparagraphs provide the maintenance technician a most effective and efficient means of performing antenna cleaning and inspection.

(1) Wire Antennas

Wire antennas should be lowered at frequent intervals and inspected for signs of deterioration, particularly at clamps, and where they connect to trunks,or transmission lines. Avoid nicking or kinking the wire while inspecting as the wire will be weakened at these points.

It is a good policy to wire-brush antennas while they are down as this removes soot and salt deposits as well as revealing any signs of weak or broken strands. Insulated-type receiving antennas should be wiped rather than wire-brushed.

(2) Whip-type Antennas

Whip-type antennas are usually hollow and have a tendency to collect moisture inside. A small hole should be drilled near the base of these antennas to permit moisture to drain out.

Whips should be inspected while down for rust spots or loose sections. Mounting straps and standoff insulators should be carefully checked for cracks, breaking, or deterioration as well as for cleanliness.

(3) Dipole Antennas

Dipole antennas usually have one pole grounded, while the other pole is connected to the inner conductor of the coaxial transmission line.

Any insulators on the dipoles should be carefully cleaned of any paint, salt, or soot deposits. Care should be taken not to damage the glazed surfaces of the insulators. The mechanical condition of the dipoles should be checked for loose mountings, rust spots, etc.

(4) Antenna Fittings

It is strongly recommended that all antenna fittings such as insulator ring bolts, shackles, turnbuckles, and any other topside antenna fittings be coated with a corrosion preventive compound after each cleaning. Satisfactory corrosion preventive compounds are available such as Hard-Film Corrosion Preventive and Gun Slushing Compound, Grade B.

(5) Enclosed Trunk Transmission Lines

Aside from collecting moisture, enclosed trunk transmission lines give little trouble and require little more than periodic cleaning for proper maintenance.

Shipboard antenna systems, including transmission lines and associated wiring, as well as inter-unit wiring and connecting cables, form an important weak-link in the electronic installation. This weak-link is neglected by many maintenance personnel in their preventive maintenance schedule. Many complaints of poor sensitivity on the part of a radio receiver or the lack of range from a radar have frequently been traced to some minor defect in the antenna or transmission line. Instability and noise are often caused by loose cable couplings or poor equipment bonding.

b. CHECKING ANTENNA LEAKAGE RESISTANCE

Aside from actual physical damage, the most common fault in the antenna system is low resistance to ground. Moisture in trunks or coaxial cables, dirty insulators, and coaxial dielectric breakdown all cause varying degrees of shunting resistance and must be guarded against if maximum system efficiency is to be expected.

The most convenient method of testing an antenna system for shunting resistance is by using a high-voltage, high-resistance ohmmeter or a megohmmeter, "megger." The megohmmeter uses a high voltage (approximately 500 volts) which is sufficient in many cases to break down and thus reveal any weak spots in the insulation.

Before proceeding with the following test, inspect the antenna for any intentional DC shorts or receiver protective devices.

1. Disconnect the equipment from the antenna and remove all protective devices and intentional shorts.

2. Connect the ground lead of the megger to the hull.

3. Connect the high side or line lead of the megger to the inner conductor of the transmission line. It may be convenient to fabricate a suitable plug to match the coaxial fittings for test purposes.

4. Make the resistance test and record the indicated resistance. For insulation resistance, the following values are suggested:

a. A resistance of 200 megohms or more to ground indicates that the antenna is in good condition.

b. A resistance of 5 to 100 megohms to ground indicates the need of cleaning the insulators.

c. A resistance of less than 5 megohms to ground indicates an immediate and urgent need for locating the leak in the antenna and taking the steps necessary to restore the system to its original condition.

Theoretically, any antenna transmission line system should read infinity on the megger, but this is not always possible to obtain. Abrupt changes in the weather, high humidity, or other natural causes often result in low readings. It is safe to say that any antenna reading under 100 megohms to ground for several successive daily readings should be investigated. In many cases, insulation resistance may be raised by cleaning the insulators or couplings. The coaxial cable and other cables and fittings used to connect the equipment together should also be tested. A continuity check of the antenna system should also be made periodically.

c. PAINTING ANTENNAS

All transmitting and receiving antenna hardware and accessories, antenna framework, and dipoles should be inspected quarterly, and those installed directly aft of the stack should be inspected monthly, as the gases and high temperature in the vicinity of the stacks tend to dry out and crack the paint which accelerates corrosion.

(1) General Painting Procedures

When damage is such that a complete repaint job is required, the old paint, soot, rust, and the like should be completely cleaned off and repainted as follows:

1. Apply one coat of wash primer pretreatment (Spec MIL-P-15328, formula No. 117 for Metals) to improve the adherence of the primer and paint.

2. Following the primer pretreatment, apply one coat of zinc-chromate primer (Spec JAN-P-735) and not less than two coats of haze-grey No. 27 (Spec MIL-P-15130).

When the extent of damage does not warrant a complete repaint, but corrosion is detected, clean and paint the effected area in accordance with the above procedures.

When just a touch up job is required where just the surface finish coat is damaged and there is no evidence of corrosion, apply one or two coats of haze-grey No. 27 after proper cleaning.

Brass dipoles need not be coated with zinc-chromate primer and under no circumstances use a metallic paint.

Where it meets the approval of the local command, all or part of the metal rings, antenna transfer switches (outside only), other hardware, and accessories associated with transmitting antennas should be painted with red enamel (Navy Spec 52P31) as a finish coat. Hardware and accessories used with receiving antennas should be painted with blue enamel (Spec MIL-P-2852) as a finish coat.

CAUTION: Paint, varnish, shellac, or grease shall not be applied to any portion of insulating materials forming a part of the antenna system.

Paint, varnish, shellac, or grease shall not be applied to the antenna bus nor the metallic portion of any insulator in contact with the antenna bus.

(2) Painting Antenna Hoods

In some instances, antenna hoods, or radomes for radar, electronic countermeasures, or other equipment are made from fiberglass which requires no paint for preservation. However, if it is desired to paint the hood to match the ship color, any nonmetallic paint may be used, providing that not more than two thin layers are applied to the surface. Various types of paint and procedures for their use in painting radar antenna hoods are given in the following subsections.

(a) Non-metallic Paint — A non-metallic paint is one that has no metallic flakes suspended in the body of the paint. Navy haze-grey paint (Navy Spec 52-P-45) falls in this category and is approved for painting Navy radar antenna hoods.

(b) Metallic Paint — Metallic paints inum, gold, and such) contain metallic flakes which attenuate electromagnetic energy. These paints should never be used where that is a consideration.

(c) Surface Preparation — Although the kind of paint used is of primary consideration, the procedure for preparing the surface and applying the paint is also quite important. The first step in the procedure is an inspection of the hood. If more than one coat of paint has been previously applied, the surface should be cleaned, either by sandblasting or by the use of a liquid paint remover.

(d) New Surface Painting — When painting a new surface, haze-grey paint (Navy Spec 52-P-45) must be sprayed on as thin as possible and still color the surface. A brush must not be used. After the painted surface has dried, the following words should be stencilled on two opposite sides about 4 inches above the bottom edge of the hood: "DO NOT PAINT."

Radar antenna hoods on Coast Guard vessels require a spar-colored paint. A suitable paint usually may be obtained from the vessel being worked on. If the vessel cannot supply the paint, it may be made up by mixing together the following ingredients:

1. One (1) gallon outside white (Navy Spec 52-P-48).
2. 1-3/4 pounds yellow ochre in oil (Fed Spec TT-P-381).
3. 2-1/2 ounces avoirdupois vermillion red in oil (Fed Spec TT-P-381).

d. ANTENNA CHANGE REQUIREMENTS

After any installation or alteration to a ship which changes or effects the antenna rigging or antenna system, photographs shall be taken by the installing or altering activity which shall contain the following views:

1. Broadside view.
2. Head on view.
3. View from directly astern.

Before a photograph is taken, that space or portion of the ship to be photographed shall be entirely complete as regards structure, and all stagings, tools, extraneous wires, piping, hose, rubbish, and such shall be removed.

The camera position should be so selected as to include as large a field as is practicable without the object within the field becoming indistinct and without objectionable foreshortening effects. The camera to be used for these photographs shall have a sufficient depth of focus so that objects in the background will not be out of focus. All antennas on each print shall be labeled as to the equipment for which they are installed.

The negatives, properly marked to indicate the applicable security classification, shall be forwarded to the U.S. Naval Photographic Center, Anacostia, D.C., for retention. Three 8- by 10-inch prints of each of the above views shall be properly marked to indicate applicable security classification and forwarded to the Naval Ship Systems Command for record and study, four copies of each print shall be forwarded to the ship, and one copy to the appropriate type commander.

Antenna rigging photographs of yard craft and small craft attached to a shore activity are only required when they are placed in service. Additional photographing of these small craft is not required for each minor change in superstructure and rigging.

e. SAFETY PRECAUTIONS WHILE WORKING ON ANTENNAS

Chapter 9670 of the NAVSHIPS Technical Manual calls for the following precautions to be observed when working on antennas:

1. Personnel shall not be permitted to go aloft while antennas are energized by electronic equipment except by means of ladders and landings rendered safe by grounded hand rails or similar structures unless it is definitely determined in advance by suitable tests that no danger exists. This will prevent casualty resulting from involuntary relaxation of the hands which might occur if a spark is drawn from a charged piece of metal or section of rigging. The spark itself might be quite harmless. The voltages, or resonant circuits, set up in a ship's structure or section of rigging will cause shock to personnel or produce open sparks when contact is broken, or when momentarily in contact with a metallic object. Personnel of the deck force or others working on rigging shall be warned regarding the hazards which may exist and the precautions to be observed. Safety belts shall be employed when working aloft to guard against falls.

2. The above precautions should be observed when other antennas in the immediate vicinity are energized by electronic transmitters unless it is definitely known that no danger exists. Other antennas may be interpreted to mean any antennas on board another ship moored alongside or across the pier or at a nearby shore station.

3. There is serious danger to men aloft from falls caused by radar or other antennas which rotate or swing through horizontal or vertical arcs. Motor switches controlling the motion of radar antennas shall be tagged and locked open before men are allowed aloft within dangerous proximity to such antennas. It also must be borne in mind that deenergizing main supply circuits by opening supply switches, circuit breakers, or circuit switches will not necessarily "KILL" all circuits in a given piece of equipment. A source of danger that often has been

neglected or ignored, sometimes with tragic results, is the inputs to electronic equipment from other sources, such as synchros, remote control circuits, and the like. For example, turning off the antenna safety switch will disable the antenna, but it may not turn off the antenna synchro voltages from the ship compass or stable elements. Moreover, the rescue of a victim shocked by the power input from a remote source often is hampered because of the time required to determine the source of power and turn it off. TURN OFF ALL POWER INPUTS BEFORE WORKING ON EQUIPMENT.

4. No non-Navy radio should be connected to a shipboard antenna. Many cases of burned-out receiver antenna coils have been a result of someone connecting a commercial receiver to a ship receiving antenna. By this means, it is possible to put the ship antenna at 120 volts above ground, thus creating a threat to someone's life and a hazard to equipment. The placement of a capacitor in series with the commercial antenna will not prevent the voltage from reaching the shipboard antenna because an AC voltage is involved. Also, commercial receivers are likely to radiate and thus create an interference problem.

(1) Stack Gas Warning

Personnel are further cautioned to guard against the poisonous effects of smoke pipe gases while servicing equipment aloft. Besides smoke particles and obnoxious fumes, stack gases also contain carbon monoxide. While the possibility of this gas building up to high concentrations in the open is remote, the results of prolonged exposure to even small concentrations can be lethal. Stack gases sometimes give no warning and can cause illness, loss of consciousness, or even death as a result of a fall from the mast. To prevent personnel from being overcome by these gases, the following precautions should be observed:

1. Warning signs (BuShips Drawing RE 10AA 529A) should be posted and located so that they will be in full view of personnel required to service equipment. It is recommended that one sign be located below the access ladder, and another aloft at the servicing platform.
2. Oxygen breathing apparatus should be used. The Type-B oxygen breathing apparatus, NAVSHIPS #S-23B 69855, because of its small size and weight, is best suited for this work. Personnel who are required to service equipment aloft in the vicinity of stack gases and who are not familiar with oxygen breathing equipment should be instructed in its use by trained personnel.
3. As a further precaution, a telephone chest or throat microphone set should be worn for communication with others in the working party. The working party should always include at least one man stationed below who is required to wear his phones and stand watch on the sound-powered telephone circuit as long as there is a man working aloft.
4. Make sure to obtain all necessary equipment before going aloft.

(2) Warning Signs

Warning signs should be posted adjacent to transmitters and transmitting antenna leads where there is even a slight possibility that personnel might come in contact with high voltages which may be injurious or fatal.

Chapter 9670 of the NAVSHIPS Technical Manual requires that "DANGER" signs and suitable guards shall be provided to prevent personnel from coming in accidental contact with high voltages and for warning personnel to guard against the possible presence of explosive vapors in certain locations and against poisonous effects of smoke pipe gases while servicing electronic equipment aloft. The following NAVSHIPS drawings have been prepared for suitable high voltage.

1. Drawing RE 10AA 608A — Warning regarding high voltage.
2. Drawing RE 10AA 529A — Warning regarding stack gases.
3. Drawing RE 10A 589A — Warning regarding explosive vapors.

(3) Safety Precuations for Mast Workers

A safety belt should be worn at all times by mast workers. The safety belt should be of the approved type and be periodically tested for its rated load. These belts should be attached to a strong permanent support, preferably the mast itself. A tool belt should be worn and care taken to prevent tools from falling. It is recommended that all hand tools be tied to the belt with a length of wire or string of sufficient length to permit ease in working. Wherever possible, work should be done from a scaffold or working platform. If a small job is to be done on the mast, it may be found that the use of a "bosun's chair" is a safer and more economical method than the construction of a scaffold.

5-3 GROUNDING

The main purpose of equipment grounding is to provide for the safety of personnel. The possibility of electrical shock can be reduced by ensuring that all motor and generator frames, metal bases, and other structural parts of electrical equipment, including portable equipment (such as test equipment), are at gound potential.

Normally on steel-hull vessels, such grounds are inherently provided because the metal cases or frames of the equipment are in contact with one another and with the metal structure of the vessel. In some instances where such inherent grounding is not provided by the mounting arrangements, such as equipments supported on shock mounts, suitable ground connections must be provided.

The conductors employed for this purpose generally are composed of flexible material (copper or aluminum) that provide sufficient current-carrying capacity to ensure an effective ground. In this manner, equipments which are not intended to operate above ground potential are efficiently grounded and the possibility of electrical shock to personnel coming in contact with metal parts of the equipment is minimized.

The secondary function of grounds is to improve the operation and continuity of service of all equipments. Faulty ground returns are detrimental to this function, and can result in intermodulation effects and noise voltage build-up, with associated service interruptions, false signals, equipment damage, or signal distortion.

A satisfactory ground connection, regardless of the application, must meet certain requirements as contained in the General Specifications for Ships of the U.S. Navy, the NAVSHIPS Technical Manual, and in the current Electronic Equipment, Naval Ship and Shore: General Specification (MIL-E-16400F). The characteristics of grounds are tested by the manufacturer of the equipment or by the Naval development laboratories. Therefore, maintenance of ground conductors and connectors consists primarily of corrective and preventive maintenance.

In all instances where equipment grounding is provided, certain general precautions and preventive maintenance measures must be taken to ensure that all bonding surfaces (connection points or metallic junctions) are securely fastened and free of paint, grease, or other foreign matter that could interfere with positive metal-to-metal contact at the ground connection point. A few of the precautions are given below:

1. Periodically clean all strap- and clamp-type connectors to ensure that all direct metal-to-metal contacts are free from foreign matter.
2. Check all mounting hardware for mechanical failure or loose connections.
3. Replace any faulty, rusted, or otherwise unfit grounding strap, clamp, connection, or component between the equipment and the ground to the ships hull.
4. When replacing a part of the ground connection, make certain that the metallic contact surfaces are clean, and electrical continuity is reestablished.
5. After the above steps have been completed, recheck to be sure the connection is securely fastened with correct mounting hardware, and paint the ground strap in accordance with current accepted procedures.

5-4 MAINTENANCE OF MOTORS AND GENERATORS

Proper maintenance is essential in order to ensure long and satisfactory service from an electric motor or generator. The two most important factors in providing this type of service from these machines are proper cleaning and lubrication as well as the replacement of worn parts.

a. CLEANING AND LUBRICATION

When specific cleaning and lubrication procedures are not provided in the equipment technical manual, the following subsections contain the acceptable methods for the cleaning and lubrication of motors and generators used in electronic installations.

(1) Cleaning

There are four acceptable methods of cleaning motors and generators. They are by wiping, use of suction, use of compressed air, and the use of solvents.

(a) Wiping — Wiping with a clean, lint-free, dry rag (such as cheese cloth) is effective for removing loose dust or foreign particles from accessible parts of a machine. When wiping, do not neglect such parts as the end windings, mica cone extension at the commutator, slip-ring insulation, connecting leads, and such.

(b) Suction — The use of suction is preferred to the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine because it lessens the possibility of damage to insulation. If a vacuum cleaner is not available for this purpose, a flexible tube attached to the suction side of a portable blower will serve as a satisfactory substitute. Always exhaust the blower to a suitable sump or over board when used for this purpose. Grit, iron dust, and copper particles should be removed by suction methods whenever possible.

(c) Compressed Air — Compressed air must be clean and dry when used for cleaning electrical equipment. Air pressure up to 30 pounds per square inch may be used on motors or generators of 50 hp or 50 kW, respectively, or less. A throttling valve should be used on air lines that carry higher pressure than is suitable for blowing out a machine. Before the air blast is turned on the machine, any accumulation of water in the air pipe or hose must be thoroughly blown out, and both ends of the machine must be opened to allow a path of escape for the air and dust.

(d) Solvents — The use of solvents for cleaning electrical equipment should be avoided whenever possible. However, their use is necessary for removing grease and pasty substances consisting of oil and carbon or dirt. Alcohol will injure most types of insulating varnishes and should not be used for cleaning electrical equipment. Solvents containing highly volatile gasoline or benzine must not be used on board ship for cleaning purposes under any circumstances. The recommended shipboard cleaning solvent to be used is inhibited methyl chloroform (1,1,1-trichloroethane) Federal Specification O-T 620 or dry cleaning solvent type II, Federal Specification P-D-680. Before using a solvent as a cleaning agent, apply it to a small area or sample of the material to be cleaned. DO NOT USE any solvent that will injure the material of the part being cleaned.

(2) Lubrication

Lubrication of motors, generators, and bearings has been covered in detail in Section 3 of this handbook.

b. BEARINGS

The annular (ring-shaped) ball bearing is the type of bearing used most extensively in the construction of electric motors and generators used in the Navy. This type of bearing is divided into three types: the radial, the angular contact, and the thrust as shown in Figure 5-1. The type of ball bearing used in a motor generator is dependent upon the load it is designed to bear.

(1) Inspection of Ball Bearings

The easiest way of determining the extent of wear in ball bearings is to periodically feel the bearing housing while the machine is running to detect any signs of overheating or excessive vibration, and to listen to the bearing for the presence of unusual noise. The indications thus obtained are comparative, and caution must be exercised in their analysis.

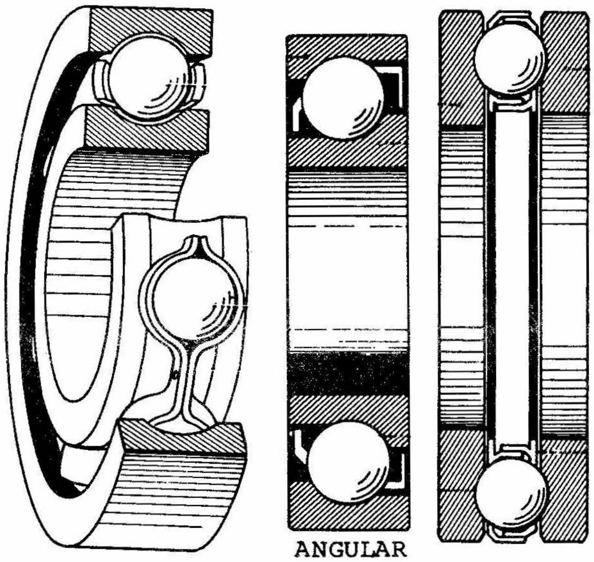


Figure 5-1. Types of Ball Bearings

When testing for overheating, the normal running temperature must be known before the test can be reliable. Rapid heating of bearings is indicative of danger. While a bearing temperature uncomfortable to the hand may be a sign of dangerous overheating, it is not always so. The bearing may be alright if it has taken an hour or more to reach that temperature, whereas, serious trouble can be expected if that same temperature is reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies to a great extent on the experience of the person conducting the test. He should be thoroughly familiar with the normal vibration of the machine in order to be able to correctly detect, identify, and interpret any unusual vibrations. Vibration, like heat and sound, is easily telegraphed and a thorough search is generally required to locate its source and determine its cause.

Ball bearings are inherently more noisy in normal operation than sleeve bearings and this fact must be borne in mind by personnel testing for the presence of abnormal noise in the bearing. A good method for sound testing is to place one end of a screwdriver or steel rod against the bearing housing and the other end against the ear. If a loud, irregular grinding, clicking, or other scraping noise is heard, trouble is indicated. As before, the degree of reliance in the results of this test depends on the experience of the person conducting the test.

The one sure method of checking ball bearing wear is also the most difficult. In this test, the bearing caps or other covers provided are removed and the actual condition of the bearing is observed. Each ball bearing should be inspected in this manner at least every two years. After the bearing has been removed and thoroughly cleaned, rotate the inner ring of the bearing slowly by hand, and if the bearing feels rough, repeat the cleaning. If the bearing still feels rough when turned slowly by hand, replace the bearing as it is not fit for service in the machine.

(2) Removal of Ball Bearings

The removal of a bearing from a shaft involves the risk of damage to the bearing, or to the shaft, or both. The bearing should be removed from a shaft with a bearing puller applied to the inner race of the bearing or to a sleeve which will apply pressure to the inner race. Removal of bearings by pulling on the outer race tends to make the balls dent the raceway even when a bearing puller is used. In rare instances, where faulty operation has subjected the bearing to such extreme temperatures so as to distort the race and balls and cause the race to shrink to the shaft more tightly than the original fit, care must be taken not to damage the shaft when removing the bearing.

(3) Cleaning Ball Bearings

Double shielded or double sealed ball bearings should never be disassembled or cleaned. These bearings are prelubricated and cleaning will remove the lubricant from the bearings or at least dilute the lubricant until it no longer possesses its original lubricating qualities.

Open, single shielded, or single sealed ball bearings may be cleaned when a suitable replacement is not available. Unless the cleaning is carefully done, more dirt may get into the bearing than is removed.

A good cleaner to use is Stoddard solvent or clean oil. Soak the bearing in the cleaner for as long as necessary to dislodge dirt and caked grease from around the balls and separators. After the bearing is cleaned, wipe it carefully with a dry, lint-free, cloth. If compressed air is used for drying, direct the air stream across the bearing so that the bearing does not spin.

Dry bearings rust quickly. Protect a dry bearing at once with a coat of clean, low-viscosity lubricating oil.

(4) Installation of Ball Bearings

When installing bearings, extreme care must be utilized to prevent dirt or other foreign particles from entering the bearing or bearing housing. A new bearing should not be removed from its original container and wrapping until every preparation has been made to install it.

Before installing ball bearings, the following points must be checked prior to the actual installation:

1. Shaft and housing diameters must conform to dimensional tolerances in the applicable specification.
2. Shaft and bearing seats must not be out-of-round or tapered.
3. Housings must be inspected for splits or cracks.
4. Shaft must be inspected for straightness.
5. Shaft and housing shoulders must be adequate and not out-of-square with the shaft.
6. Shafts, bearing housings, keyways, splines, etc., must be clean and light oiled.

There are four shop methods for mounting bearings; the arbor press, the infrared, the oven, and the hot-oil. These four methods will be discussed briefly in the following paragraphs.

The arbor press method, if available and adaptable, may be used if proper precautions are taken. Place a pair of flat steel blocks under the inner ring or both rings of the bearing. Never place the blocks under the outer ring only. Line up the shaft vertically above the bearing and place a soft pad between the shaft and the press ram. Make sure the shaft is started straight in the bearing. Press the shaft into the bearing until the bearing is flush against the shaft or housing shoulder.

The infrared method is where the bearing is heated in an infrared oven to expand the inner ring of the bearing for assembly. This method ensures a uniform heating all around the bearing. The bearing should not be heated above a temperature of 200°F.

The oven method is an alternate to the infrared method where the bearing is heated in a temperature controlled oven to expand the inner ring for assembly. The furnace temperature should never exceed 200°F and the bearing should not be left in the furnace beyond the time necessary to expand the inner ring the desired amount. Heating for an excessive period of time will give rise to the possibility of the deterioration of the grease with which the bearing is prelubricated.

The hot-oil method is where the bearing is heated in oil at a temperature of 200°F until the inner ring is expanded and then slipped on the shaft. This method is not desirable and should not be used unless absolutely necessary. The disadvantages to this method are:

1. The possibility of grease deterioration.
2. The possibility of bearing growth.
3. Inadequate or no temperature controls.
4. The possibility of contaminating the grease by the use of dirty oil.

When it is not possible to use any of the four methods previously discussed, or they are not available, a drift pipe of soft steel or malleable iron may be used to mount a bearing on a shaft. The inside diameter of the pipe must be large enough to clear the shaft or any locknut threads, and its outer diameter must be no larger than the maximum diameter of the bearing inner ring. Mount the bearing square with the shaft; fit the pipe squarely against the inner ring and lightly tap the pipe with a clean metal hammer until the inner ring of the bearing is seated tightly against the shaft shoulder.

A most important point to remember and strictly follow is that when pressing a bearing onto a shaft, pressure must be applied to the inner ring, but when pressing a bearing into a housing, the pressure must be applied to the outer ring.

c. BRUSHES

The brushes used in electric motors and generators are usually made of carbon, and are pressed against a commutator, or collector ring (slip ring) to provide a passage for electrical current for an external circuit. The brushes are held in position by brush-holders mounted on studs or brackets attached to the brush-mounting ring, or yoke, The brush-holder studs or brackets, and brush-mounting ring comprise the brush rigging. The brush rigging is attached to, but insulated from, the frame of the machine. Flexible leads (pigtails) are used to connect the brushes to the terminals of the external circuit. An adjustable spring is provided to maintain the proper pressure of the brush against the commutator in order to ensure good commutation.

Brushes are manufactured in different grades to meet the requirements of the varied types of service. The properties of resistance, ampere-carrying capacity, coefficient of friction, and hardness of the brushes are determined by the maximum allowable speed and load of the machine in which it is used. Only the grade of brush recommended by the manufacturer should be used in a machine. The brush grade is shown on the plan of the machine and in the equipment technical manual.

(1) Inspection and Care of Brushes

If the correct grade of brushes is used, and the brushes are correctly adjusted and cared for, good commutation will result. Periodic inspections of the brushes and brush rigging are required to ascertain their condition. The brush pigtails must be securely connected at the brushes and terminals. Brushes should move freely in the holders, but must not be loose enough to vibrate. Brushes should be replaced when they are worn down to half their original length or if chipping has occurred at the corners or edges of the brush. The brush holders and brush rigging should be cleaned before inserting new brushes. The brush holders should be mounted so that the edges nearest the commutator are the same distance from the commutator (nor more than 1/8-inch, nor less than 1/16-inch). The leading edges (toes) of all brushes on each stud must align with each other and one commutator segment.

When brushes are properly mounted, they will be evenly spaced around the commutator. To check the spacing, a strip of clean paper is wrapped around the commutator and marked where it laps. The paper is then removed from the commutator, cut at the lap mark, folded or marked, into as many equal parts as there are brush studs. Replace the paper on the commutator and adjust the brush holders so that the brush toes are at the creases or marks.

The pitting effect on the commutator differs under the positive and negative brushes, making it necessary to stagger the brushes in order to prevent grooving of the commutator, as illustrated in Figure 5-2. The positive and negative brushes are staggered in pairs so that the differences in pitting effect are distributed equally over the full brush-contact area of the commutator surface, as illustrated in Figure 5-2a. In a machine having an odd number of pairs, it is impossible to stagger all the brushes in this manner. In this machine, the brushes are staggered as before, except that the brushes of the odd pairs are staggered separately, as illustrated in Figure 5-2b.

(2) Measuring Brush Tension

As the brushes wear, the brush spring tension must be changed to keep the brush pressure approximately constant. On some machines, the design of the brush holder and spring allow for changing the brush-spring setting. Unless it is stated otherwise in the technical manual for the machine, the proper

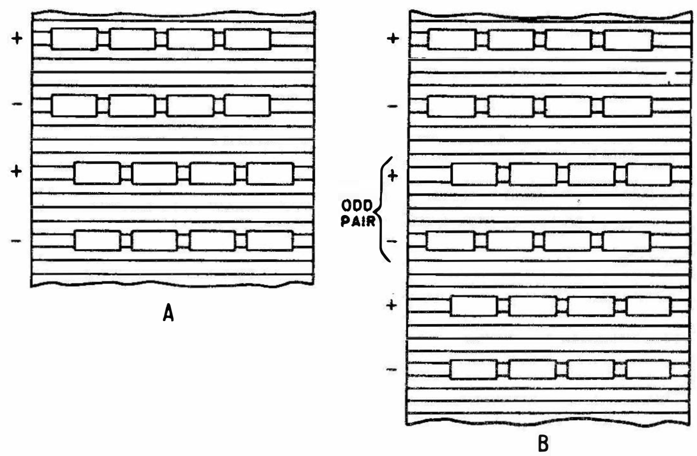


Figure 5-2. Method of Staggering Brushes.

brush pressure should be between 1-1/2 to 2-pounds per square inch of brush-contact area.

Brush pressure is easily measured. Attach a small spring balance to the pigtail end of the brush, insert one end of a strip of paper between the brush and the commutator, then exert a pull on the spring balance in the direction of the brush holder axis, as illustrated in Figure 5-3. Note the reading of the spring balance when the pull is barely sufficient to release the paper so that it can be pulled from between the brush and commutator without offering resistance. Divide this reading by the contact area of the brush to obtain the amount of brush pressure.

(3) Setting Brushes On Neutral

When a machine is running without a load and with only the main-pole field windings excited, the point on the commutator at which minimum voltage is induced between adjacent commutator bars is the no-load neutral point. This point is the best operating position of the brushes on most commutating-pole machines. Usually, the brush studs are doweled in the proper position, and the correct setting is indicated on a stationary part of the machine by a chisel mark or an arrow. In some cases, commutation may be improved by shifting the brushes slightly from the marked position.

There are two methods of finding the neutral position; the mechanical and the reverse rotation method.

(a) Mechanical — The commutator is turned until the two coil sides of the same armature coil are equidistant from the centerline of one main-field pole. The position of the commutator bar to which the coil is connected will indicate the approximate mechanical neutral.

(b) Reverse Rotation — The use of the reverse rotation method is possible only where it is practicable to run a machine in either direction of rotation with a rated load applied. This method differs for motors and generators.

For motors, the speed of the motor is, at first, accurately measured when the field current becomes constant under full load at line voltage with the motor running in the normal direction. The rotation of the motor is then reversed, full load is applied, and the speed is measured. The brushes are then shifted so that the speed of the motor is the same in both directions of rotation. This position is the neutral position.

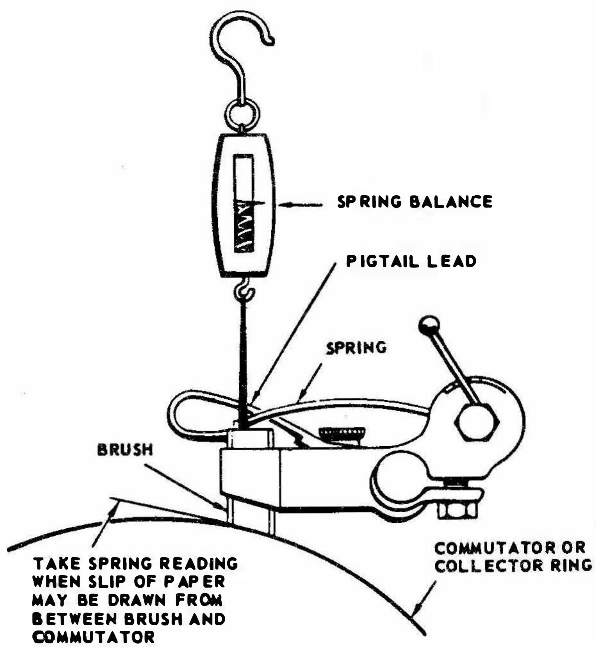


Figure 5-3. Measuring Brush Tension

Generators are run at the same field strength and same speed in both directions and the brushes are shifted until the full-load terminal voltage is the same for both directions of rotation. To ensure accuracy, a reliable tachometer must be used to measure the speed of the machine for this method.

(4) Fitting Brushes

An accurate fit of the brushes must be assured where their surfaces contact the commutator. The sandpaper method or the brush seater method is the best way to accomplish a true fit. These two methods are described below.

(a) Sandpaper — All power must be disconnected from the machine and every precaution must be taken to ensure that the machine will not inadvertently be started before using sandpaper to seat the brushes. Lift the brushes to be fitted and insert a strip of fine grade (No. 1) sandpaper, approximately the width of the commutator, between the brush and the commutator with the rough side against the brush. Hold the sandpaper tightly against the commutator surface to conform with the curvature and hold the s down by normal brush-spring pressure. Pull the sandpaper in the direction of normal rotation of the machine, as illustrated in Figure 5-4. When returning the sandpaper for another pull, the brushes must be lifted. Repeat this process until the fit of the brush is accurate. Always finish by using a finer grade (No. 0) sandpaper. A vacuum cleaner is required for removing the dust while sanding. Emery cloth, emery paper, or emery stone should never be used on a commutator or collector ring. After sanding, the commutator and windings must be thoroughly cleaned to remove all carbon dust.

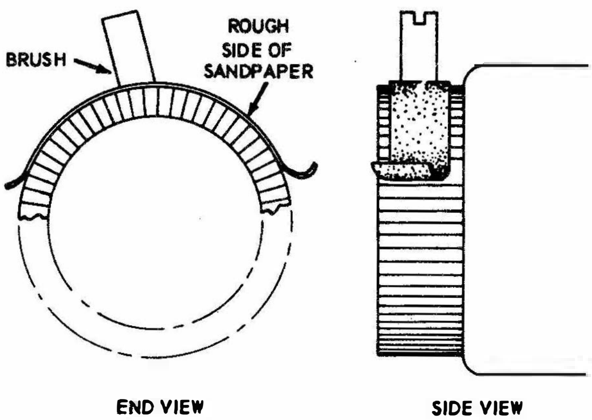


Figure 5-4. Method of Sanding Brushes

(b) Brush Seater — The brush seater is a compound of a mildly abrasive material loosely bonded and formed in the shape of a stick about 5-inches in length. The brush seater is applied to the commutator while the machine is running. Every precaution should be taken to prevent injury to the person applying it.

The brush seater is touched lightly, for a second or two, exactly at the heel of each brush, as illustrated in Figure 5-5. If the brush seater is placed even a 1/4-inch away from the heel, only a small part of the abrasive will pass under the brush. Pressure may be applied to the brush by setting the brush-spring tension at maximum or by pressing against the brush with a stick of insulated material. The dust is removed, during the operation, and the machine is cleaned thoroughly after the operation, in the same manner as for sanding brushes.

d. COMMUTATORS AND COLLECTOR-RINGS

Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum. After approximately two weeks of use, the commutator of a machine should develop a uniform, glazed, dark brown color on the places where the brushes ride. If a nonuniform or bluish colored surface appears, improper commutation conditions are indicated.

(1) Cleaning

One of the most effective ways of cleaning a commutator or collector-ring is to apply a canvas wiper while the machine is running. The wiper can be made by wrapping several layers of closely woven canvas over the end of a strong stick between 1/4- and 3/8-inch thick, as illustrated in Figure 5-6a. The canvas may be secured to the stick with rivets if the rivets are, in turn, covered with linen tape to prevent the possibility of their contacting the commutator. The manner of applying the wiper to the commutator is illustrated in Figure 5-6b. When the outer layer of canvas becomes worn or dirty, it must be removed to expose a clean layer. The wiper is most effective when used frequently. When using the wiper, exercise care to keep from fouling moving parts of the machine.

When machines are secured, a toothbrush can be used to clean out the commutator slots, and clean canvas or a lint-free cloth may be used for wiping the commutator and adjacent parts. In addition to being cleaned by wiping, the commutator should be periodically cleaned with a vacuum cleaner or blown out with clean, dry, air.

A fine grade (No. 00), sandpaper may be used to clean a commutator that is only slightly rough, but not out of true. Sandpapering is recommended for reducing high mica and for finishing a commutator that has been ground or turned. The sandpaper, attached to a wooden block shaped to fit the curvature of the commutator, is moved slowly back and forth across the surface of the commutator while the machine is running at a moderate speed. Rapid movement or the use of coarse sandpaper will cause scratches. Emery cloth, emery paper, or emery stone should never be used on a commutator or collector ring.

(2) Care of Commutators

Commutators must be true within close limits. For the most satisfactory operation, runout (eccentricity) of the commutator surface (as checked on the radius with an indicator) should not exceed two mils (0.002 inch) Handstoning, grinding with a rigidly supported stone, and turning the commutator are measures that will correct some of or all out-of-true conditions of the commutator.

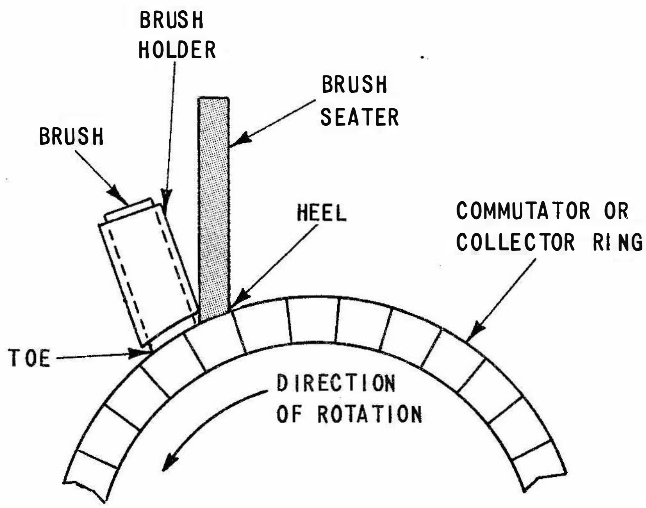


Figure 5-5. Using the Brush Seater

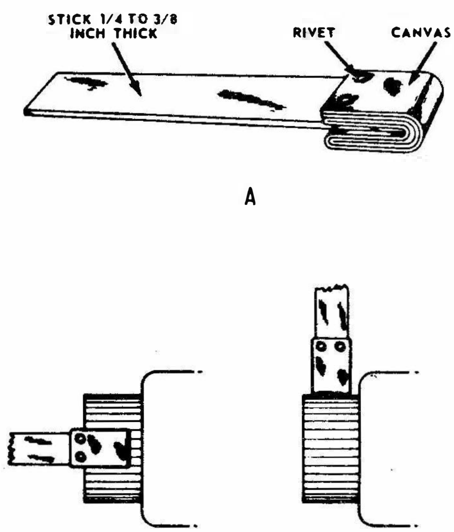


Figure 5-6. Using the Canvas Wiper on a Commutator

(a) Handstoning — For handstoning, the machine should be running at, or below, the rated speed. For motors, remove all except enough brushes to keep the armature turning at the proper speed. The stone to be used should fit the curvature of the commutator and have a surface substantially larger than the largest flat spot to be removed. Hold the stone in the hand and move it very slowly back and forth, parallel to the axis of the commutator, applying only enough pressure to keep the stone cutting. Crowding the stone will roughen the surface. Care must be exercised to avoid electric shock and to prevent jamming the stone between fixed and moving parts of the machine. Using the handstone is illustrated in Figure 5-7.

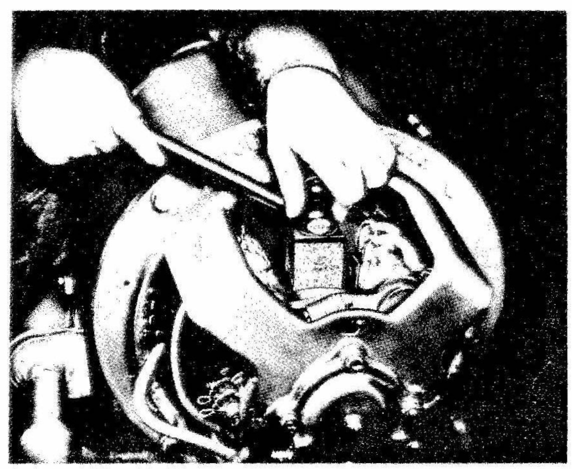


Figure 5-7. Handstoning the Commutator

(b) Rigidly Supported Stone — Either a nonrotating or a revolving stone can be used when grinding the commutator with a rigidly supported stone. Irrespective of which stone is used or whether the grinding is done with the commutator within the machine or in a lathe, extreme care must be taken to align the supports so that the motion of the stone is accurately parallel to the axis of the commutator. Failure to properly align the supports will taper the commutator, and failure to maintain the support rigid will cause the stone to dig into the commutator. Using the ridigly supported stone is illustrated in Figure 5-8.

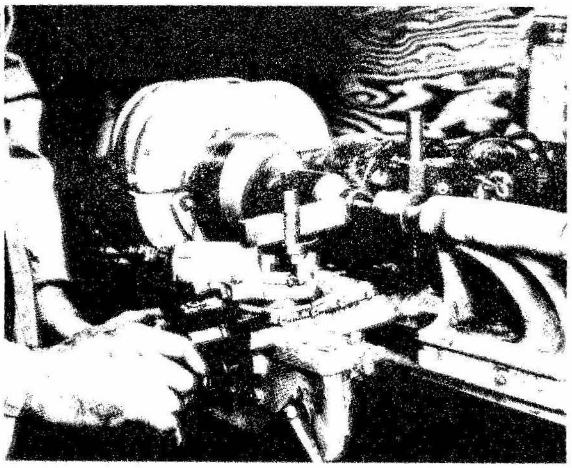


Figure 5-8. Using the Rigidly Supported Stone on the Commutator

(c) Turning the Commutator — For turning, the armature should be supported in a lathe. A cutting tool that is rounded sufficiently so that the cuts will overlap must be used to make the cut. Proper cutting speed is about 100-feet per minute with a feed of about 0.010-inch per revolution. The depth of cut should not exceed 0.010-inch. Truing the commutator by turning is illustrated in Figure 5-9.

The windings of the machine must be adequately protected from grit during stoning and grinding operations conducted with the commutator in the machine. Afterwards, the brushes, brush holders, and commutators must be thoroughly cleaned, and a complete insulation test should be made to determine that no ground or short circuits exist. After truing-up operation has been completed, regardless of the method used, always finish with a fine grade of sandpaper, undercut the mica to a depth no greater than 1/16-inch, and slightly bevel the edges of the commutator bars.

When the oxide film (dark brown color) has been removed by truing operations, it can be replaced by burnishing the commutator with a hardwood block. After the end grain of the block has been shaped to the curvature of the commutator, the block is pressed hard against the surface of the commutator while the machine is running. A commercial burnishing stone may also be used for this purpose. Less pressure is required in applying the stone because friction is greater, and the heat developed is high. Do not raise the commutator temperature above its normal operating level.

Commutator mica that has become carbonized loses its insulating value. It should be scraped out and replaced with sodium silicate or other insulating

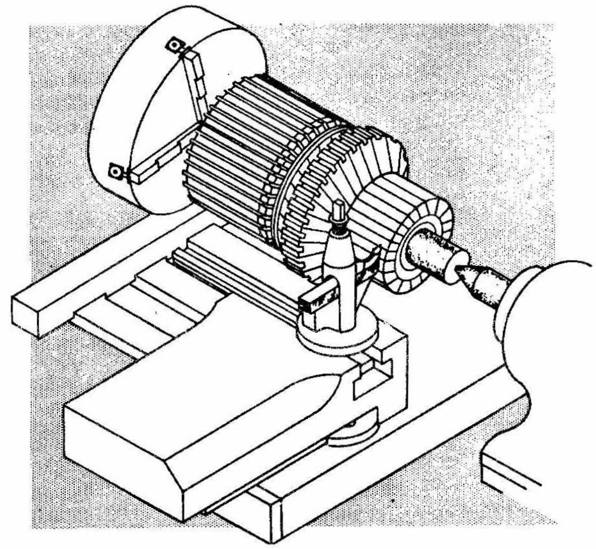


Figure 5-9. Truing Commutator by Turning

cement. Poor commutation will develop if the commutator bars are worn down to, or below, the level of the mica. The mica should be undercut to a depth of between 3/64-inch and 1/16-inch below the level of the commutator bars. A small motor-driven, circular saw especially designed for the purpose, a slotting file having an angle of 60 degrees between faces, or a hacksaw blade that has been ground to the right thickness and fitted to a handle, may be used for undercutting mica. Before using a motor-driven circular saw, install a canvas cover around the armature in a manner to prevent copper dust from becoming embedded in the armature windings. When undercutting has been completed, the edges of the bars should be beveled to a depth of about 1/32-inch below the surface. Finally, all mica, copper dust, and other foreign materials must be cleaned from the slots and commutator.

(3) Care of Collector Rings

Collector rings (slip rings) require the same careful attention as the commutator. Out-of-round conditions of the rings may be corrected in the same manner as for commutators, except for the fact that crocus cloth is used to apply a mirror-like finish following any turning, grinding, or sanding operations.

Pitting can develop because of the electrolytic action on the surface of collector rings caused by current flow. It may occur in only one ring, but will be general over the whole ring area. This condition can be corrected by reversing the polarity of the rings every few days. Reversing the polarity of the DC field of a 3-phase generator will not affect the phase rotation of the generator.

Field current must not be left on while a machine is secured because it will cause spot pitting and burning of the rings beneath the brushes.

e. ARMATURES AND ROTORS

In both AC and DC machines (motors and generators), the rotor is the moving part and the stator is the stationary part. The DC generator is similar to the AC generator in every respect except in the method of taking the output from the rotating coil. In a DC generator the rotating coil, called the armature, is connected to the external circuit by the commutator. In the AC generator the rotating coil, called the rotor, is connected to the external circuit by the slip rings.

(1) DC Armatures

There are two types of DC armatures; the ring-type and the drum-type. The drum-type is the only type in common use today. In the smaller machines, the armatures are coil-wound about the drum, while the large multi-polar machines usually have form-wound coils that are held in the armature slots with keepers or wedges. The DC armature is illustrated in Figure 5-10.

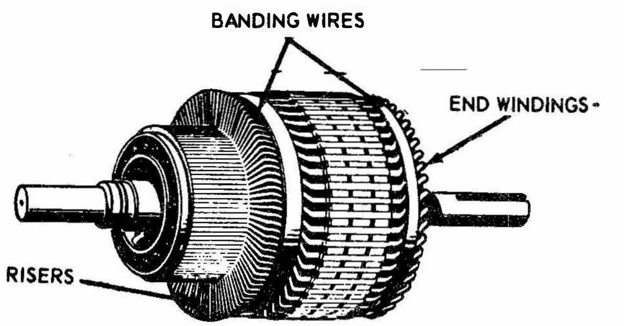


Figure 5-10. DC Armature

(a) Inspection of Armatures — Frequent checks must be made of the condition of the banding wire that holds down the windings of the armature to see that the wires are tight, undamaged, and have not shifted. At the same time, the clips securing the wires should be checked to see if any solder has loosened. When repairs of the wires are required, the banding wire size, material, and the method of original assembly should be duplicated as far as possible. Only pure tin must be used to solder banding wire.

Periodically, all end windings should be inspected and cleaned. There should be sufficient clearance between the end windings and end brackets or any air deflecting shields to prevent chafing or other damage. In cases where chafing is slight, or where shop overhaul is not feasible, air-drying varnish may be applied to the end windings with a brush after the windings have been cleaned and dryed.

Risers must be inspected periodically to determine the condition of the solder that secures the windings of the commutator segments.

(b) Cleaning — All dirt and lint should be removed by thorough cleaning to ensure that cooling passages will not be clogged. For generators, it may be necessary to do this each time the machine is secured. Cleaning is easier to accomplish while the machine is warm.

(c) Trouble Indications — Indications of troubles in armatures may be detected while making inspections of running machines.

Heat and odor of burning insulation may indicate a short-circuited armature coil. In a coil that has some turns shorted, the resistance of one turn of that coil will be very low and the voltage generated in that turn will cause high-current flow resulting in excessive heating which will cause the insulation to burn. In idle machines, a short-circuited coil may be identified by the presence of charred insulation.

An open coil in a running machine is indicated by a bright spark which appears to pass completely around the commutator. When the segment, to which the coil is connected, passes under the brushes, the brushes momentarily complete the circuit; when the segment leaves the brushes, the circuit is broken causing a spark to jump the gap. Eventually, it will definitely locate itself by scarring the commutator segment to which one end of the open coil is connected.

When a ground occurs in the coil of a running machine, it will cause the ground test lamps on the main switchboard to flicker on and off as the grounded coil segment passes from brush to brush during rotation. Two grounded coils will ~~have~~ the same effect as a short circuit across a group of coils. Overheating will occur in all of the coils in the group and burn out the winding. Grounded coils in idle machines can be detected by measuring the insulation resistance.

(d) Testing — The following paragraphs provide testing methods to locate and determine the various types of troubles in armatures.

To properly measure coil insulation resistance, connect one lead of a megger to the commutator and the other lead to the shaft or frame of the machine.

To locate a ground in an armature coil, the following procedure may be used:

1. Disconnect the machine from its normal power source and then lift all except one pair of brushes from the commutator.

2. Connect a low DC voltage source, such as a storage battery, lighting circuit, or welding set, across the positive (+) or negative (-) brushes through a resistance, lamp, lamp bank, or rheostat and use a milliammeter or low-reading voltmeter to make the measurements.

3. With the armature held in a fixed position, attach one lead of the meter to the shaft and the other meter lead to each commutator bar in turn.

If there is a ground, two or more bars will indicate practically zero readings. Some of these indications will be real grounds and others will be phantom grounds. All bars indicating grounds should be marked with chalk.

4. Rotate the armature a few degrees and repeat step 3.

The real grounds will remain in the same bars while the phantom grounds will shift to other bars as illustrated in Figure 5-11. For example, in Figure 5-11b, the phantom ground has shifted from bar b to bar c, while the real ground has remained in bar a. The ground will be in a coil connected to a bar showing a real ground with the lowest voltage reading.

To locate an open or short circuit in an armature, the following procedure may be used:

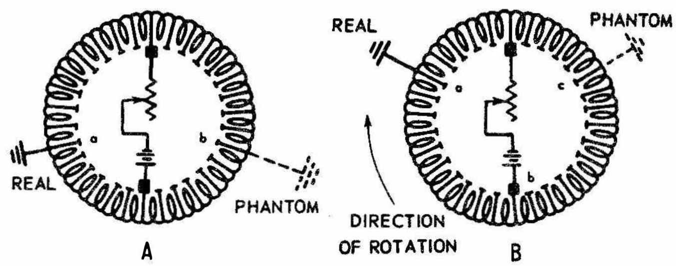


Figure 5-11. Real and Phantom Grounds in a Bar-to-Bar Test

1. Remove all brushes except one positive (+) brush holder and the adjacent negative (-) brush holder.

2. Connect a low voltage potential to these brushes, as illustrated in Figure 5-12, and adjust the current, if required, so that the readings obtained with the meter will be roughly 1/3- to 1/2-full scale on the meter. The current must not exceed one-fourth of that normally carried by one set of brushes.

3. With the armature held in a fixed position, using the meter, measure the voltage drop betwen one pair of adjacent bars, as illustrated in Figure 5-12.

4. Move the meter leads from one pair of adjacent bars to the next until a test has been made of all pairs of adjacent bars between the brushes.

5. Turn the armature to bring different bars between the brushes and repeat steps 3 and 4.

6. Repeat step 5 as necessary to test all around the commutator.

In a simplex winding, an open coil is located where the meter reading is maximum. A shorted coil is where the meter reading is minimum.

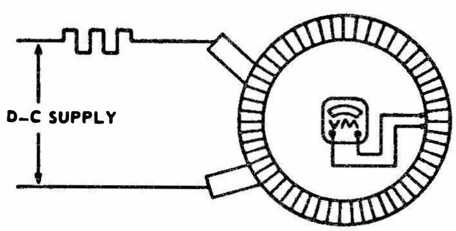


Figure 5-12. Testing for Open Coil or Shorted Coil

For most armatures in use aboard naval vessels, the windings will be free from fault if all the voltage readings are a small fraction of the voltage between the brushes and are equal within the limits of measurement. However, in some cases, a duplex winding may be encountered. This type of winding is indicated when the readings are only a small fraction of the voltage between the brushes and follow each other in a regularly repeating pattern, such as O, R, O, R, O, R, and so on, where R is a reading different from zero. When this happens, a further test must be made by measuring the voltage drop between alternate bars: 1 and 3, 2 and 4, 3 and 5, 4 and 6, and so on. If these readings are equal within the limits of measurement, the winding will be free from faults.

When an open circuit is present, the voltmeter reading across one pair of adjacent bars will be approximately equal to the voltage between the brushes, and zero readings will be obtained on several pairs of bars on each side of the pair with the high reading. The open-circuited coil will be connected to one or both of the bars in the pair with the high reading. Should the voltmeter readings taken between adjacent pairs of bars increase or decrease in magnitude and be alternately plus and minus, a duplex winding is indicated. A further test by measuring the voltage drop between alternate bars is then necessary to locate the open circuit. When a reading approximating the voltage between the brushes is thus obtained, the open-circuited coil will be connected to one or both of the bars in the pair with the high reading.

When a short circuit is present, the interpretation of the indication given by readings between adjacent bars or between alternate bars (duplex windings) depends upon whether the armature has a lap or a wave winding. In an armature having a lap winding, a voltmeter reading considerably lower than the others will indicate that a short-circuited coil is connected between the pair of bars that shows the low reading. A short-circuit coil in an armature with a wave winding will cause low readings to be obtained on as many pairs of bars as there are pairs of poles, and the short circuit will be in a coil connected to bars in these pairs.

The best method for locating the ends of a faulty coil in a wave-wound armature is to separate the coil from the rest of the winding in the following manner. In a six-pole machine, a short-circuited coil in a wave-wound armature would be indicated at three positions during the test. These positions should be marked with chalk. When the riser connections on these segments are lifted, six coils will be isolated from each other and the rest of the winding. The shorted coil is located by comparing the resistances of the six coils, and it will have less resistance than the others.

Emergency repairs can be effected by cutting out a short-circuited or open-circuited armature coil. This will permit restoration of the machine to service until permanent repairs can be made. However, permanent repairs should be made as soon as possible. The coil is cut out by disconnecting both ends of the coil and installing a jumper between the two risers from which the coil was disconnected. The coil itself is then cut at both the front and rear of the armature to prevent overheating of the damaged coil. A continuity test from one end to the back of the coil will locate the turns of the faulty coil. If a pin or needle is used to puncture the insulation for this test, insulating varnish can be used to fill the tiny hole in the event the wrong coil is pierced. All conducting surfaces exposed by the change in connections should be insulated, and all loose ends should be tied securely to prevent vibration.

Sometimes a spare armature, especially one from a repair shop, will apparently be normal but will not produce the proper output and should be tested for reversed coil connections. This condition may be readily checked by using a low-voltage source (approximately 2-volts) and a compass as illustrated in Figure 5-13.

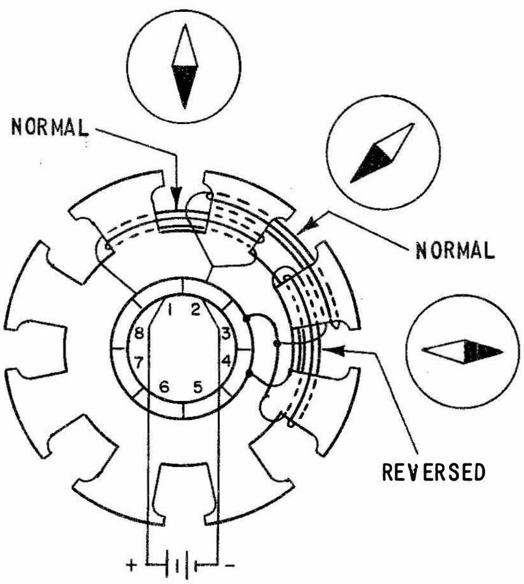


Figure 5-13. Test for Reversed Coil Leads

(2) AC Rotors

Basically there are two types of rotors in AC machines; the cage rotor, shown in Figure 5-14a, and the wound rotor, shown in Figure 5-15.

(a) Cage Rotors — The cage rotor usually consists of heavy copper or aluminum bars fitted into slots in the rotor frame. These bars are connected to short-circuiting end rings by bolts or rivets and are then brazed or welded together. In some cases, the cage rotor is manufactured by die-casting the rotor bars, end rings, and cooling fan into one piece as shown in Figure 5-14b.

The cage rotor must be kept clean and the rotor bars must be checked periodically for evidence of loose or fractured bars and localized overheating.

(b) Wound Rotors — In the wound rotor the uninsulated bar winding of the cage rotor is replaced with a distributed winding of performed coils similar to those of a DC armature. The windings are Wye-connected and the ends are brought out to the collector rings. Wound rotors, like other windings, require periodic inspections, tests, and cleaning.

(c) Testing — The following paragraphs provide testing methods to locate and determine various types of troubles in rotors.

Insulation resistance of the windings may be tested with a megger to determine if grounds are present. An open circuit in a wound rotor may cause reduced torque accompanied by a growling noise, or failure to start under load. In addition to reduced torque, a short circuit in the rotor windings may cause excessive vibration, sparking at the brushes, and uneven collector ring wear. With the brushes removed from the collector rings, a continuity check of the rotor coils will reveal the presence of a faulty coil. Emergency repair of a faulty coil in a wound rotor may be effected in the same manner previously described for cutting out a damaged armature coil.

Some single-phase AC motors, such as the split-phase motor, are equipped with a centrifugal switch mounted on the rotor shaft. This device functions to open the starting winding circuit when the motor has reached almost normal speed. The condition of this device must be checked periodically to determine that the switch contacts are clean and that all moving parts function properly. Stalling while starting or failure to start may indicate a faulty centrifugal switch. If this happens, power to the motor must be secured immediately or the starting winding will soon overheat and burn out.

f. SUPPRESSION OF RADIO FREQUENCY INTERFERENCE

Every motor and mechanically driven generator is included in the large category of rotating machinery. In this category are the rotary inverter (DC to AC converter), the dynamotor (DC motor and generator operated from a single magnetic field that functions to either step-up or step-down DC voltage), and the alternator (AC generator).

These machines operate on the principle of the conversion of energy, either converting mechanical energy to electrical energy or converting electrical energy to mechanical energy. These equipments create various forms of radio frequency interference (RFI) because of their nature of operation. RFI energy may arise from any of the following:

1. RFI may result from arcing when the brushes sweep over the commutator segments in DC motors and generators.

2. RFI may be induced due to the action of the magnetic fields associated with rotating electrical machines.

3. RFI may result from the characteristic ripple found in the output of all DC generators if it is not adequately filtered.

4. RFI may result from the presence of slot harmonics in the output of ship service generators and is usually caused by the lack of uniformity of the field. In present generators, this lack of uniformity is brought about primarily by the effect of the armature slots on the distribution of the magnetic flux, which causes harmonics to appear in the output.

The methods of suppressing RFI must be adapted to the particular equipments to which they are applied and may be done as described in the following paragraphs.

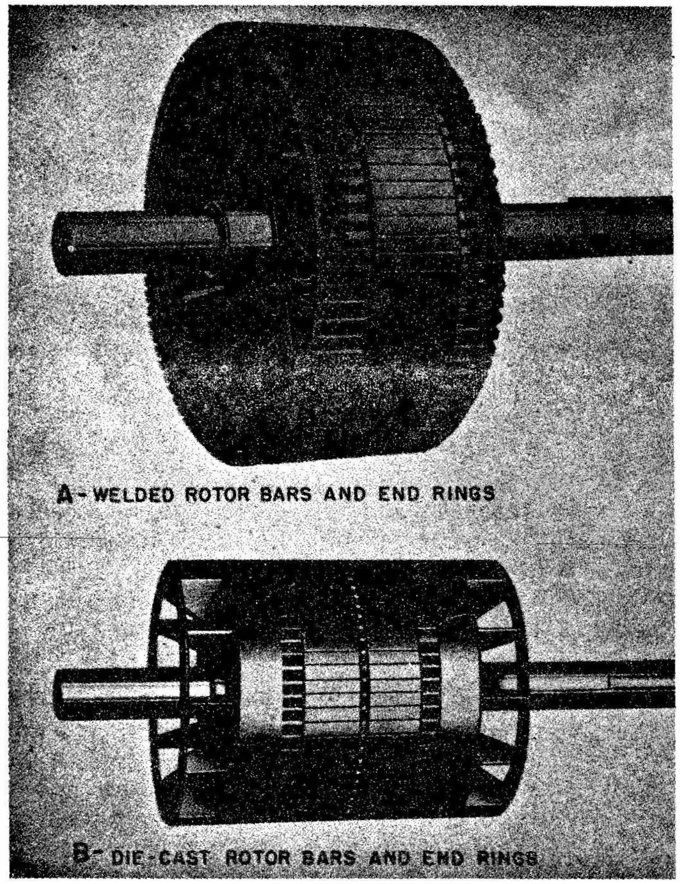


Figure 5-14. Cage Rotors

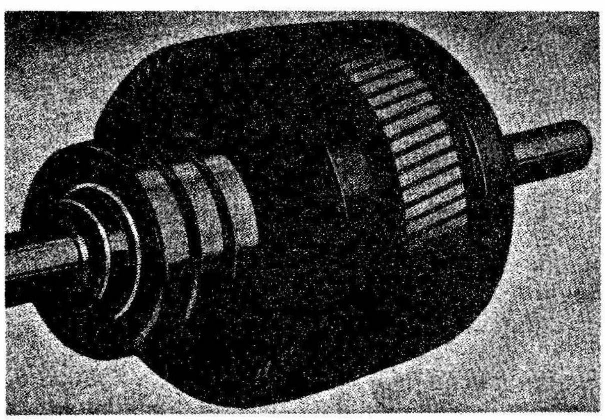


Figure 5-15. Wound Rotor

(1) DC Motors and Generators

RFI from DC motors and generators may be suppressed by one or more of the following methods.

1. Capacitors installed at the brushes as shown in Figure 5-16.
2. A feed-through (preferred) or bypass capacitor installed at the armature terminals as shown in Figure 5-17.
3. Shielding provided by the housing. The housing should have screened louvers and if there is an inspection plate, it should be tightly fitted to the housing.

(2) Alternators

RFI from alternators may be suppressed by one of the following and should be checked for proper action:

1. Capacitors installed at the slip ring brushes.
2. Capacitors installed at the exciter brushes.

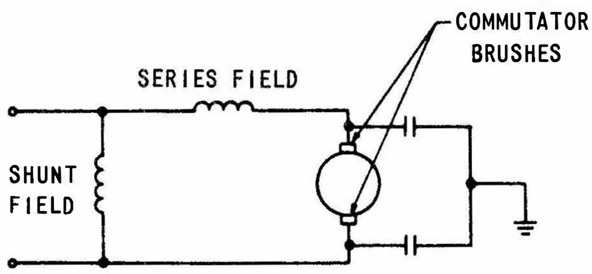


Figure 5-16. Suppression Capacitors Connected from Brushes to Ground

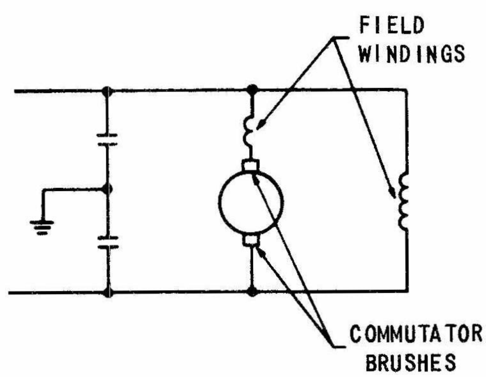


Figure 5-17. Suppression Capacitors Connected Across Terminals

3. Feed-through capacitors in the output leads (preferred) or bypass capacitors connected to the brush terminal outlet inside the shield.

(3) Synchronous Motors

RFI from large synchronous motors are suppressed basically by the same techniques as those used for alternators since they use slip rings and brushes. Small synchronous motors do not use slip rings and are not normally a source of interference.

(4) Dynamotors

RFI from dynamotors may be suppressed by the same techniques as those used for motors and generators. Feed-through capacitors should be mounted through the shield on both the input and output leads.

5-5 MAINTENANCE OF SYNCHROS

Synchros are not expected to operate forever without repair or overhaul; but like other precision instruments, they require the care of a specialist. Unless you, the maintenance technician, are trained as a competent synchro technician, there are two basic rules to follow:

1. If it works — leave it alone.
2. If it goes bad — replace it, do not attempt to repair it.

a. TROUBLESHOOTING SYNCHRO SYSTEMS

Shipboard system troubleshooting is limited to determining if the trouble lies in the system, which is comprised of one or more synchros, or in an individual synchro. Repairs may be made to the system connections, but if something is wrong with a unit, it must be replaced. There are two major categories of troubles occurring in synchro systems: those likely to occur in new installation and those likely to occur after the system has been in service for awhile.

In a newly installed system, the trouble is usually the result of improper zeroing or wrong connections. Make certain that all units are zeroed correctly and then check the wiring. Do not trust the color coding of the wires; use an ohmmeter. One of the major sources of trouble is improper excitation. The entire system must be energized from the same power for proper operation.

In systems which have been working, the most common sources of trouble are shorts, opens, grounds, corrosion, and wrong connections. Trouble may also be caused by water or oil from nearby equipment leaking into a synchro. If this is the trouble, correct the leak before replacing the synchro with a new unit. Check all system terminals boards for loose lugs, frayed wires, corrosion, and wrong connections. Check all units to see that they are properly zeroed.

Wrong connections and improper zeroing in any system is usually the result of careless workmanship or inadequate information. Do not rely on memory when removing or installing a unit, always refer to applicable technical manuals or standard plans. Tag all leads or make a record of the connections as someone else may need the information.

In synchro systems where two or more receivers are connected to one transmitter, similar symptoms occur. If all the receivers act up, the trouble is in the transmitter. If the trouble appears in one receiver only, check that unit and its connections. Check the entire system for proper zero before replacing any units.

In control systems the existence of trouble is readily indicated when the system does not properly respond to the input order. A good way to locate the trouble in an operating system is to use known operating voltages as references for faulty operation.

b. ZEROING SYNCHROS

If synchros are to work together properly in a system, it is essential that they be correctly connected and aligned with respect to each other, and the other devices with which they are used.

Electrical zero is the reference point for alignment of all synchro units. The mechanical reference point for the units connected to the synchros depends upon the particular application of the synchro system. The procedure for zeroing synchros depends on how it is used in the system. The methods used are different for each type of synchro.

(1) Synchro Receiver

To zero a synchro receiver, the voltage between the S1 and S3 leads must be zero and the phase of the voltage at the S2 lead must be the same as that of the voltage at the R1 lead. This may be accomplished by connecting the S2 lead to the R1 lead and the S3 and S1 leads to the R2 lead. Energize the rotor and it will line up in zero position. If the indicator does not point to zero on the dial, loosen the synchro in its mounting and rotate it until the dial reads zero and retighten the synchro mountings at this position.

(2) Synchro Transmitter

To zero a synchro transmitter, connect an AC voltmeter across the S1 and S3 leads. Rotate the energized rotor until a zero reading is obtained on the voltmeter. Since rotor positions at 0 degrees and 180 degrees will produce this zero reading, it is necessary to determine if the phase of the S2 voltage is the same as that of the R1 voltage. This is accomplished by connecting the voltmeter across the S2 and R1 leads and connecting the S1 lead to the R2 lead. If the proper polarity relationship exists, the voltmeter will indicate less than the line voltage applied to the rotor. On the other hand, if the voltmeter indication is greater than the line voltage, the rotor must be rotated 180 degrees. Disconnect the R2 and S1 leads and reconnect the voltmeter across the S1 and S3 leads. Rotate the energized rotor until a zero reading is obtained on the voltmeter. The pointer connected to the rotor should be adjusted to indicate zero.

(3) Synchro Differential Transmitter

To zero a synchro differential transmitter, connect a voltmeter across the S1 and R1 leads and connect the R2 lead to the S2 lead. Turn the energized synchro in its mounting until the voltmeter indication is minimum. After completion of the above, connect the voltmeter across the R1 and R3 leads and connect the S3 lead to the S1 lead. Again turn the synchro slightly in its mounting until a minimum voltage is indicated on the voltmeter.

(4) Synchro Differential Receiver

To zero a synchro differential receiver, connect the R3, R1, S1, and S3 leads together and connect the R2 lead to the S2 lead. Energize the synchro and the rotor will line up in the electrical zero position. Set the dial at zero and reconnect the unit in the circuit.

(5) Synchro Control Transformer

To zero a synchro control transformer, connect a voltmeter across the R1 lead and S1 leads and connect the R2 lead to the S3 lead. Apply power and turn the synchro in its mounting until a minimum reading is indicated on the voltmeter. After completion of the above, connect the voltmeter across the R1 and R2 leads and connect the S3 lead to the S1 lead. Again turn the synchro slightly in its mounting for a minimum indication on the voltmeter.

5-6 MAINTENANCE AND REPAIR OF MODULAR ASSEMBLIES

The advent of modular assemblies has created maintenance problems which are, in many cases, beyond the scope of the average maintenance technician's experience. The expanding use of transistor circuits and the growing emphasis on compactness and miniaturization has increased the utilization of modular construction. In today's modern Navy, the technician who maintains electronic equipment must familiarize himself with the maintenance techniques of modular construction.

Certain standards must be met to successfully service modular assemblies. More skill is usually required for this kind of service than is required for the servicing of wire circuits. Specialized techniques, an adequate complement of the proper type and size of tools, a certain degree of dexterity, and patience are musts for this type of servicing.

a. AUTOMATED TESTING

Automated testing of modular assemblies may be done with the Assembly Test Set (AN/SSM-6). This test set is designed for shipboard use and is capable of providing power, signals, loads, and also checking both analog and digital modules. It measures radio frequency signals, audio frequency signals, pulse signals, square waves, and triangular pulses. It is programmed automatically by the means of digital coding on 16 millimeter microfilm.

Through the use of graphic display techniques, proper power signals, and loads, it permits the technician to perform manual piece part troubleshooting as required.

b. MODULE TESTING

Module testing may be done by visual inspection, when it is removed from the equipment in which it is designed to function as follows:

1. Remove module covers and visually inspect all parts of the module for evidence of overheating caused by short circuits or leakage paths. Discoloration of wires or components indicates that excessive heat has been generated.
2. Inspect the module for broken or lifted printed circuit wiring, cracked or warped printed circuit boards, bulging capacitors, shorted transistor leads, and broken wiring. In addition, inspect all connectors and plugs for broken, worn, or warped contact surfaces.

If any of the above conditions appears, make or check to find the cause, and then make the necessary repairs.

(1) Test Equipment

Test equipment used for modular assembly maintenance and repair, other than the test set (AN/SSM-6) previously discussed, are the transistor test set (TS-1100/U), multimeter, vacuum-tube voltmeter (VTVM), the electronic voltmeter (TS-352/U), and an oscilloscope (AN/USM 140A).

The TS-1100/U measures the amplification (beta) of a transistor without the need of removing the transistor from the circuit. It will also test for collector leakage current with the transistor in or out of the circuit and will also test for shorts. The great advantage of this test set, other than its portability, is its use of AC as the testing current. This eliminates interference from any DC currents and voltages that may be present and permits the measurement of the gain of a transistor in-circuit, thus making it unnecessary to unsolder or disconnect the transistor for this test. Refer to the test set technical manual, NAVSHIPS 93277, for operating instructions and use of this test set.

Multimeters, when used for voltage measurements in transistor circuits, should have a sensitivity of 20,000 ohms per volt on all voltage ranges. Meters with low sensitivity will drain too much current from the circuits under test when used on their low-voltage ranges. It is important that no meter range having less than 20,000 ohms in the meter circuit be used. A 20,000 ohms per volt meter or an electronic voltmeter with an input resistance of 11 megohms or higher on all voltage ranges is preferred. However, a VTVM should be used only under isolated conditions, for example, with an isolation transformer between the VTVM and the power line.

Ohmmeter circuits which pass a current of more than 1 milliampere through the circuit under test cannot be used safely in testing transistor circuits. Many electronic voltmeters which have ohmmeter circuits, exceed this safe value of 1 milliampere. High-sensitivity multimeters are often shunted down on ohmmeter ranges so that they also pass a current of more than 1 milliampere through the circuit under test. Before using any ohmmeter on a transistor circuit, the current it passes should be checked on all ranges. Do not use any range which passes more than 1 milliampere. To check the current, adjust the ohmmeter for resistance measurements; then connect a milliammeter in series with the test leads (as shown in Figure 5-18), as if measuring the resistance of the milliammeter and observe the indication on the milliammeter. The milliammeter used should have a low resistance, such as a TS-352/U or equivalent. The oscilloscope must have a high input impedance and low shunt capacitance, together with good high frequency response, high deflection sensitivity and a large horizontal sweep range, such as in the AN/USM-140A or better.

(2) Precautions

The following precautions should be observed before attempting to connect any test equipment to or test any modular assembly or printed circuit.

1. Make sure all power has been removed from the equipment under test before servicing, testing, or removing a transistor or transistorized assembly.

2. Before using a piece of test equipment, determine that the test instrument to be used meets the requirements for the test and type of circuit in which it is to be used.

3. Be sure that any line-powered test equipment is properly grounded to the chassis of the equipment under test.

4. Before making any measurements, ensure that the voltages to be applied are of the correct polarity for the circuit to be tested. Do not depend on indicated polarities; use a voltmeter connected across the test leads for this check.

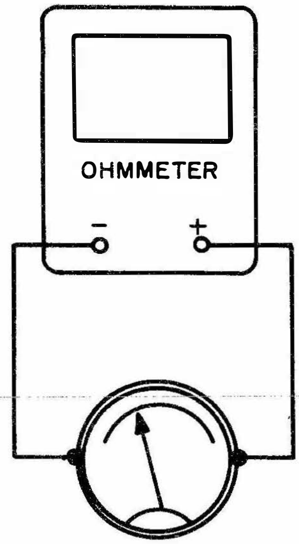


Figure 5-18. Measuring Current Passed by Ohmmeter

5. Do Not troubleshoot transistor circuits by the shorting-to-ground method. Short circuits of any kind will damage a transistor. Use special insulated test probes to prevent accidental shorting.

(3) Tests

The tests which can be made on modular assemblies are very similar to troubleshooting procedures performed on individual components. A simulated input signal must be applied to the assembly under test using the proper type of input signal generator, and the power input connections must be made to a supply which will furnish the required voltage and current to operate the module. For modules containing more than one stage or circuit the input signal is traced from point-to-point through the circuits. Check for proper input and output waveforms with the oscilloscope, and for proper voltages and current with the voltmeter and multimeter. When stage gain figures are available, use the VTVM to determine if there is a loss of gain. Where the signal changes from normal, or where abnormal voltage or current is indicated usually pinpoints the trouble to the parts effected. Simple continuity checks then are made with an ohmmeter, or checks for resistance and grounds or shorts will usually locate the defective part. Make use of in-circuit testers wherever available to verify the parts values as described in section 6 of this handbook. A single stage module or part check is all that is needed.

c. MICRO-MINIATURE TOOLS

Tools not ordinarily used in servicing the conventional wired-circuit chassis are required to be used in servicing a modular assembly or printed circuit board. Transistors and associated components used in this type of assembly are extremely small and require the use of tools of greatly reduced size in order to cope with the limited space encountered with this type of construction. In addition, special devices which extend the vision, aid the reach, and sometimes act as a third hand are required.

Some of the tools required in this type of repair are shown in Figure 5-19. Many of these tools may be obtained through the ship's medical or dental officer. Others, if not carried in the normal supply system, may be procured through commercial supply sources. All other tools normally required are standard handtools and are listed in the Electronics Tools Allowance List.

The number of micro-miniature tools should be held to a minimum compatible with the actual maintenance needs.

d. REMOVING AND REPLACING PARTS

The removing and replacement of a part without damaging the modular assembly or printed circuit board and its associated parts requires that the soldering tool and other handtools required be used with precision and skill. Thought should be given to the most appropriate procedure or method to use in the removal and replacement of the part involved.

A part to be removed may be too close to a heat-sensitive semiconductor or other part to allow a hot pencil-soldering iron to be applied. A quick test to determine this safe distance is to place your finger between the semiconductor (or heat-sensitive part) and the part to be removed. Place the hot soldering iron in the position it is to be used. If the heat is too great for your finger it is too hot for the semiconductor. After determining that the heat-sensitive parts are too close, place a shield (asbestos or like substance) between the parts before applying the hot soldering iron, and place heat sink clamps on all leads from the heat-sensitive part.

Solid-state parts and their associated circuitry are extremely sensitive to thermal changes (heat). Therefore, particular care must be taken to prevent exposing them to heat. Heat sinks and shunts must be applied with shield inserted to protect the associated parts any time repair or removal of a part requires the use of a hot soldering iron. Solid-state parts and associated assemblies require the same care in handling and skill of repairing that is applied to assemblies in equipment of unitized or modular construction containing transistors, tantalum capacitors, crystals, etc.

Removal of an axial-lead part that has been bonded to a printed circuit board (with epoxy resin or similar compound) may be accomplished by breaking the defective part or by applying heat to the bonding compound. The method to use depends upon the part itself and its location.

If the defective axial-lead part cannot be removed by heat, cut or break the part away from the bonding compounds as illustrated in Figure 5-20. "A" and "B" of Figure 5-20 illustrates two different methods of breaking the part away from the bonding compound where the part is too close to the other parts to use cutting pliers. In some instances, the part to be replaced is so closely positioned between other parts that one lead must be cut close to the body of the defective part to permit application of the prying tool as illustrated in "A". Wherever possible, cutting the defective part with end-cutting pliers or diagonals, as illustrated in "C" is the preferred method to use.

Regardless of which tool is employed (round-pointed or spade type), great care must be used in its application to prevent the printed circuit board or other parts from being damaged or broken. Apply the point of the tool against the bonding compound between the part and the printed circuit board. Use the tool in such a manner that it works away the bonding compound from the part to be broken away until enough has been removed by the tool to exert pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board; this helps to prevent the tool from gouging or breaking the board. BE CAREFUL—NEVER APPLY MUCH PRESSURE AGAINST THE PRINTED-CIRCUIT BOARD.

After the defective part has been removed from the bonding compound, remove the leads or tabs from their terminals on the printed circuit board and clean the area thoroughly before installing the new part. Do not remove the bonding compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as for the new part; thus inserting the new part in this mold helps secure it from vibration. Install the new part and after repairs have been completed and the circuit tested, spray the newly soldered area with an insulating varnish (MIL-V-1137A or equivalent). Coat the new part or parts with a bonding compound (Epibond by Furane Plastics or equivalent).

To remove a proven defective transistor, first cut all of its leads, and then remove it from the assembly. Transistors are mounted on circuit boards in many different ways; therefore, it is necessary to study how the transistor is mounted before attempting to remove it. A transistor with clamp-type mounting requires only a pointed tool between the clamp and the transistor to remove it. A transistor mounted in a socket may have a wire spring clamp. Remove the clamp before pulling the transistor out of its socket. Where the transistor is bolted through the board, remove the nut and washer, and then remove the transistor. Where vibration is a prime factor, the manufacturer will mount the transistor through the circuit board and bond it with epoxy resin or similar compound. For this type of mounting, a flat-ended round-rod-type tool (drift punch) of a diameter less than that of the transistor case is required. Before removing the transistor, ensure that the printed circuit board, on which the transistor is mounted, is secured in a proper device as illustrated in Figure 5-21, and in such a way that the pressure exerted against the circuit board will be relieved by a proper support on the other side. Apply a hot-pencil soldering iron to the bonding compound and simultaneously apply the drift punch against the top of the transistor, exerting enough pressure to remove the transistor from the softened compound, and then on through and out of the circuit board as illustrated in Figure 5-21.

After the defective transistor has been removed, remove the remaining pieces of the leads from the terminals on the board. Clean and prepare the terminals on the board before installing the new part.

Before installing a new transistor, great care must be taken to prepare the new part for installation.

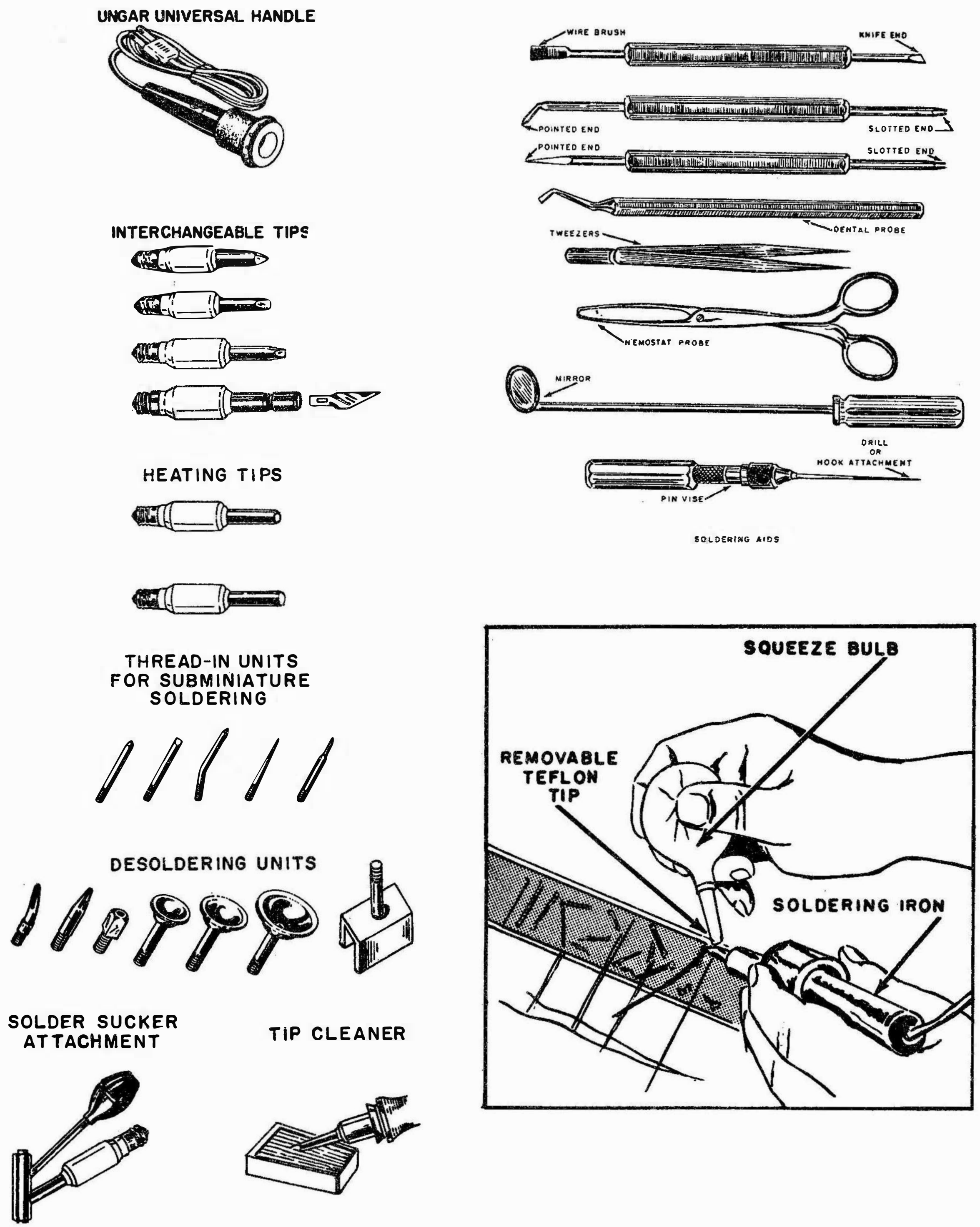


Figure 5-19. Microminiature Tools

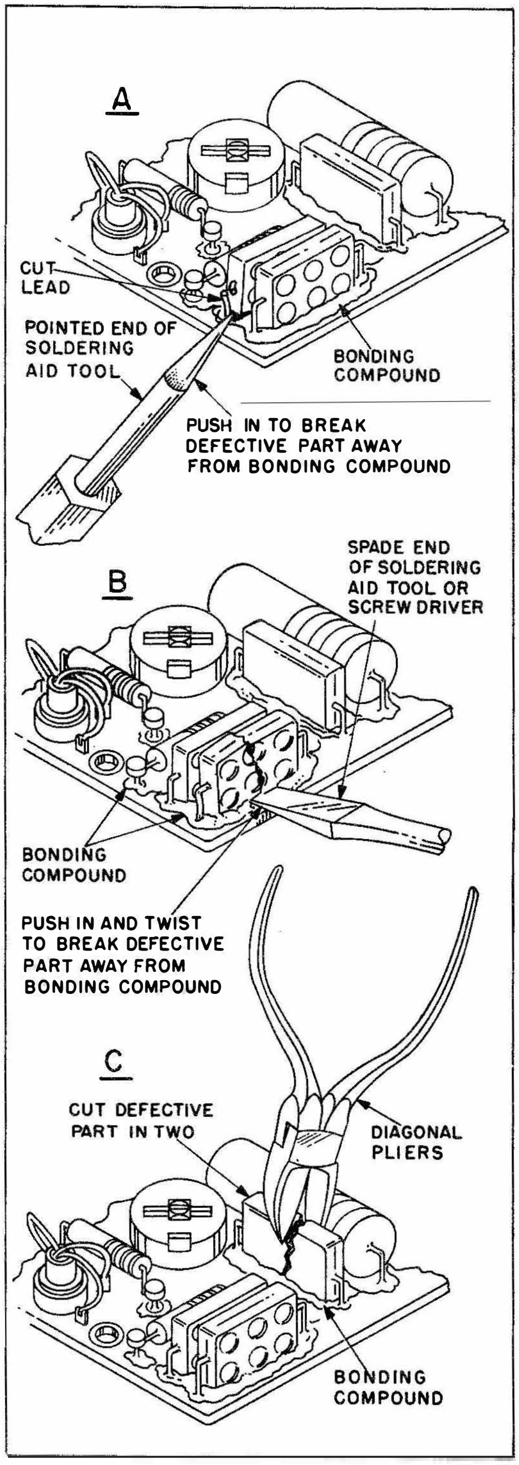


Figure 5-20. Removing a Defective Part from Bonding Compound

Test the transistor in a transistor tester (TS-1100/U or similar equipment) before installing. This precaution will assure that the transistor is good before it is installed.

Pre-shape and cut the new transistor leads to the shape and length required for easy replacement. Use sharp cutters and do not place undue stress on any lead entering the transistor. The leads are fragile and are therefore susceptible to excessive bending or too sharp a bend. Shape and bend as required in a gradual curve, and at least 1/4-inch to 3/8-inch from the base of the transistor. A safety measure which can be taken to ensure that the lead does not break off at the base is to use two pairs of needle-nose pliers. Grasp the lead close to the transistor base with one pair of pliers, while shaping the rest of the lead with the other pair.

The above procedure and precaution is applicable to any and all semiconductors, tantalum capacitors, and other miniaturized parts in equipment of modular or unitized construction.

Where the defective transistor was removed from a through-board mounting and bonded, care must be taken that the new transistor clears the hole before it is connected to its terminals. If the hole is too large, shim with a thin plastic sleeve (fabricated). If the hole is too small, ream it to accept the new transistor. Rebond the fitted transistor after testing the repaired circuit and it is proven to be operative. DO NOT use heat to rebond semiconductors.

To remove and replace a multi-lug part, such as a transformer, choke, filter, or other similar potted, canned or molded part, release the part from its mounting before disconnecting or cutting its conductors. Before applying pressure to remove such a part, carefully inspect it to be sure that the part is completely free of all its connections to the printed circuit board, and that all bent or twisted mounting lugs have been straightened; otherwise, you may break the board by applying undue pressure to it. Never wrench or twist a multi-lug part to free it, because this will cause the conducting strip to become unbonded from the board. Work this type of part in and out in line with its lugs as shown in Figure 5-22A, while applying a hot-pencil soldering iron (using a bar-type tiplet adapter or desoldering tool).

Whenever possible, cut the conducting of mounting leads and lugs of the defective multi-lug part on the mounting side of the board, as shown in "B" of Figure 5-22. Heat and straighten the clipped leads with a hot-pencil soldering iron and a slotted soldering-aid tool (or slotted soldering iron tiplet adapter or similar desoldering tool) applied to the circuit side of the board; pull the leads or tabs through with pliers as shown in "C" of Figure 5-22.

When installing a new multi-lug part, be sure that all of the lead holes or slots are free and clean, allowing easy insertion of the part. If the part does not position easily, check and rework the terminals and holes (or slots) until it does seat freely. DO NOT force any part into position on a printed circuit board. You may break the board or lift the printed circuit strip and eyelet terminal.

Considerable care must be taken when replacing a defective part that terminates on miniaturized standoffs, feedthrough terminals, and such. These small terminals break easily from applied pressure (too heavy an application when applying a tool or soldering iron), or thay may melt loose from excessive

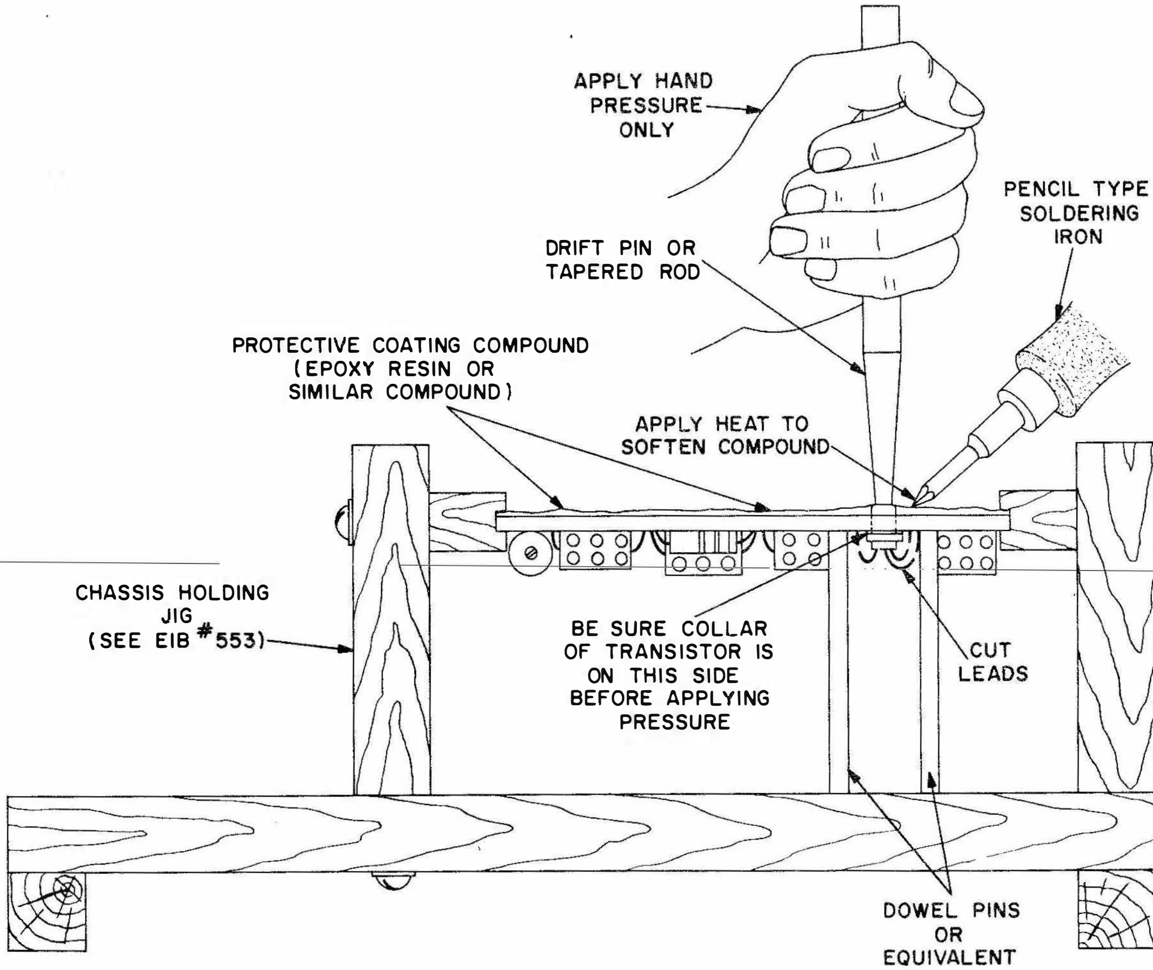


Figure 5-21. Removing a Transistor that has been Through-Board Mounted

heat produced by prolonged application of the hot soldering iron.

e. SPECIAL SOLDERING TECHNIQUES

Replacement of miniature and subminiature parts found in modular assemblies requires more consideration than is normally given to parts in the servicing of other electronic equipment. Before attempting repair, maintenance personnel should become thoroughly familiar with the correct repair and soldering techniques, since servicing procedures used differ in a number of ways.

The compactness of modular assemblies makes it imperative that a small, low-wattage pencil iron be used. The soldering iron should have a small tip so that heat can be applied directly to the terminal of the part to be removed or replaced, without overheating the printed circuit board or adjacent parts.

Practical soldering irons, with tips specially designed for soldering and unsoldering parts from printed circuit boards, have been developed by a number of companies.

The off-set or straight-slotted tiplets will simultaneously melt the solder and straighten the leads, tabs, and small wires bent against the board or terminal.

The bar tiplet will remove straight-line multiterminal parts quickly and efficiently.

The cup-shaped tiplets, the triangle tiplet, and the hollow-cube tiplet are specially designed to withdraw solder from circular or triangular mounted parts in one operation.

The most important requirement for repairing modular assemblies and printed circuit boards is skill in the soldering and unsoldering of parts. Careless work creates unnecessary damage. Take time and be precise. When applying solder, remember that the iron must heat the metal to solder-melting temperature before actual soldering can take place. The solder-melting temperature is reached in a matter of seconds (5 to 10 seconds); therefore, the

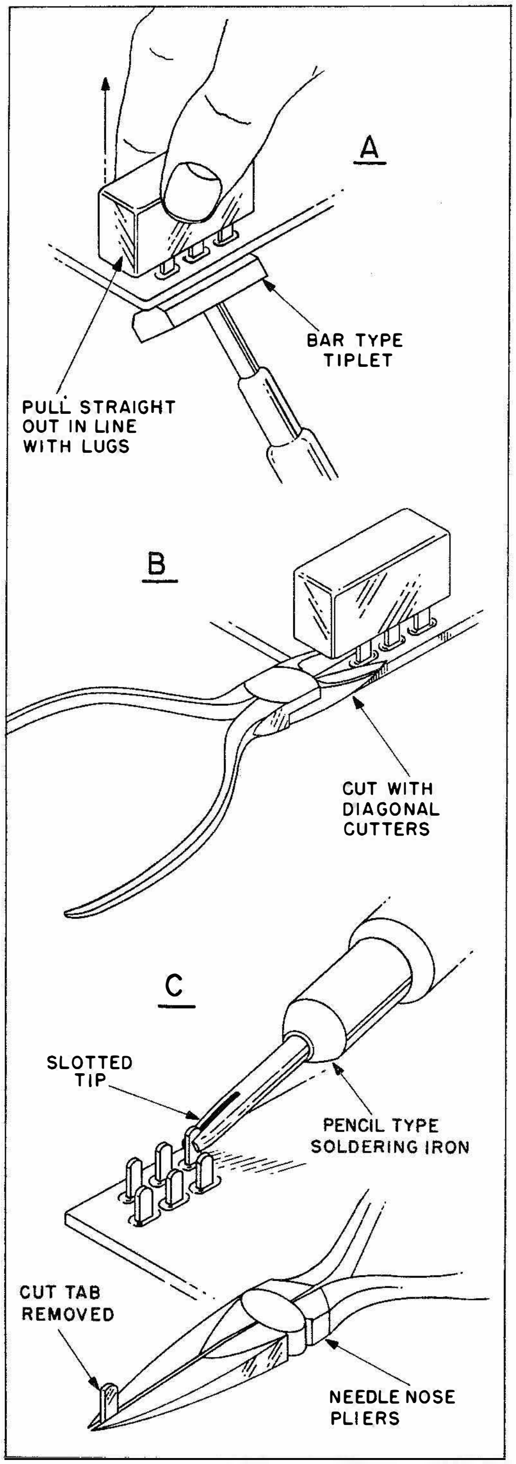


Figure 5-22. Removing a Defective Multi-lug Part

soldering iron and the solder strand must be applied simultaneously. Make certain to apply the solder to the joint, wire, or contact to be soldered, not to the soldering iron.

Before applying any solder to a part be sure that the terminal, or any portion of the part to be soldered, is properly cleaned and tinned before positioning it for soldering. Do Not tin printed circuit terminals; just clean any moisture, grease, or wax from the printed ribbon with a stiff-bristle brush and methyl chloroform or alcohol. Be sure the cleaning solvent is dry before applying the hot soldering iron.

CAUTION: Alcohol is flammable. Methyl chloroform is not flammable, but heating it increases its toxic hazard.

Use methyl chloroform only with adequate ventilation and avoid prolonged or repeating breathing of vapor or contact with the skin.

f. PRINTED CIRCUIT AND MICROELECTRONICS TECHNIQUES

Printed circuits are small and compact and it is therefore essential that maintenance personnel become familiar with the special servicing techniques required for this type of repair.

In all instances, it is advisable to first check the defective printed circuit before beginning work on it to determine whether any prior servicing has been performed. Not all personnel having access to this type of equipment have the skill and dexterity required; hence, some preliminary service may be necessary. By observing this precaution, you may save a great deal of time and labor.

The defective part should be pin-pointed by a study of the symptoms and by careful and patient analysis of the circuit before attempting to trace trouble on a printed circuit board.

It must be ascertained whether the lands (conducting strips) are coated with a protective lacquer, epoxy resin, or similar substance. If any of these protective coatings have been applied, they must be removed and the surface must be properly cleaned before corrective maintenance can be performed on the equipment.

(1) Removal and Replacement of Protective Coatings

Many manufacturers of equipments used by the Navy apply protective coatings, also called conformal coatings, to their equipments. These protective coatings include epoxies, silicones, polyurethanes, varnishes and lacquers. Most of the coatings consist of a synthetic resin dissolved in a volatile solvent. When properly applied to a clean surface, the solvent evaporates, leaving a continuous layer of solid resins. After curing, this coating protects against environmental stress, corrosion, moisture, and fungus.

These protective coatings may be removed by chemical or mechanical means. The application of chemical solvents is not recommended as they may cause damage to the printed circuit boards by dissolving the adhesive materials that bond the circuits to the boards. These solvents may also dissolve the potting compounds used on other parts or assemblies.

Most polyurethane protective coatings can be removed by applying heat to the area to be cleaned and gently scraping the coating with an X-acto knife. Detailed procedures for the removal and replacement of conformal coatings by this method and the tools and materials required are given in the following subsections.

(a) Tools and Materials — The tools and materials in the following list are required to remove and replace protective coatings. The FSN or manufacturer's part number are given in Table 5-1.

Printed circuit card holder	Cotton swabs
Teflon tape	Alcohol, Isopropyl
Soldering iron	3X, 4X, and 12X viewers
Brush, Nylon	Polyurethane coating or epoxy-resin compound
X-acto knife	

(b) Removal of Protective Coating — To remove the protective coating from the printed circuit board the following procedure is recommended:

1. Place the printed circuit board in the card holder as shown in Figure 5-23.
2. Mask the area that is not to be stripped of the protective coating with Teflon tape as shown in the figure.

CAUTION: Excessive heat may damage the printed circuit board or surrounding parts.

3. Heat a small area of the coating to be removed by holding a soldering iron close to the surface, but do not touch the board with the iron.

Table 5-1. Recommended Tools and Equipment

Item	Quantity	FSN or Mfg. Part No.	Manufactured by or Equivalent
Part I—Required Tools			
Ungar Universal Handle	1	777	Ungar
Thread-in Element, 23-1/2 Watts	1	535	Ungar
Thread-in Element, 37-1/2 Watts	1	1235	Ungar
Thread-in Element, 47-1/2 Watts	1	4045	Ungar
Pencil Tip	1	PL331	Ungar
Pencil Offset Tip	1	PL332	Ungar
Chisel Tip Long Taper	1	PL333	Ungar
Tapered Needle Tip	1	PL338	Ungar
Stepped Pencil Tip	1	7154	Ungar
Ungar Hot Knife Tip	1	4025	Ungar
Offset Slotted Tip	1	862	Ungar
Straight Slotted Tip	1	857	Ungar
Hollow Cube Tip	1	863	Ungar
Cup Tip, 5/8" Dia.	1	856	Ungar
Cup Tip. 3/4" Dia.	1	855	Ungar
Cup Tip, 1" Dia.	1	854	Ungar
Desoldering Tip (DIP)	1	859	Ungar
Desoldering and Cleaning Tool	1	7800	Ungar
Soldering Iron Holder	1	8000	Ungar
Kleen-Tip Sponge and Tray	1	400	Ungar
Low Voltage Soldering Iron	1	6970	Ungar
Printed Circuit Card Holder	1	371	Henry Mann Co.
Steel Bench Clamp	1	356	Henry Mann Co.
Miniature Vise	1	353	Henry Mann Co.
Illuminated Magnifier, 3 Power	1	LFM-1	Henry Mann Co.
Clip-on Lens, 4 Power	1	No. 1	Henry MannCo.
Desoldering and Cleaning Tip, 0.33"	1	7812	Ungar
Hemostat	1	8-907	Fisher Scientific Co.
Hand tool - lead trimmer (TO type package)	1		Henry Mann Co.
Desoldering and Cleaning Tip, 0.057"	1	7806	Ungar
Desoldering and Cleaning Tip, 0.069"	1	7813	Ungar
High Intensity Lamp	1	5975	Tensor
Lead Forming Tool	1	ATH-3260	Astro Tool Co.
DIP Package Puller	1	6982	Ungar
45° Chain-Nose-Tip Cutter	1	A119	Henry Mann Co.
Tooth Picks, Round	1 Box		
Wooden Dowels, 1/4" x 6"	10		
Triceps Tweezer, 8"	1	T8	Henry Mann Co.

Table 5-1. Recommended Tools and Equipment—Continued

Item	Quantity	FSN or Mfg. Part No.	Manufactured by or Equivalent
Part II—Required Chemicals and Materials			
Insulating Varnish	1 pt	5970-280-4920	
Epoxy-Resin Compound	1 Kit	8040-777-0631	
Potting Syringes	12	E-602	Fishman
Epibond	1 Kit	H-1331	Furane Plastics
Acid Brushes	12		
Solvent Dispensers	4	613	Henry Mann Co.
Polyurethane Coating	1 Kit	CE-1155	Conap, Inc.
Isopropyl Alcohol	1 pt	TT-1-735	
Methyl-Ethyl Ketone	1 pt	TT-M-261	
Acetone	1 qt	6810-281-1864	
Copper Shim Stock	.003"		
Aluminum Oxide Abrasive Paper	10 Shts/Box	5350-967-5080	
Cotton Swabs			Johnson & Johnson
Teflon Tape - 1"	1 Roll		
Part III—Standard Tools			
Soldering Aid Tool	1	G5120-629-2697	
End Nippers, 4-1/2"	1	G5110-221-1503	
Diagonal Pliers, 4"	1	G5110-541-4079	
Long-Nose Pliers, 4-1/2"	1	G5120-541-4078	
Round-Nose Pliers, 4-1/2"	1	G5120-239-8252	
Phillips Screwdriver, 3"	1	G5120-240-8716	
Phillips Screwdriver, 4"	1	G5120-234-8913	
Phillips Screwdriver, 6"	1	G5120-234-8912	
Phillips Screwdriver, 10"	1	X1010	XCelite/Henry Mann Co.
Flat Tip Screwdriver, 2"	1	G5120-227-7377	
Flat Tip Screwdriver, 4"	1	G5120-278-1383	
Flat Tip Screwdriver, 5"	1	G5120-278-1271	
Flat Tip Screwdriver, 10"	1	R31610	XCelite/Henry Mann Co.
Jeweler's Screwdrivers	1 Set	G5120-288-8739	
Swiss File Set	1 Set	G5110-288-7685	
Allen Wrenches	1 Set	G5120-288-8732	
Allen Wrenches	1 Set	G5120-315-3358	
Spin Tite, 1/4"	1	5120-770-0016	
Spin Tite, 5/16"	1	5120-770-0017	
Spin Tite, 3/8"	1	5120-770-0025	
Spin Tite, 7/16"	1	5120-770-0030	
Tweezers, Curved	1	G5120-288-9685	
Tweezers, Straight	1	G5120-247-0867	
Tweezers, Lock	1	G5120-293-0149	
Drill Bit Set #33 to #80	1	20-087	Hunter Tools
Hand Drill	1	F-223	Hunter Tools
Brass Wire Brush	1		
Heat Sinks, Medium	6	51F	Hunter Tools
Nylon Brush			
X-acto Knife (with Blades)	1	5110-595-8400	
Material Loot	1 Box		Johnson & Johnson
Solder Eutectic, 63/37 Rosin Core	1 lb		
Tool Box	1	7817	Union Steel Chest Corp.
Primary Page			
Teflon Tape, 1"	1 Roll		
Forceps, Straight, 5"	1	G6515-334-5600	
Forceps, Curved, 5"	1	G6515-334-4900	
Forceps, Straight, 9"	1	L6515-334-9900	
Forceps, Curved, 8"	1	L6515-334-4100	
"C" Clamp - 3 inch	1	5-810	Fisher Scientific Co.
Wire Stripper	1	101-S	Henry Mann Co.

*Trade Mark

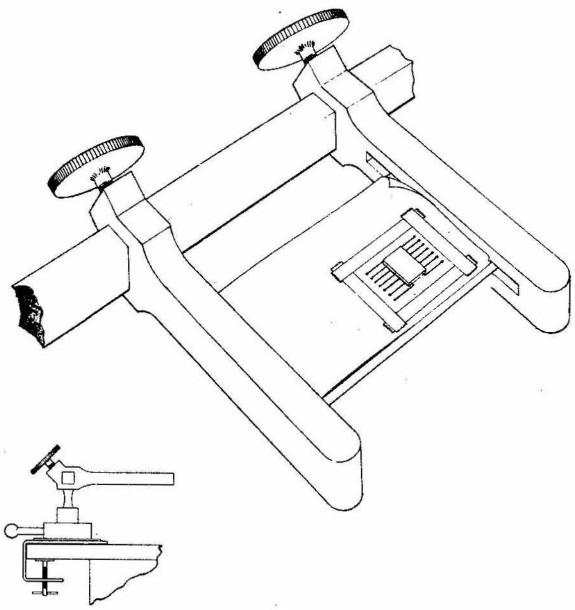


Figure 5-23. Printed Circuit Card Holder

CAUTION: Do not apply excessive pressure during scraping as this may cause nicks on the lands of the board or damage to the leads of other parts.

4. When the protective coating softens, gently scrape it away from the surface with an X-acto knife.
5. Remove loosened particles of protective coating by gently brushing. Assure that loose particles of coating do not contaminate any moving parts.
6. Repeat steps 3 through 5 until all coating has been removed from the area exposed by the mask.
7. Cleanse the area with a cotton swab that has been dipped in alcohol to remove all loose particles of protective coating that remain after brushing.
8. Remove the mask and clean the area with a cotton swab and alcohol to ensure, that no loose particles of coating remain on the perimeter of the stripped area.
9. Using a 12X viewer, visually examine the cleansed area to assure that the area is clean and that no damage was done during the cleaning operation.

(c) Replacement of Protective Coating — To replace the protective conformal coating on the printed circuit board the following procedure is recommended:

CAUTION: Protective coatings may affect the capacitance (air dielectric capacitors, distributed capacitance between leads) and the Q of inductors in RF assemblies. Refer to the appropriate maintenance procedures in the equipment technical manual concerning alignment procedures and the proper use of protective coatings for RF assemblies.

1. Using a 12X viewer, visually inspect the repaired board for foreign particles.
2. Clean are to be coated with a cotton swab that has been dipped in alcohol.
3. Allow the printed circuit board to dry thoroughly. Drying time will depend on the cleansing agent used (alcohol is recommended).
4. Mask the area that is not to be coated as shown in Figure 5-23. The unmasked area should be large enough to allow some overlapping with the old coating to assure adequate protection.
5. Spray the exposed area with three layers of protective coating material, allowing sufficient time for curing between successive coats. Several thin coats are more effective than one heavy coat. If the coating material has a tendency to porosity, it is unlikely that the pinholes will occur in exactly the same positions on successive coats.
6. Remove the mask and inspect the reworked area, using a 12X viewer, for any voids or pinholes. If any voids or pinholes are observed, add another coat of protective coating.

(2) Repair of Printed Circuit Boards

Printed circuit assembly wiring patterns are formed in three basic ways, by painting, chemical deposit, and stamped or etched metal foil.

Shipboard repair of painted and chemically deposited printed wiring patterns is not recommended because specialized equipment is not always available.

The metal foil printed wiring patterns consists of a thin metal foil bonded to a nonconductive base. The wiring pattern is produced by stamping the foil before bonding it to the base, or by chemically etching away unwanted portions of the metal foil after bonding to the base.

Because metal foil is the most readily repairable and most commonly used type of printed wiring board, the repair techniques described in this subsection apply to metal foil printed circuits only.

The major cause of printed circuit board failures attributable to maintenance actions is mishandling during the fault isolation and replacement of parts. It is important, therefore, that care be exercised in performing maintenance.

After isolation of a fault to a printed circuit board, the board should be visually examined to determine the possible cause of the fault. If the cause is not readily apparent, the lands on the boards should be checked for continuity with an ohmmeter and needle probes. Place the probes at each end of the land. If the land is open, remove one probe along the board until continuity is observed on the meter. Then locate the break in the land with a 12X viewer.

The three major types of circuit failures are caused by cracks, voids, or peeling of the lands. During the visual examination, it may be observed that the copper laminate used for the contact fingers has separated or peeled away from the board. This type of damage can be repaired by following the procedures described in the following subsections.

(3) Void Repairs

To repair a void in a land, the following procedure may be used:

1. If the land has been covered with a conformal coating, remove it in accordance with the procedure outlined in 5-6f of this handbook.
2. Using an X-acto knife, trim each end of the broken land at a 45-degree angle (see Figure 5-24). Ensure that the remaining end of each land is firmly attached to the board.
3. Strip the insulation from a small piece of AWG 22 hook-up wire. Lay the stripped wire on the board and solder as shown in Figure 5-24(b).

CAUTION: Excessive heat may cause the ends of the conductor to lift from the board.

4. Clean the soldered areas with cotton swabs that have been dipped in alcohol.
5. Using a 3X viewer, visually inspect the area for solder flux and solder splashes and remove any residue.
6. Check repaired area for continuity.
7. Replace the conformal coating as described in 5-6f of this handbook.

(4) Lands Repairs

To repair cracked lands, the following procedure may be used:

1. If the land has been covered with a conformal coating, remove it in accordance with the procedure outlined in 5-6f of this handbook.
2. Flow solder the cracked sections together as shown in Figure 5-25.

CAUTION: Ensure that solder does not flow over the edges of the land as this will reduce the spacing between lands and affect the electrical performance characteristics of the board.

3. Clean all residue from the board with a cotton swab that has been dipped in alcohol.
4. Using a 3X viewer, visually inspect the area for solder flux and solder splashes and remove any residue.
5. Replace the conformal coating as described in 5-6f of this handbook.

(5) Peeled Conductors

To repair peeled conductors, the following procedure may be used.

1. If the land has been covered with a conformal coating, remove it in accordance with the procedure outlined in 5-6f of this handbook.
2. Using an X-acto knife, trim each end of the land at a 45-degree angle. Ensure that the remaining end of each land is firmly attached to the board.
3. Use a length of AWG 22 hook-up wire with teflon insulation that will span the void in the conductor. Strip both ends and tin.
4. Position the wire as shown in Figure 5-26 and solder ends to terminals.
5. Pot the wire to the board with general-purpose adhesive to prevent breakage during handling of the board.
6. Using a 3X viewer, visually inspect the area for solder flux and solder splashes and remove any residue.
7. Check for continuity.
8. Replace the conformal coating as described in 5-6f of this handbook.

(6) Loose Connector Tabs

The repair of loose connector tabs may be done in the following manner:

1. Place the edge of an X-acto knife between the board and the loose tab; lifting tab as shown in Figure 5-27.

CAUTION: Do not allow the tab to curl or form right-angle bends as this will damage the tab.

2. Place a piece of teflon on the top part of the tab and clean the underside of the tab with aluminum oxide sandpaper until it is a bright copper color.
3. Remove all old adhesive from the board by gently scraping with an X-acto knife.
4. Gently wipe the underside of the tab and board with cotton swabs that have been dipped in acetone.

CAUTION: Acetone is flammable.

5. Using potting syringe, apply adhesive to the tab and board surfaces.
6. Place teflon on top of the tab and clamp both to the board with a "C" clamp as shown in Figure 5-27a.

CAUTION: Do not move teflon or rotate clamp while tightening clamp. Such movement may result in improper orientation of the tab.

7. Allow adhesive to cure in accordance with the manufacturer's specifications.
8. Remove clamp and teflon.
9. Gently scrape the board with an X-acto knife to remove excess adhesive.
10. Clean tab by wiping with a cotton swab that has been dipped in acetone.
11. Assure that the repaired contact fits into the connector.
12. Check continuity.

(7) Broken Connector Tabs

The repair or broken connector tabs may be done in the following manner:

1. Using an X-acto knife, cut off the rough edge of the broken tab by making a 45-degree-angle cut as shown in Figure 5-27.
2. Ensure that the undamaged section of the tab is still bonded to the board.
3. Clean the board by scraping off any residue and wipe with a cotton swab that has been dipped in acetone.
4. Cut a replacement contact from a piece of copper foil stock 0.002 inch thick of the same dimensions as the tab to be replaced, allowing 1/4-inch for a lap-joint at the point of contact with the existing copper land.
5. Clean the replacement contact by holding it with tweezers and dipping in acetone. Place the cleaned contact on a clean piece of paper.

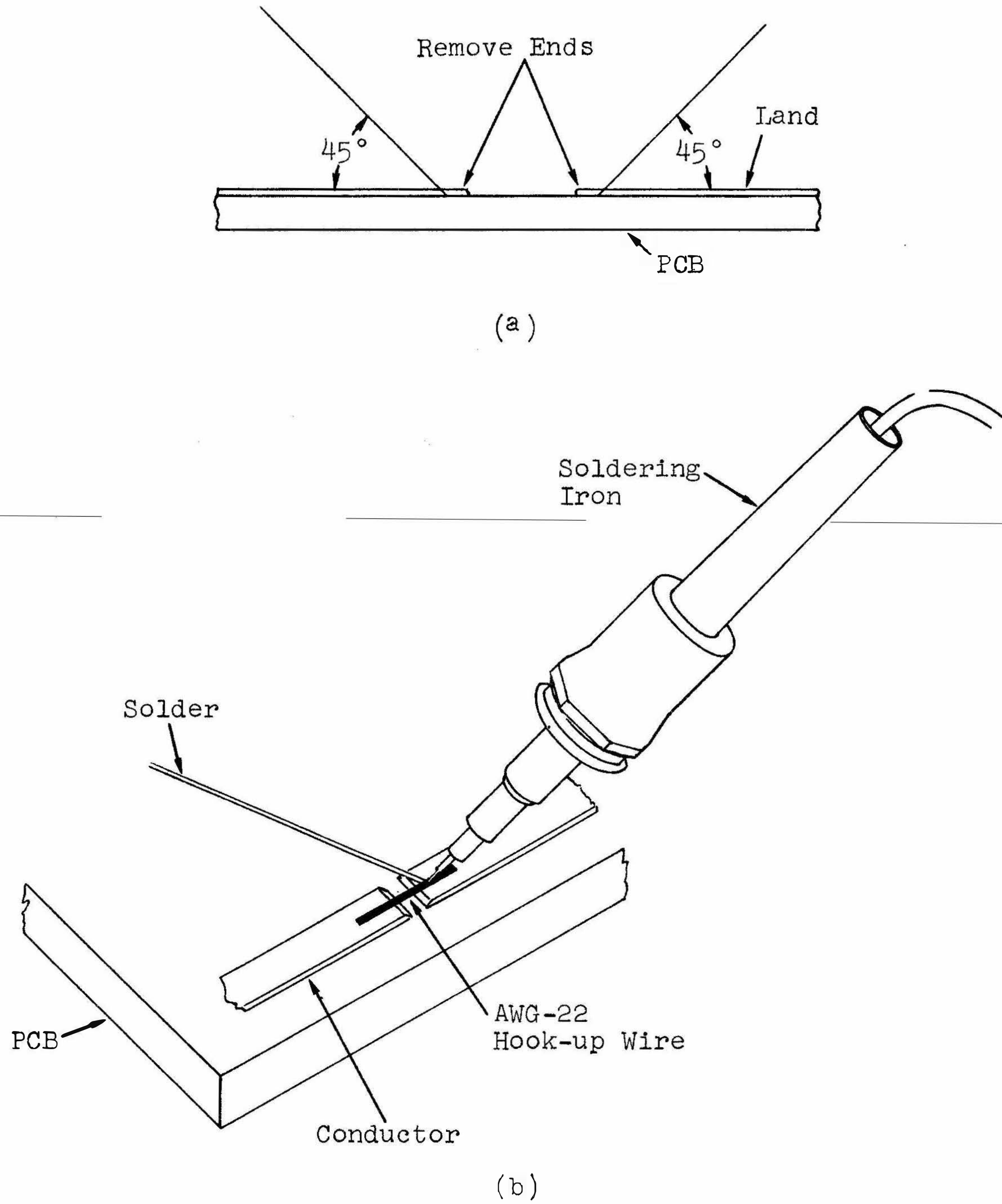


Figure 5-24. Repair of Land With Void

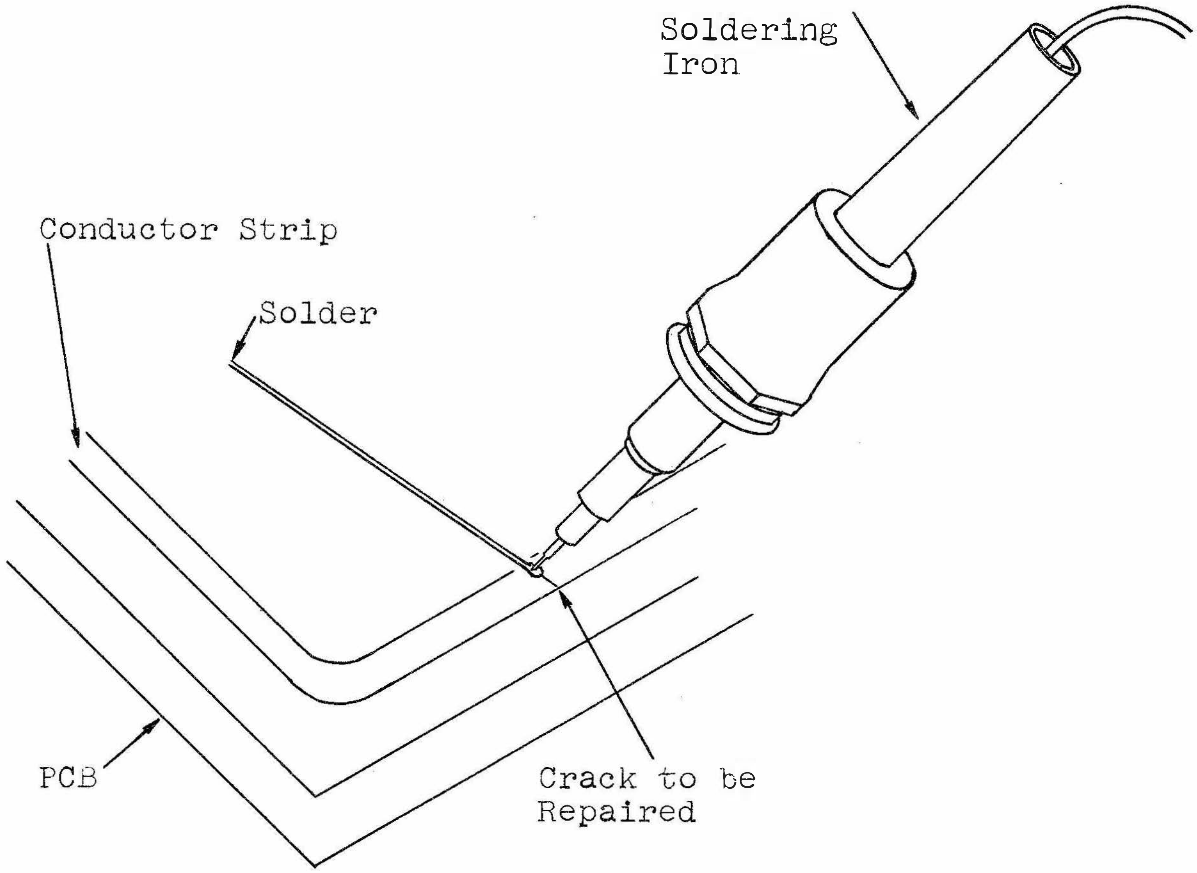


Figure 5-25. Repair of Cracked Lands

6. Using the potting syringe, prepare adhesive in accordance with manufacturer's directions and apply to the board.
7. Using tweezers, align the replacement contact and press flat.
8. Using an X-acto knife, scrape off excess adhesive, leaving a thin film on the board.
9. Place a piece of teflon over the replaced tab and clamp with a "C" clamp as shown in Figure 5-27a.

CAUTION: Do not move teflon or rotate clamp while tightening. Such movement may result in improper orientation of the tab.

10. Allow adhesive to cure in accordance with the manufacturer's specification. To decrease curing time, place a lamp (60 to 100 watts) approximately 5 inches from the board.
11. Remove clamp and teflon.
12. Solder at the point of overlap between the new and original circuitry, using a miniature low voltage soldering iron.
13. Using a small, flat file, bevel the edge of the tab at a 45-degree angle to conform to the bevel of the board as shown in Figure 5-27b.
14. Gently scrape the board with an X-acto knife to remove excess adhesive.
15. Clean contact and solder joint by wiping with cotton swabs that have been dipped in alcohol.
16. Assure that the repaired contact mates evenly with the proper connector.
17. Check continuity.

(8) Removal and Replacement of Flat Packs

Because of their small size, extreme care must be exercised in soldering and unsoldering flat-pack leads. Careless work may cause damage to the mounting surfaces and/or the circuits.

Orientation of the flat pack with respect to the mounting surface is also of major importance. All flat packs have index points, usually located in one corner or on the package centerline. Before removing any flat pack, the board to which it is attached should be marked or a sketch made of the location of the index point so that the replacement device may be properly oriented as shown in Figure 5-28.

(a) Tools and Materials — The tools and materials in the following list are required to remove and replace flat packs. The FSN or manufacturer's part numbers are given in Table 5-1.

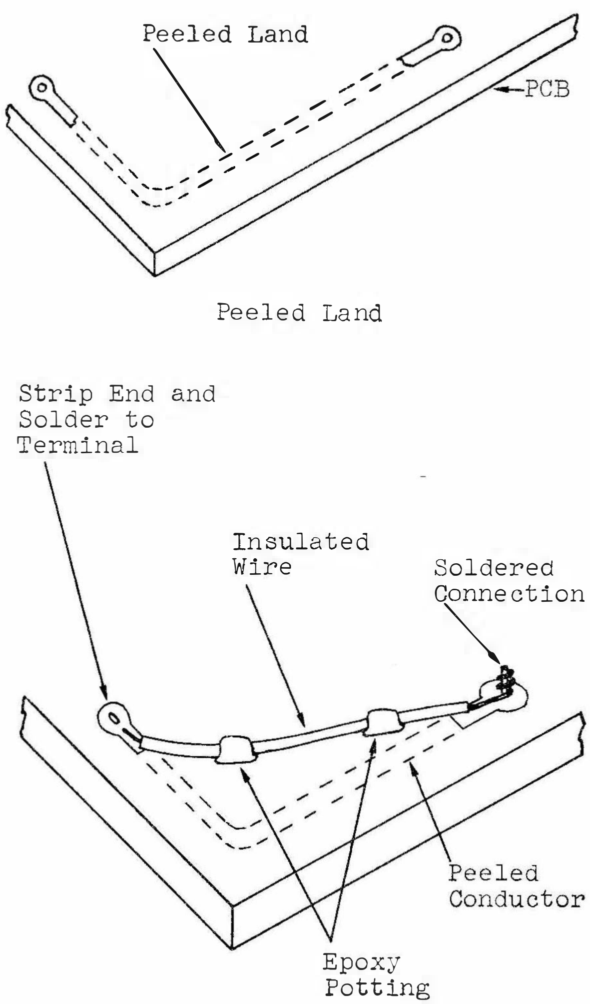


Figure 5-26. Repair of Peeled Conductors

45-degree chain noise tip cutter
Desoldering and cleaning tool (solder sucker)
Low voltage soldering iron
Solder sucker
X-acto knife
Printed circuit card holder
Teflon tape
Epoxy resin compound
3X, 4X, and 12X viewers
Alcohol, Isopropyl
Cotton swabs
Tricep tweezers
Lead cutting and forming tool (or wooden form)
Potting syringe

(b) Removal and Replacement of Soldered-In Flat Packs — Upon completion of subsystem checkout and the localization of the defective flat pack, the following removal and replacement procedure is recommended:

1. Insert the printed circuit board in the card holder with the flat pack face up as shown in Figure 5-23.

CAUTION: Solvents and abrasives may damage the board or surrounding parts and are not recommended for shipment maintenance. They should be used only under controlled conditions.

2. If the flat pack has been covered with a conformal coating, remove the coating in accordance with detailed procedures given in 5-6f of this handbook.

3. Mark board to show the location of the index mark on the flat pack as shown in Figure 5-28.

4. Using a pair of sharp chain-nose-tip cutters, cut the flat pack leads halfway between the soldered joints and the body of the flat pack as shown in Figure 5-28.

5. If thermally conductive adhesive has been used between the flat pack and the board, hold the device with tricep tweezers and place the heated blade of an X-acto knife between the flat pack and the printed circuit board on one side of the flat pack and gently move the knife back and forth in a cutting motion. Repeat this process on all four sides until the flat pack has been loosened.

CAUTION: Do not tap board to remove excessive solder as this may cause bridging of lands on other parts of the board.

6. Unsolder the remaining leads, one at a time, using a desoldering iron and solder sucker attachment to remove excess solder.

7. After removing the flat pack, remove mask and visually examine the printed circuit board with a 12X viewer. Remove all residue (conformal coating. solder flux, and solder splashes) and clean the board with a cotton swab that has been dipped in alcohol.

CAUTION: Assure that cleaning solvent is dry before applying a hot soldering iron—alcohol is flammable.

8. Examine the replacement device for damage. Review applicable circuit specifications and test circuit in accordance with the applicable technical manual.

9. Remove the flat pack from the handling container. If a suitable lead cutting and forming tool is not available, place the flat pack on a wooden form and cut the leads to the proper length, one at a time, with a sharp X-acto knife as shown in Figure 5-29.

CAUTION: Make certain that the replacement flat pack circuit is properly oriented with respect to the index mark previously scribed on the printed circuit board. Incorrect positioning of the package will result in destruction of the circuit and have a deleterious effect on system performance.

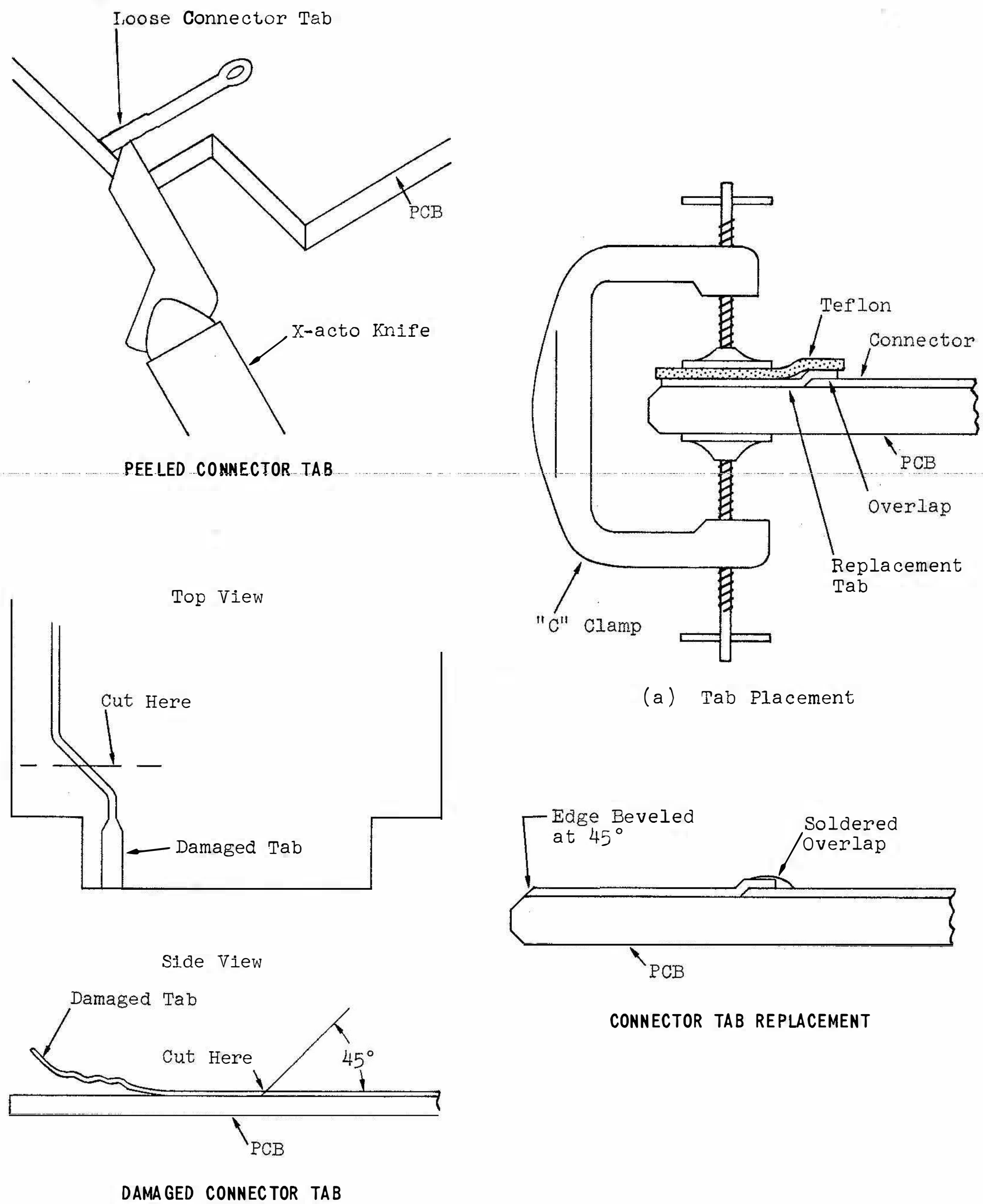


Figure 5-27. Repair of Loose Connector and Broken Connector Tabs

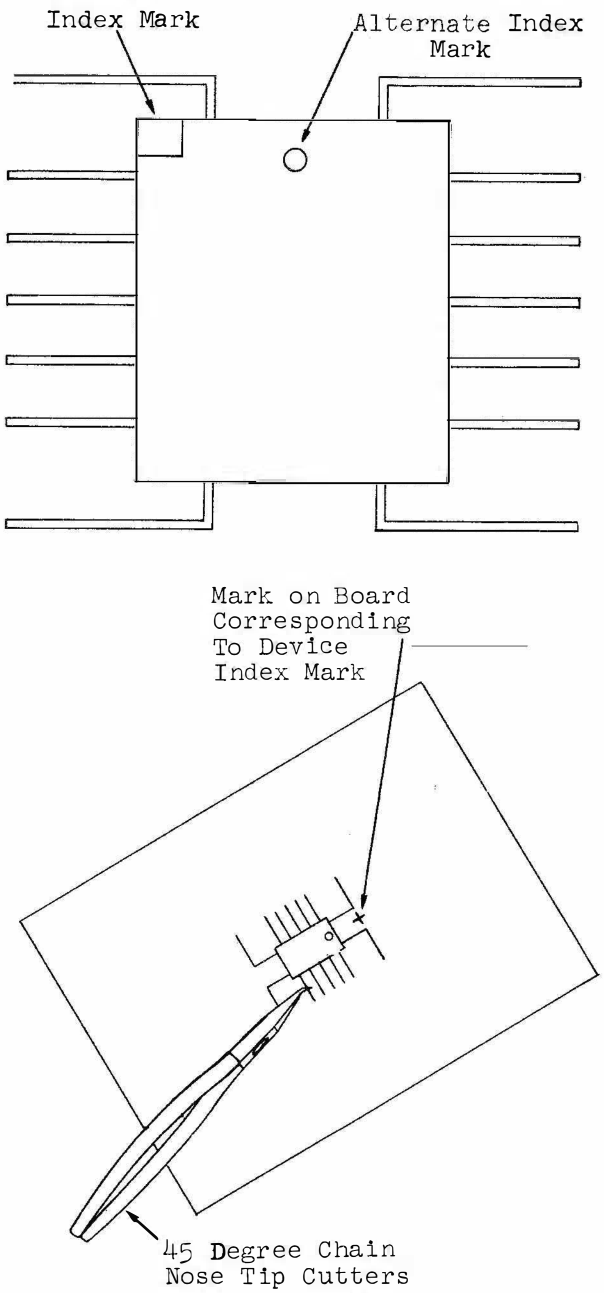


Figure 5-28. Location of Device Index Mark

10. Using the potting syringe, apply epoxy resin compound to the underside of the flat pack and place the package in position, using tricep tweezers.

11. Allow the adhesive to cure in accordance with the manufacturer's requirements.

CAUTION: Use a miniature low voltage soldering iron. Excessive heat will damage the flat pack and/or the printed circuit board.

12. Flow solder the flat pack leads to the board, one at a time, using a miniature low voltage soldering iron as shown in Figure 5-30.

13. Using a 12X viewer, visually examine the area surrounding the replaced device for bad solder joints, bridging of solder between the leads, flux residue, or excessive adhesive.

14. Clean all residue from the leads and printed circuit board with a cotton swab that has been dipped in alcohol.

15. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated in accordance with specified test procedures and the output monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

16. Replace conformal coating as described in 5-6f of this handbook.

(c) Removal and Replacement of Welded-In Flat Packs — Welded-In flat packs are removed and replaced by following the procedure given for Soldered-In flat packs except that the portions of the leads remaining on the printed circuit board, after removal of the package, are clipped as closely as possible to the welded joint to facilitate the soldering of the lapped joint of the replacement leads.

(9) Removal and Replacement of DIPs

Because of their smallness, extreme care must be exercised in soldering and unsoldering DIP leads. Careless work may damage the mounting surface and/or circuits.

Orientation of the DIP with respect to the mounting surface is also of major importance. All DIPs have index points, usually located in one corner or on the package centerline. Before moving any DIP, the board to which it is attached should be marked or a sketch made of the location of the index point so that the replacement device may be properly oriented as shown in Figure 5-31.

(a) Tools and Materials — The tools and materials in the following list are required to remove and replace DIPs. The FSN or manufacturer's part numbers are given in Table 5-1.

45-degree chain-nose-tip cutter
Desoldering and cleaning tool (solder sucker)
Low voltage soldering iron
Solder sucker attachment
X-acto knife
Printed circuit card holder
Teflon tape
Epoxy resin compound
3X, 4X, and 12X viewers
Alcohol, Isopropyl
Cotton swabs
Tweezers, straight

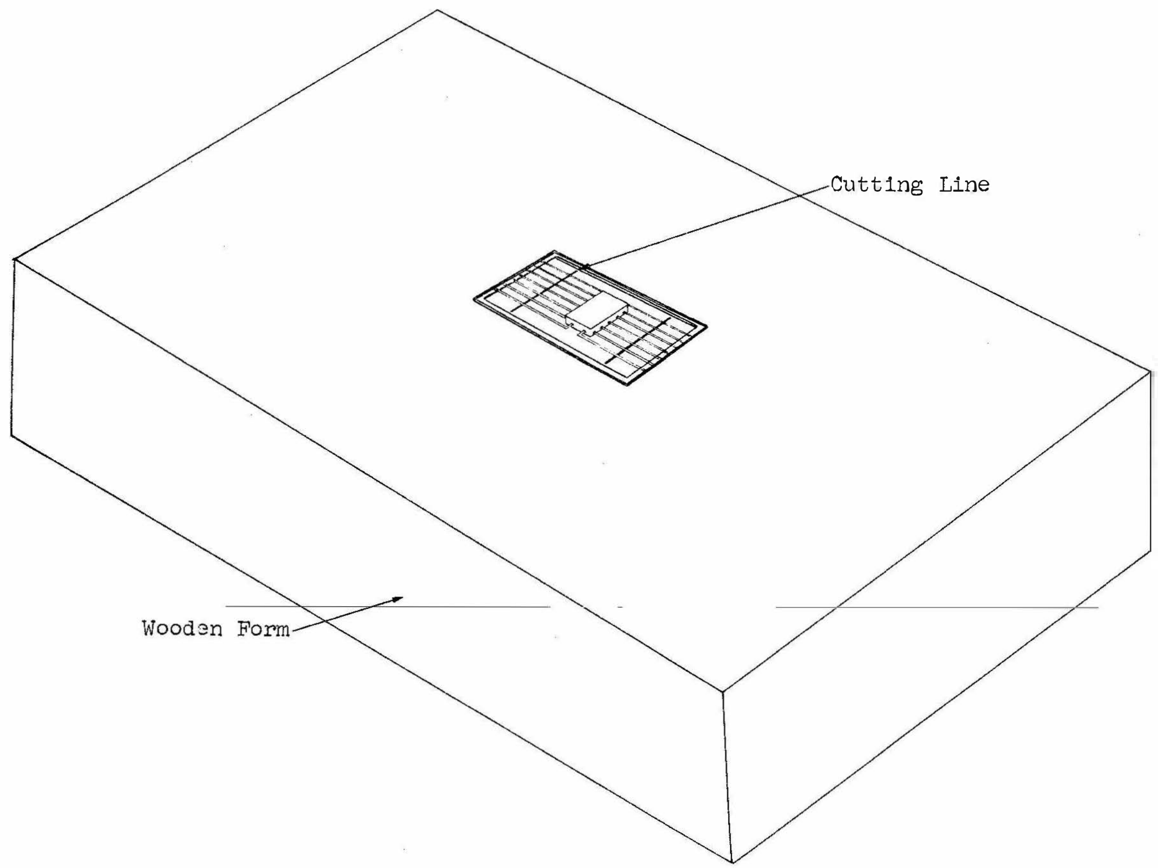


Figure 5-29. Flat Pack Lead Trimming

Insulating varnish
DIP package puller
Toothpicks

(b) Removal and Replacement of DIPs on Boards With Conformal Coating — Upon completion of subsystem checkout and localization of the defective DIP, the following removal and replacement procedure is recommended:

1. Insert the printed circuit board in the card holder as shown in Figure 5-23.

2. Construct a teflon tape mask over the circuit board, exposing the DIP to be removed as shown in Figure 5-23 and remove conformal coating in accordance with procedure given in 5-6f of this handbook.

3. Mark board or make a sketch indicating location of the index mark on the DIP.

4. Using a pair of 45-degree chain-nose-tip cutters, cut the package leads, one at a time as shown in Figure 5-32 (step (1).

5. Lift the portion of the leads attached to the package, one at a time, with tweezers, bending the leads upward as shown in Figure 5-32 step (2).

CAUTION: Do not apply a prying or lifting motion with the X-acto knife as this may damage the printed circuit board.

6. Using a heated X-acto knife blade, loosen the conformal coating beneath the package and gently lift the package.

7. Remove conformal coating remaining on the board in accordance with the procedure given in 5-6f of this handbook.

8. Remove solder from each lead remaining in the board, using a soldering iron and solder sucker and heater. Simultaneously remove leads with tweezers.

9. Clean holes in the printed circuit board with a toothpick.

10. Remove all residue (conformal coating, solder flux, and solder splashes) and clean board with a cotton swab that has been dipped in alcohol.

11. Examine the replacement device for damage. Review the applicable circuit specification and test circuit in accordance with applicable technical manual.

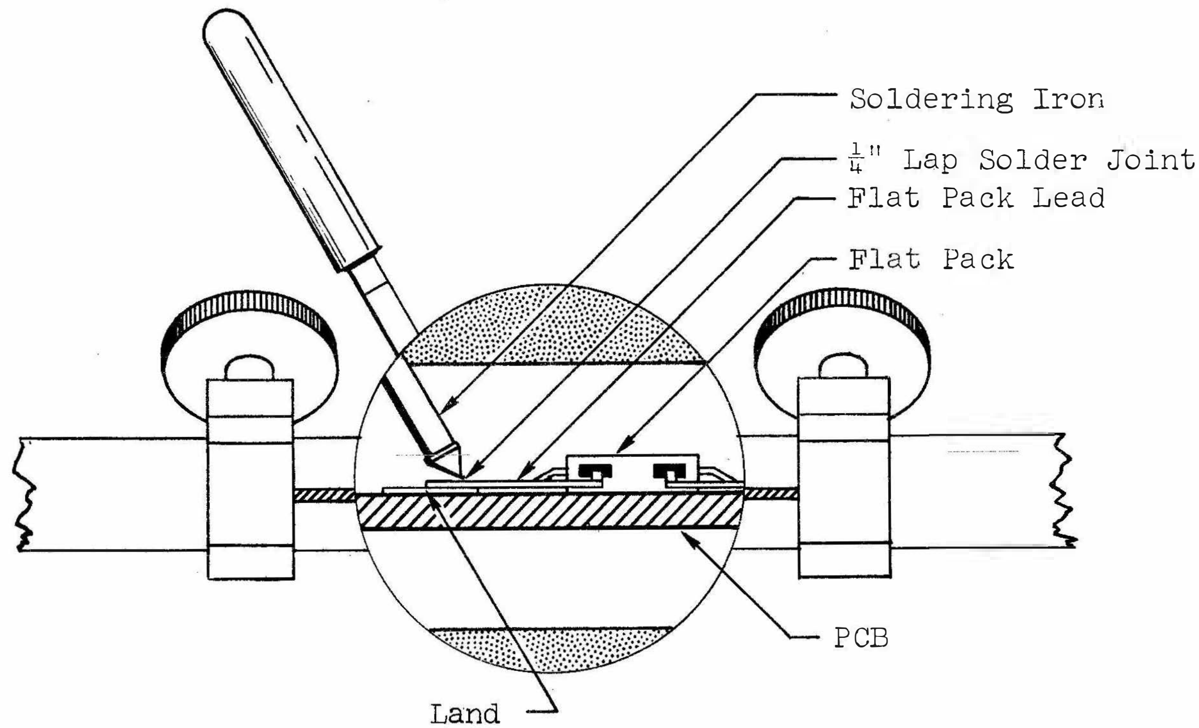


Figure 5-30. Lap Soldering of Flat-Pack Leads

12. Upon completion of the visual and electrical tests, align the circuit pins.

CAUTION: Assure that the circuit is properly oriented. Improper positioning of the package may result in destruction of the circuit and have a deleterious effect on system performance.

13. Insert DIP in the board and solder leads individually, using low-voltage soldering iron.
14. Using a 12X viewer, visually inspect the area surrounding the replaced device for bad solder joints, bridging of solder between leads, and flux residue.
15. Clean all leads and surrounding areas with a cotton swab that has been dipped in alcohol.
16. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

(c) Removal and Replacement of DIPs on Boards Without Conformal Coating — Upon completion of subsystem checkout and localization of the defective DIP, the following removal and replacement procedure is recommended:

1. Mark the printed circuit board or sketch the location of the index mark on the DIP.
2. Heat the solder at each lead, individually, and remove the molten solder from top of board with a solder sucker or wicking tool.

CAUTION: Do not apply twisting or prying forces as this may damage the printed circuit board or break DIP pins within the board.

3. Using a DIP package puller, illustrated in Figure 5-33, grasp the DIP as shown. Heat all leads simultaneously, using the solder sucker attachment. Gently pull the DIP away from and perpendicular to the board. The DIP should be easily freed from the printed circuit board.
4. Clean holes in the printed circuit board with a toothpick.
5. Remove all residue (solder flux and solder splashes) and clean board with a cotton swab that has been dipped in alcohol.
6. Examine the replacement device for damage. Review the applicable circuit specification and test circuit in accordance with the applicable technical manual.
7. Upon completion of the visual and electrical tests, align the circuit pins.

CAUTION: Assure that the circuit is properly oriented. Improper positioning of the package may result in destruction of the circuit and have a deleterious effect on system performance.

8. Insert DIP in the board and solder leads individually, using low-voltage soldering iron.

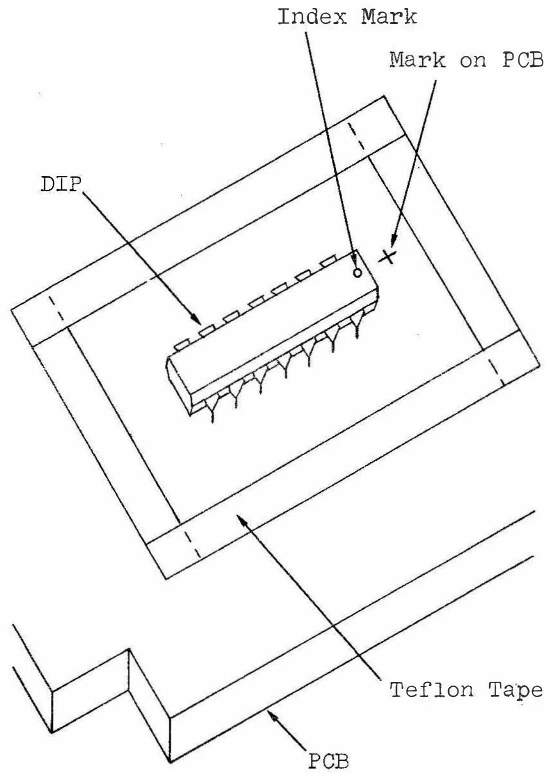


Figure 5-31. DIP Masking and Alignment

9. Using a 12X viewer, visually inspect the area surrounding the replaced device for bad solder joints, bridging of solder between leads, and flux residue.

10. Clean all leads and surrounding areas with a cotton swab that has been dipped in alcohol.

11. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and outputs monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

(10) Removal and Replacement of TO-Type Packages

TO packages containing integrated circuits are available with 8 to 12 leads. The leads are usually arranged in a symmetrical pattern and mounted directly to lands on the printed circuit board. Two of the most common mounting techniques are the embedded and the plug-in.

The procedures currently used to remove and replace transistor TO packages are also applicable to modified TO packages containing integrated circuits. The major difference between the two packages is that the number of leads on modified TOs is greater and the space between leads is less than on standard TOs thus limiting the space available for lead clipping, desoldering, and soldering. The

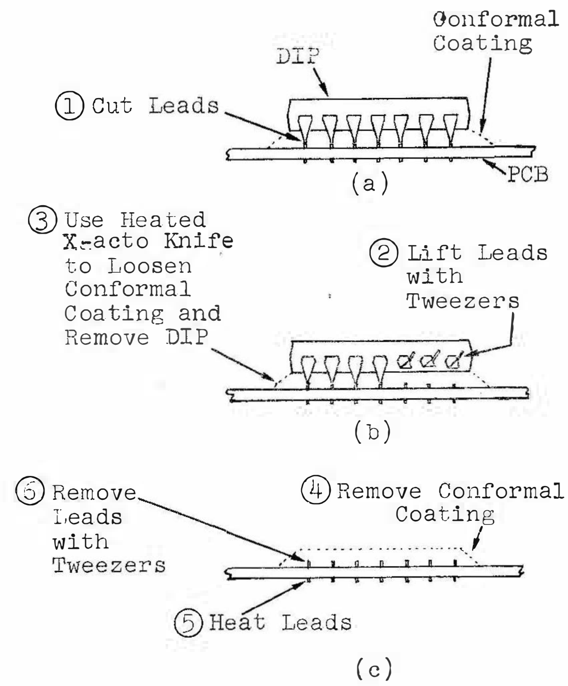


Figure 5-32. DIP Lead Cutting and Package Removal

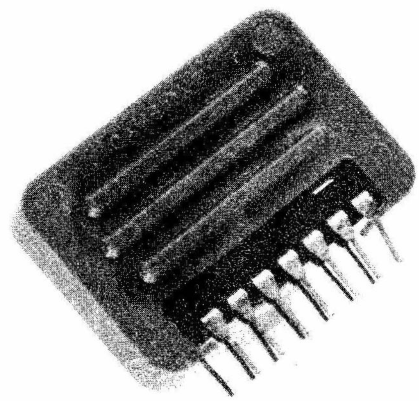
smaller packages also require greater manual dexterity on the part of repair personnel. Other constraints such as spacing of lands on the printed circuit board, removal of conformal coatings and such, present additional problems to the maintenance technician.

Protective conformal coatings contribute to the difficulty in unsoldering leads, removing devices from the mounting surface, and preparing the mounting surface for device replacement. Subsection 5-6f of this handbook contains procedures on removal and replacement of conformal coatings. After the protective coating has been removed, device leads must be disconnected and the device removed, but the procedure to be followed in removing the TO will depend on the mounting configuration. If the package to be removed is embedded or plugged in without a spacer, the leads should be clipped and the package removed before those segments of the leads remaining in the board are unsoldered. If this is not possible—as would be the case with packages that are flush mounted or plugged-in with a spacer—all leads should be heated simultaneously to allow package removal.

Procedures for removing embedded, plug-in, and flush-mounted packages are given in the following subsections.

Replacement TO circuits should be electrically tested in accordance with the applicable detailed specifications and subsystem operating requirements.

(a) Tools and Materials — The tools and materials in the following list are required to remove and replace TOs. The FSN or manufacturer's part numbers are given in Table 5-1.



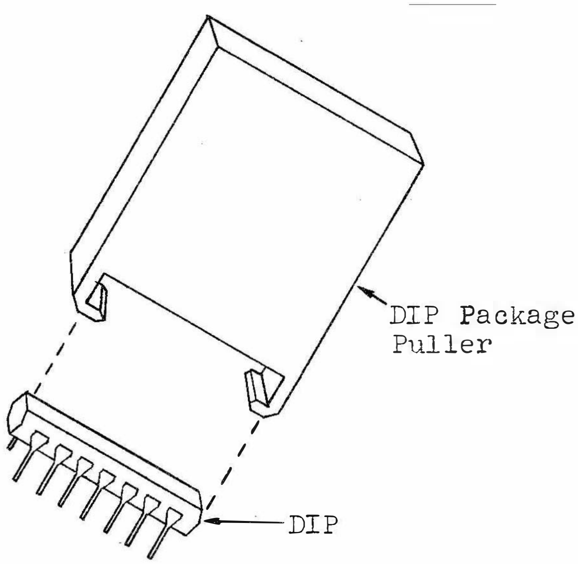


Figure 5-33. DIP Package Puller

Teflon Tape
Desoldering and cleaning tool (solder sucker)
Low voltage soldering iron
45-degree chain-nose-tip cutter
Long-nose pliers
Printed circuit card holder
Toothpick
Hemostat
Alcohol, Isopropyl
Cut tip
Cotton swabs
3X, 4X, and 12X viewers

(b) Removal and Replacement of Embedded TOs and TOs Without Spacers — Upon completion of subsystem checkout and localization of the defective TO, the following removal and replacement procedure is recommended:

1. Place the printed circuit board in the card holder as shown in Figure 5-23 of this handbook. If the board has been covered with a conformal coating, mask all portions of the board except for the TO that is to be removed.

CAUTION: Excessive heat may damage the TO package and/or printed circuit board.

2. Remove coating from the terminal areas and area where the package is inserted into the board. This can best be accomplished by holding a soldering iron close to the board and gently scraping the conformal coating with an X-acto knife.
3. Using a 45-degree chain-nose-tip cutter, clip the leads near the TO package.
4. Apply pressure to top of TO package with a wooden dowel to remove TO from the board as shown in Figure 5-34.
5. Heat terminals with a soldering iron and remove molten solder with a solder sucker attachment.

CAUTION: Do not forcibly pull or apply twisting motion to leads. This may damage terminals.

6. Remove those segments of leads remaining in the board by applying the desoldering iron to the land on the board and gently pull downward on the lead using long-nose pliers.

CAUTION: Wait until alcohol is dry before using soldering iron—alcohol is flammable.

7. Clean all terminal areas with a cotton swab that has been dipped in alcohol.
8. Using a 12X viewer, inspect terminals for loose solder, solder flux residue, and damage to terminals.
9. Visually examine replacement device for damage, review applicable circuit specification, and test replacement circuit in accordance with requirements of the appropriate operational specification and MIL-STD-883.
10. Align leads and insert new TO package into the printed circuit board.
11. Solder leads individually with a miniature low-voltage soldering iron, using long-nose pliers as a heat sink.
12. Inspect repaired area with a 12X viewer and remove any solder splashes or foreign materials with a cotton swab that has been dipped in alcohol.
13. If required by the equipment maintenance manual, apply conformal coating in accordance with subsection 5-6f of this handbook.
14. Place the repaired printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and following procedures in the appropriate equipment test and checkout manual.

(c) Removal and Replacement of Flush-Mounted TO's and Plugged-In TO's With Spacers — Upon completion of subsystem checkout and localization of the defective TO, the following removal and replacement procedure is recommended:

1. Place the printed circuit board in the card holder as shown in Figure 5-23. If the board is

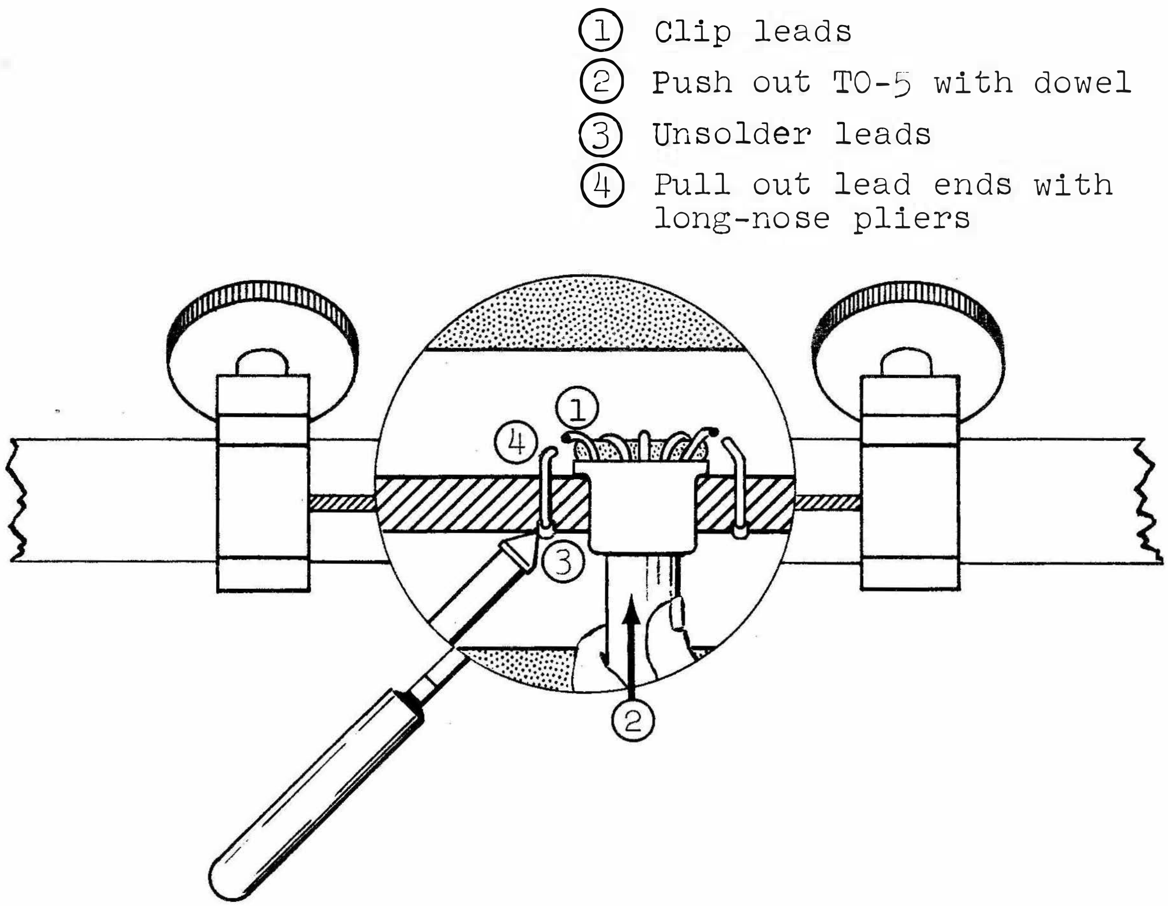


Figure 5-34. TO Package Removal (Embedded)

covered with a conformal coating, mask all portions of the board except for the TO that is to be removed.

2. Heat each lead individually and remove molten solder from the board with the solder sucker attachment.

> CAUTION: Do not apply twisting motion to TO package. This may damage the printed circuit board or terminals.

3. Heat all leads simultaneously with the cup-type tiplet adapter to the desoldering iron as shown in Figure 5-35. Using hemostats, gently grasp the package and remove from the printed circuit board.

> CAUTION: Wait until alcohol is dry before using soldering iron—alcohol is flammable.

4. Clean all terminal areas with a cotton swab that has been dipped in alcohol.

5. Using a 12X viewer, inspect terminals for loose solder, solder flux residue, and damage to terminals.

6. Visually examine replacement device for damage. Review applicable circuit specifications and test circuit in accordance with requirements of the appropriate operational specification and MIL-STD-883.

7. Align leads and insert new TO package in printed circuit board.

> CAUTION: Excessive heat may destroy the terminal or the replacement circuit.

8. Solder leads, one at a time, with a miniature low-voltage soldering iron.

9. Using a 12X viewer, inspect the repaired area and remove any solder splashes or foreign materials with a cotton swab that has been dipped in alcohol.

10. If required by the applicable equipment maintenance manual, apply conformal coating in accordance with subsection 5-6f of this handbook.

11. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper

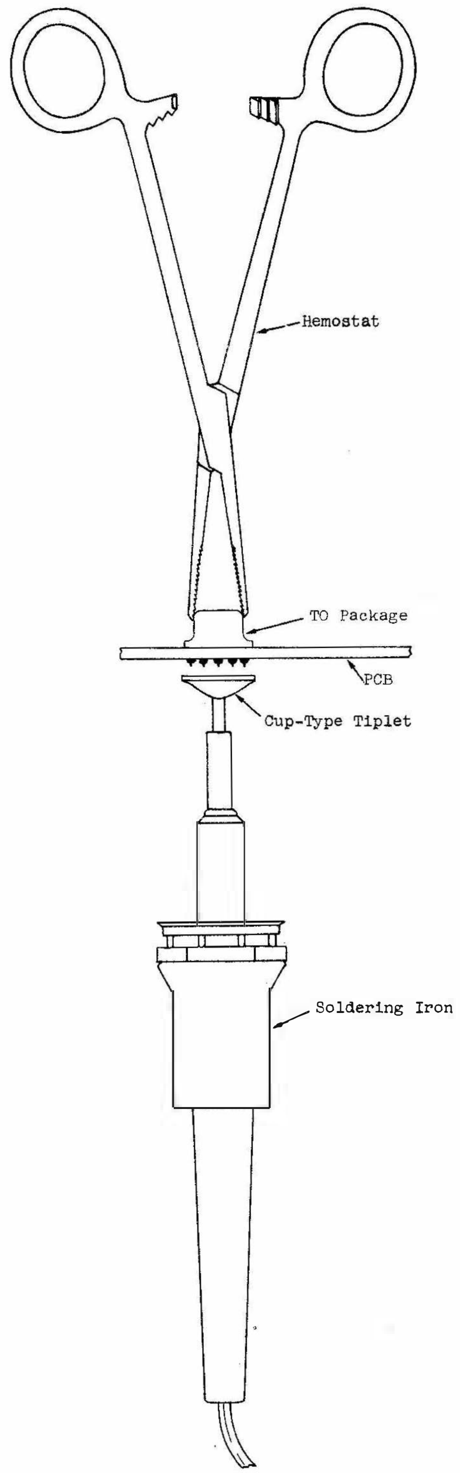


Figure 5-35. TO Package Removal (Flush-Mounted)

inputs should be duplicated and the outputs monitored using bench test equipment and following procedures in the appropriate equipment test and checkout manual.

g. HANDLING AND PACKAGING

Care in handling and proper packaging to provide protection against damage in transit between the using activity and repair facilities is a must for modular assemblies.

A new assembly is received packaged in accordance with the applicable packaging specification (MIL-P-1755D (SHIP) (Series)). When the outer bulky casing (crate or outer carton with its shredded paper dunnage or similar material) is removed, the unit or units remain packed in a watertight package. This package should be stored by the issuing activity until drawn by the using activity. In this manner, the packaging material that the using activity saves from new assemblies can be used for the packaging of defective assemblies.

For the correct method and the proper material to use for protective packaging of defective assemblies, see Figures 5-36, 5-37, and 5-38.

The material shown is available to all activities, and should be used in the manner prescribed for storing or transferring defective assemblies until they are received by a shipping facility, which will properly package them for shipment to the restoration facility.

In order to maintain electronic equipment at as high a level of operating performance as possible, it is necessary that new, repaired, or repairable modular assemblies transported from one activity to another reach their destination safely and without damage while in transit.

However, some of these items have been damaged in transit, and are unsuitable for use as replacement or repairable repair parts. In many cases, such damage is the direct result of careless handling and packaging methods employed in the preparation for transport of the equipment to or from the restoration facility, Fleet, or manufacturer.

An example of improper packaging, and the resulting damage to repair or repairable parts and assemblies, is shown in Figures 5-39 and 5-40.

To avoid such damage to equipment in transit, the Naval Ship Systems Command has initiated a program to procure re-usable shipping containers molded or formed from a polystyrene material. This packaging method provides maximum protection to the modular assembly contained therein during transport or stowage. See Figure 5-41.

Upon receipt of new or repaired modular assembly packaged by this method, the receiving activity should first visually inspect the outer carton, wrapper, or box for signs of visible transport damage. If no visible damage is evident, the compact re-usable polystyrene shipping container should be removed from its outer protective covering and inspected for signs of transport damage. If no visible signs of transport damage are evident, remove the new or repaired modular assembly from its re-usable shipping container and then perform the test procedures required to further ensure that the assembly is serviceable. Upon completion of the test procedures, and if the assembly tested satisfactorily, restore the assembly into its re-usable shipping container for

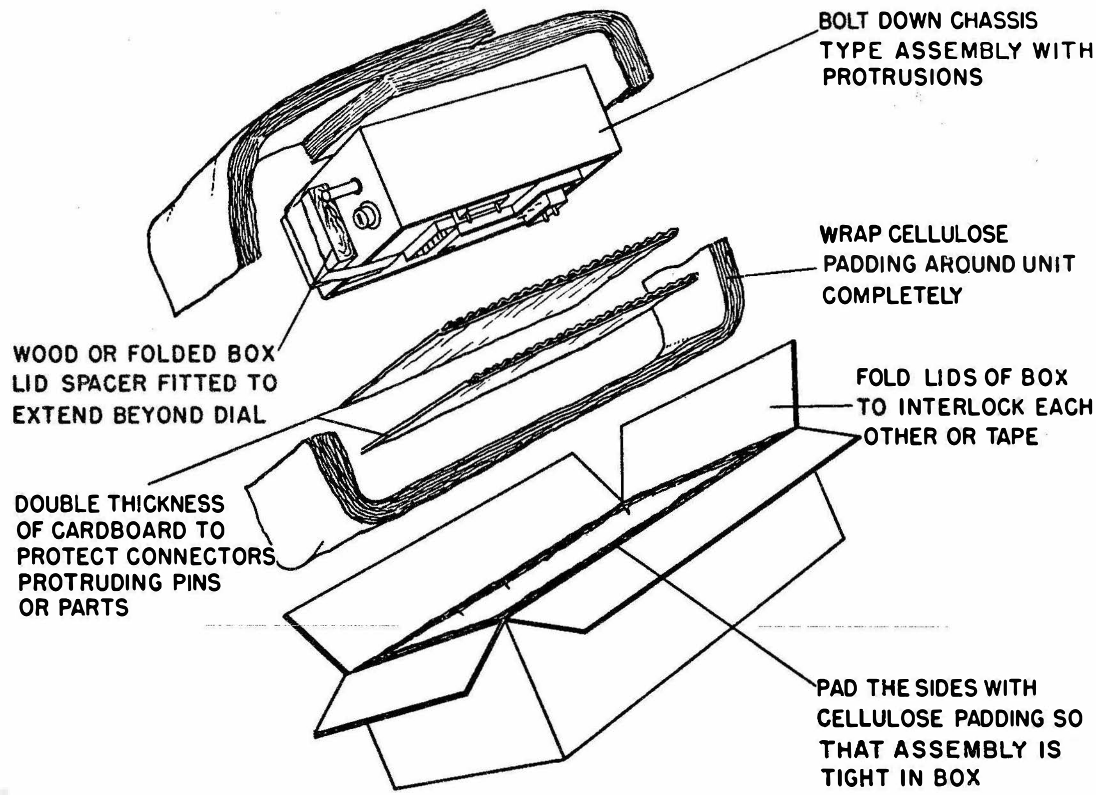


Figure 5-36. Protective Packaging of a Bolt-Down, Chassis-Type Modular Assembly

storage in its assigned bin, box, or shelf until issued to the using activity.

In this manner, when a defective modular assembly requires replacement (and it is beyond the capabilities of the ship's force to repair), the shipping container of the replacement assembly can be re-used by the ship's force to ship the defective assembly to the repair facility and/or the manufacturer.

Regardless of the modular assembly design, if its pins, shaft, dials, protruding parts, etc., are adequately fitted with packing spacers, and if the assembly is properly packaged in re-usable shipping containers or is wrapped with a resilient cushioning material (Kimpak, Resilo-Pak, or similar material), the using activity will have done its part in preventing transport damage to the modular assembly.

New modular assemblies crated for shipment are normally packaged with desicant crystals. These crystals are retained in a bag and placed within the crated or packaged equipment in such a manner that they will not come loose.

DO NOT USE THESE DESICCANT CRYSTALS WHEN PACKAGING DEFECTIVE MODULAR ASSEMBLIES.

If a modular assembly becomes exposed to loose desiccant crystals, clean the assembly immediately. DO NOT TURN ITS MOVING PARTS ANY MORE THAN ABSOLUTELY NECESSARY until all of the crystal particles have been removed from the assembly. In testing the moving parts for cleanliness, turn them very slowly and gently—DO NOT FORCE IF GRITTY. Work out the crystal particles with a brush or dry-filtered compressed air. Wash the modular assembly in accordance with the general cleaning particles described in "Handbook of Cleaning Practices," NAVSHIPS 250-342-1.

A semiconductor unit may also be damaged by r-f fields. It is therefore essential that the unit be protected by a metal container until ready for use, at which time the equipment should be de-energized before the semiconductor is inserted.

Much unnecessary damage has occurred to modular assemblies because of improper packaging and rough handling. Particular care must be given to the method employed in packaging of a modular assembly, and also to the method employed during removal or insertion of an assembly into the equipment. If it is a plug-in, board-type assembly, be sure that the guide pins are adequately fitted with packing spacers before shipment. Properly align the guide pins or dowels before pressing the assembly into place. If the board should tilt while being inserted, do not continue to press into position; straighten it, and then apply even pressure to avoid tilting. Forcing any tilted or cocked modular into position may result in bent or broken pins.

REMEMBER—ASSEMBLY PARTS ARE FRAGILE. CARELESS HANDLING OR PACKAGING WILL

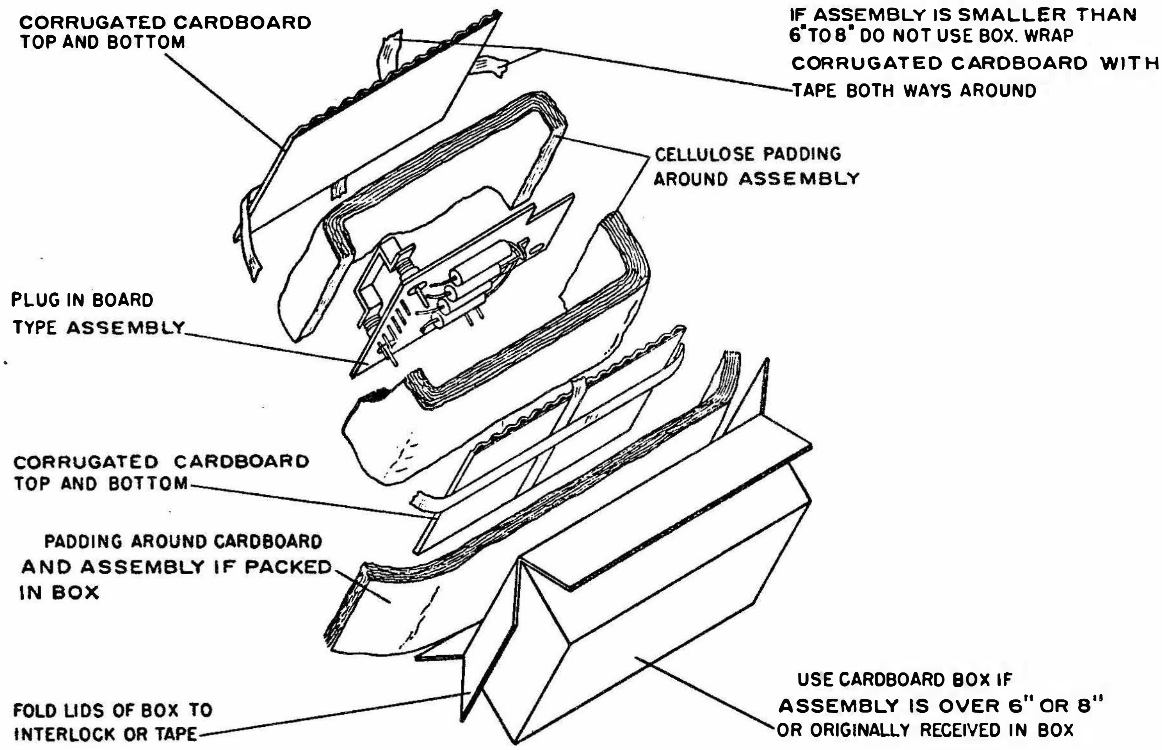


Figure 5-37. Protective Packaging of a Plug-In Board-Type Modular Assembly

DESTROY A GOOD ASSEMBLY. USE GREAT CARE WITH A MODULAR ASSEMBLY.

5-7 CLEANING PRACTICES FOR FLOODED EQUIPMENT

Shipboard equipment may become flooded with water or fuel-oil-contaminated water during a fire or other casualty. Procedures for cleaning this equipment to remove contaminants and to prevent further corrosion have been developed and were promulgated by Bureau of Ships Instruction 4740.3, serial 643A-23, dated 19 January 1961.

The following procedure is suggested for the treatment of electronic equipment after saltwater immersion:

1. Dismount transmitters, receivers, frequency indicators, direction finders, and such, and remove all covers, access and mounting plates, vacuum tubes, fuse covers and fuses, and armatures from dynamotors or motor-generator sets. Disconnect and remove all meters from equipment and cases. Break the dial glass, if required, to drain off water.

2. Flush all parts of the equipment thoroughly, using warm fresh-water under slight pressure. To not subject the internal parts of pressure-sealed units to the water treatment without first ascertaining that salt water is present inside the pressure-sealed portion; then remove the salt water from the exposed parts only. Place the equipment in a tank and soak it not less than four hours in circulating warm water. If non-circulating, change the water at intervals of one hour. As an added precaution against corrosion, if the material is available, it may be desirable to add a minute quantity of potassium dichromate to the fresh water solution in the strength of 1/2 oz. to every 10 gallons of water.

3. Remove the equipment from the water and drain it. Blow out all moisture with low-pressure air and place the equipment in any available oven. Dry it thoroughly for 24 hours at a temperature of approximately 150°F.

4. If storage is required prior to overhaul, spray all exposed metal parts slightly, using light clear oil.

Experienee indicates that if equipment is treated as outlined immediately after immersion, a minimum of replacement parts and overhaul work is required. It has not been found practical, however, to attempt to salvage vacuum tubes, meters or externally shielded cables (except plugs, which are removed and included with the equipment being preserved). Power transformers in transmitters, likewise, must practically always be replaced, even though megger tests after baking may show normally high insulation resistance to ground. It has likewise been found that replacement of sockets, relay contacts and such, may be required, particularly if immersion took place before power voltages were removed from the equipment. Glass tubes having their leads coming directly out of the glass envelope without

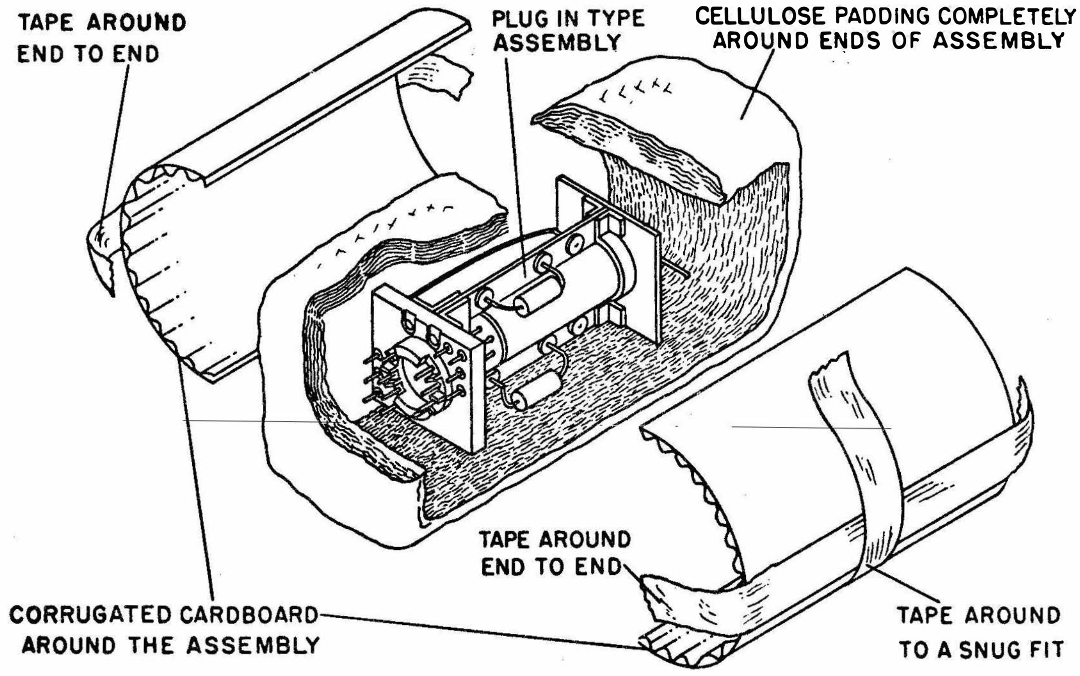


Figure 5-38. Protective Packaging of a Plug-In Modular Assembly

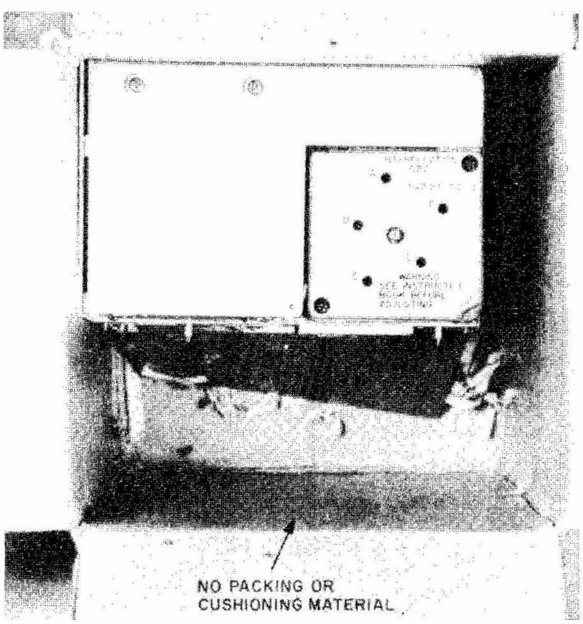


Figure 5-39. Improper Packaging of Repair Parts

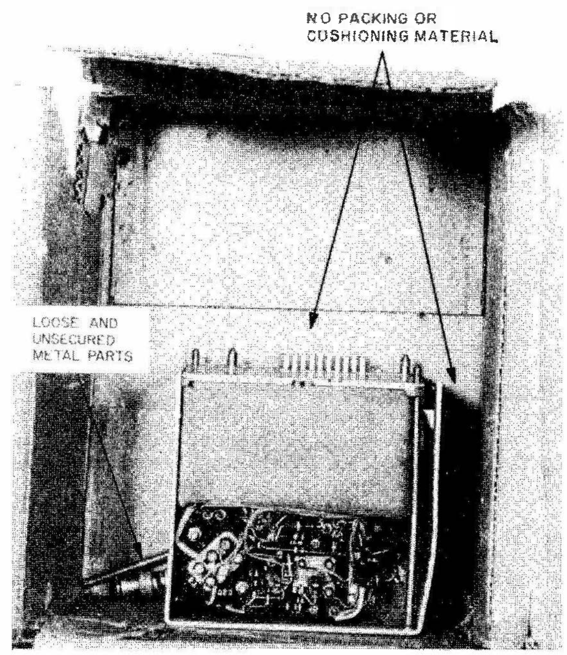


Figure 5-40. Improper Packaging of a Module

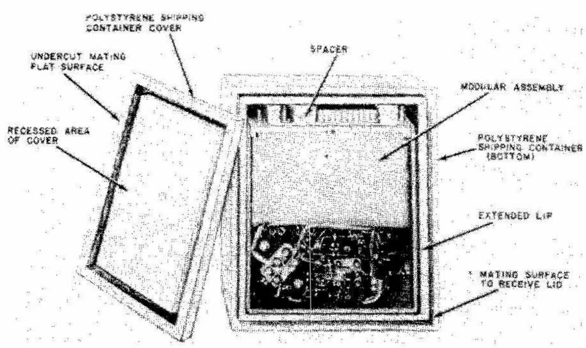


Figure 5-41. Modular Assembly Packaged in Polystyrene Material

a tube socket will not need to be replaced unless proven defective. On tubes of this type, it is necessary to remove all corrosion from the tube leads. It is possible to salvage cathode-ray tubes by removing the plastic base from the tube, remove all corrosion and salt water and replace the plastic base.

If the immersion was for a prolonged period or if the equipment has not been properly washed and preserved, it is usually found that so much corrosion of the cases and mechanical parts has taken place that it cannot be economically overhauled.

a. SALVAGE TREATMENT

Before equipment to be salvaged is removed from fresh or sea water, arrangements should be complete to proceed immediately with salvage operations, since ferrous surfaces rust rapidly after the equipment is removed from water and exposed to air. The equipment required for the salvage of flooded equipment is as follows:

1. Oil or paint spray guns operating 75 lbf/in^2 air.
2. Portable hot and cold blowers.
3. Drying ovens with temperature control.
4. Ultrasonic cleaning tank with associated oscillators and amplifiers.
5. Steel tanks.

The following precautions should be observed in all salvage operations:

1. Journal Bearings—Remove waste packing in bearing chambers, clean as directed herein for other equipment, add new packing, and saturate with a suitable lubricant.
2. Ball and Roller Bearings—Remove grease either by disassembly and cleaning or by forcing new grease through bearings until all old grease has been displaced.
3. Carbon Brushes—Replace all carbon brushes and carbon contacts.
4. Contact Points in Switches and Relays—Remove rust inhibitor film left from water-displacing fluid on contact points. For this purpose, use lintless cloth soaked in naptha solvent or ethyl alcohol.

The following steps should be taken after removing submerged equipment from the liquid:

1. Determine whether there has been any oil or other hydrocarbon contamination. If the equipment is contaminated, steps 2 and 3 should be performed before following subsequent steps. If there is no contamination, steps 2 and 3 may be omitted.
2. Mix the hydrocarbon cleaning concentrate with an equal volume of water as directed in Table 5-2.

Table 5-2. Hydrocarbon Cleaning Emulsion

Chemicals	Percent By Volume
Dry Cleaning Solvent (140°F solvent, type II) Fed P-D-680	44.5
Diesel fuel oil (type 1) MIL-F-16884c (Ships)	5.0
Surfactant*	0.5
Water	50.0
	100.0

*Any of the following three sulfactants may be used:

"Polyethyleneglycol 400, Monooleate S1006," a product of Glyco Products Company, Inc., Empire State Building, New York, N.Y.

"Pluronic L-63," supplied by Wyandotte Chemicals Corporation, Wyandotte, Michigan.

"Nonisol 100," supplied by Geigy Industrial Chemicals Company, Ardsley, New York.

3. Spray the exterior of the equipment thoroughly with the cleaning emulsion to remove as much contaminant as possible. Flush the equipment with fresh water. Repeat the cycle, if necessary, until all contaminant is removed. If access can be gained to the interior of the equipment, spray the interior thoroughly, then flush with fresh water. If the construction of the equipment prevents access to the interior, partial disassembly for inspection and service may be required.
4. When the equipment is free of contaminants, flush it thoroughly with fresh water to remove all traces of sea water and cleaning formulation. If possible, several cycles of alternate immersion in fresh water and draining should be employed to remove sea water not reached by the flushing process.
5. The last traces of sea water and contaminant can be removed from complicated equipment by ultrasonic treatment. Complicated electronic assemblies and small electric motors are examples of equipment requiring ultrasonic treatment.
6. Blow as much water as possible from the equipment with clean compressed air. Do not exceed a pressure of 50 lbf/in^2.
7. Spray all parts of the equipment with water-displacing formulation. See Table 5-3. This fluid must penetrate to all parts of the equipment that have been wet with water. After spraying, allow 20 minutes for the water-displacing formulation to penetrate and displace the water remaining in the equipment.
8. The residual mixture of water and water-displacing fluid should next be evaporated from the

Table 5-3. Water-Displacing Formulation

Chemicals	Percent By Volume
Butyl alcohol (1-butanol)	93.75
2, 6 ditertiary butyl, 4 methyphenol*	0.25
Basic barium napthalene sulfonate**	6.00
	100.00

*An oxidation inhibitor supplied under the trade name "Paranox 441," available from Paraflor Sales, Stanco Distributors, Inc., 26 Broadway, New York, N.Y.

**A rust inhibitor concentrate (50 percent inhibitor in naptha solution) supplied under the trade name "Nasul," available from T.T. Vanderbilt Company, Inc., 930 Park Avenue, New York, N.Y.

equipment by blowing with clean, heated compressed air, or with heated air from an electric blower, or by placing the equipment in an electric oven (160°F) with good air exchange, or by simply allowing enough time for the equipment to air dry. (No further corrosion will take place on the equipment after it has been sprayed with the water-displacing fluid.)

b. ULTRASONIC TREATMENT

Ultrasonic cleaning and cleaning procedures are discussed in detail in Section 3 of this handbook.

The following procedure is given as a follow-up to the salvage treatment discussed in subparagraph "a" above.

1. Disassemble the equipment as far as necessary to let liquid emulsion reach all remote locations.

2. Immerse parts in tank containing hydrocarbon cleaning emulsion as given in Table 5-2 and an ultrasonic generator. Operate according to the instructions supplied by the manufacturer of the ultrasonic apparatus. A minimum ultrasonic power level of 300 watts per cubic foot of solution is recommended.

3. After ultrasonic treatment in the presence of the cleaning formulation, process the equipment in an ultrasonic bath, in another tank that contains fresh water, to remove the excess cleaning formulation. If a second equipment tank with an ultrasonic generator is not available, flush the equipment thoroughly with fresh water.

c. INSULATION CHECKS

Rewiring of equipment is not normally required, the criterion used being a check of circuit resistance to ground from various terminals, using a megger, after removing normal circuit grounds or resistor shunts.

An insulation resistance in excess of 50 megohms is taken as satisfactory evidence that rewiring is not required.

Rewiring, replacement of parts, and final testing of equipment is accomplished as with other types of overhaul procedure.

SECTION 6

PARTS MAINTENANCE

6-1 APPLICATION OF PARTS MAINTENANCE

Parts maintenance is the maintenance action that may be performed on individual components used in electronic equipments. All components require being kept, clean, securely mounted, and cool. The parts that are repairable or where maintenance actions can be performed are discussed in the following subparagraphs in this section. All other parts, after having been determined to be faulty by appropriate tests and troubleshooting procedures, require replacement.

6-2 BATTERIES

Batteries are grouped into two broad categories; dry cell and wet cell (storage). The maintenance requirements pertaining to each category is discussed in the following subparagraphs.

a. MAINTENANCE OF DRY CELLS

Dry cells require very little or no maintenance during their service life. To determine the true condition of a dry cell, it must be tested under load as a simple voltmeter test will not give a true reading. When batteries, tested under load, are found to be below 60 percent of the rated value they should be replaced.

Any dry cell left standing for a prolonged period of time will become chemically unstable and therefore useless. For this reason, the shelf life of a dry cell should be known and stowage should not be in excess of the time allowed.

Any dry cell in use that shows signs of corrosion should be replaced. Never, if at all possible, replace a new dry cell in series with an old cell as the old cell will restrict the current drain of the new cell.

b. MAINTENANCE OF WET CELLS

Wet cells (storage batteries) have the advantage of high current and long life and therefore require more constant attention than the short lived dry cell. A wet cell will deteriorate rapidly if not kept charged. The condition of a wet cell can be determined by the use of a hydrometer. This instrument determines the specific gravity of the electrolyte and a reading of 1.240 or less indicates that the battery requires recharging. The electrolyte, usually a solution of distilled water and sulfuric acid, must be replenished at frequent intervals by the addition of distilled water. This liquid should be kept at a level of about 1/2-inch or more above the plates.

Remove all corrosion from the terminals with a stiff non-metallic brush and then wash the terminals with a solution of bicarbonate of soda and water. This solution will neutralize any electrolyte that may collect on the terminals. After washing, dry the terminals thoroughly and apply a thin coating of terminal grease or vaseline to the metal terminals.

The vent caps should always be kept in place during cleaning of the top of the battery and terminals. After cleaning, inspect the vent caps carefully to ensure that the gas escape holes are clear.

c. NICKEL-CADMIUM CELL

The nickel-cadmium cell in use today is a sealed wet cell battery that is rechargeable and free of the usual routine maintenance required for other types of wet cells, such as the addition of water. This battery can be recharged many times to give a long useful life and is not adversely affected by long standing, either charged or discharged. It is difficult to accurately determine the condition of this battery. The only way to be certain, is to put it through several discharge and charge cycles. If the voltage of a cell is low, less than 1.0 volt, it may merely mean that the cell needs to be charged. If the open circuit voltage reads 1.40 volts, it can be assumed that it is fully charged.

The storage life or shelf life of a nickel-cadmium cells far exceeds that of other types of batteries. During storage, the sealed cell will lose some of its charge. A storage temperature of 100 to 120°F will increase the self discharge considerably as compared to a cell stored at a temperature of 70°F. Cold storage of these cells offers a definite advantage.

If the cell has been stored for a long period of time, regardless of the temperature of storage, it should not be charged immediately for use. It should be first fully discharged and then charged. Discharging the cell first breaks down any oxide that forms on the cadmium electrode.

d. WET CELL CHARGING TECHNIQUES

Before charging a battery for immediate use or for storage, certain precautions should be observed and preparations made as follows:

1. Clean the top and the case of the battery with water.
2. Apply a mild solution of bicarbonate of soda and water (1-pound of bicarbonate of soda per gallon of water) to the terminals after the corrosion has been removed by brushing with a stiff non-metallic brush.
3. Inspect the general condition of the case after cleaning.
4. Remove filter caps and add distilled water if required.
5. Batteries are to be charged with DC only and may be done in groups in series or in parallel.

> WARNING: Exercise extreme care when attaching or detaching the charging leads in order to prevent arcing which could ignite the hydrogen gas which is liberated during charging. Power to the charger should be secured before attaching or detaching the leads.

6. While the battery is being charged, unscrew the vent caps but leave resting over the cell openings

to prevent electrolyte from spraying out of the cells and keep foreign matter out of the battery.

> CAUTION: When handling electrolyte, wear goggles, rubber gloves, apron and protective overshoes to avoid acid burns.

> WARNING: When preparing electrolyte solution, always POUR THE ACID INTO THE WATER: NEVER POUR WATER INTO ACID. Water is lighter than sulfuric acid and will spatter both acid and water upon the operator. The electrolyte container should be glass to avoid a reaction with the sulfuric acid.

New batteries are received from the manufacturer without electrolyte. These batteries should be stored in a cool, dry compartment and should be removed for use in the order received. Any battery stored longer than 15 months should be tested for its capacity before being placed in service. Stored batteries containing electrolyte should be recharged each month if the temperature is 89°F or less, and biweekly if the temperature exceeds 89°F.

e. SAFETY PRECAUTIONS FOR CHARGING AND HANDLING NICKEL-CADMIUM BATTERIES

Recently, a nickel-cadmium battery exploded while being charged, resulting in minor injury to three personnel. This was probably due to not using the proper precautions when charging the battery, rather than a defective battery.

> WARNING: Nickel-cadmium batteries or cells must be charged only in series, never in parallel. Cell imbalances cause different resistances which vary the charging rates of the cells when charged in parallel. This may cause a "thermal runaway."

The manual charging rate for a nickel-cadmium battery is $\frac{c}{10}$, where "c" is the ampere-hour capacity of the battery. This is the recommended constant current charging rate at the ten-hour rate. For example: the charging rate for a 4.0-ampere-hour nickel-cadmium battery or cell would be 0.4 amperes at a maximum voltage of 1.5 volts per cell. A completely discharged battery requires 14 to 16 hours of charging. With properly design batteries, gassing due to overcharging is practically nil under these conditions. Constant voltage charging is not recommended.

All nickel-cadmium sealed cells can be "floated" or "trickle-charged" to maintain a fully charged condition in standby for emergency power applications. The usual trickle-charge rate is $\frac{c}{100}$ unless the manufacturer recommends otherwise. To obtain optimum life and performance, care should be taken to maintain a nickel-cadmium battery as near room temperature as practical. The nickel-cadmium battery may be used over a wide temperature range. It may be discharged at about 0°F to 110°F, stored at approximately -40°F, and even discharged at a maximum temperature of 160°F or a minimum of -60°F for a short time, if necessary. However, at temperatures over 110°F, degradation of the battery increases rapidly.

> WARNING: Higher than recommended charging rates or voltages may result in gas evolution of hydrogen and oxygen, an explosive mixture which is easily ignited.

A nickel-cadmium battery should not be installed near other heat producing components. In high-rate discharge applications the battery should be ventilated if possible. Care should be taken to insure proper handling to prevent short-circuiting. High current discharges result in high temperatures which may cause cell damage.

Battery shops for nickel-cadmium batteries should have their own tools and service area, separate from those used for lead-acid batteries. This reduces the possibility of contamination problems.

In summary, the following precautions are recommended:

1. Only charge nickel-cadmium batteries or cells in series, never charge them in parallel.
2. Use the proper constant current charging rate of $\frac{c}{10}$ or $\frac{c}{100}$ for trickle or float charge at 1.5 volts per cell.
3. Maintain the battery temperature below 113°F, if possible.
4. Avoid possible short circuits.
5. Have separate tools and service area for nickel-cadmium batteries. (EIB 760)

6-3 CABLES, CONNECTORS, AND TRANSMISSION LINES

Cables, connectors, and transmission lines used in connecting component parts of electronic equipment are often the cause of many maintenance problems encountered in the Navy today. The following subparagraphs give some of the most common faults along with the preventive and corrective maintenance procedures to correct these faults.

a. POWER CABLES

Many cable failures are caused by normal wear received during the rought usage to which all military equipment is inevitably exposed. Cable failures may occur at a time when dependable communications or equipment operation is vitally necessary for the success of a tactical operation. It is of the utmost importance to insure against such failure by frequent periodic inspections. Operators and technicians should be continuously on watch for defects in cables that may develop into equipment failures unless corrected at the earliest opportunity. Some of these defects and the trouble that may result are given in the following paragraphs.

(1) Frayed Conductors

Frayed conductors may cause intermitten or unreliable operation.

(2) Broken Conductors

Broken conductors may cause shutdown of the equipment.

(3) Chafed Insulation

Chafed insulation may cause shorts between conductors or shorts between conductors and ground.

(4) Insulation Damage

Insulation damage may be caused by coming in contact with oil gasoline, acid, and other harmful materials.

When any of the above conditions are discovered, the cable should be replaced immediately or temporary repair made until replacement can be made at the earliest opportunity. Always replace the damaged cable with the same type or equivalent cable to avoid possible injury to personnel or damage to the equipment.

b. RF CABLE

RF cables (coaxial cable) are divided into three types; the solid dielectric, the foam dielectric, and the gas-filled. The solid and foam dielectric cable is in prominent use today aboard ships whereas the gas-filled is becoming obsolete.

Solid coaxial cables require little maintenance outside of regular cleaning and inspection. Cables containing polyethylene dielectric are not designed to withstand heat. Even heat resistant cables will deteriorate when subjected to high temperatures over an extended period of time and therefore should never be routed through high temperature spaces (galleys, laundry spaces, fire rooms, and the like). If the cable must go through these spaces, it should be mounted as far away as possible from heat sources such as steam lines, dryers, and ovens.

c. CONNECTORS

Most plug connections on Navy equipment fit tightly and caution must be exercised when uncoupling such connections. Such tight-fitting plugs must be disconnected by working them back and forth while applying a steady pull. A quick hard jerk may break the cable. After removal of a plug from its socket, it should be inspected for bent or loose contact prongs, burned spots on the contacts which are evidence of short circuits or poor connections, stripped threads on screw-type connectors, and worn gaskets or washers in sockets of power cables which might permit the entrance of water.

Many plugs or connectors are equipped with rubber washers through which the cable must be threaded before attachment to the plug insert. Check to insure that these washers have not been reamed out or that the cable insulation has been whittled down to insure a good fit. When replacing this type of plug, lubricate the cable with soap, do not use a petroleum product as a lubricant as it will cause the rubber to deteriorate.

Wire connectors used on antennas and transmission lines can be cleaned for re-use by dipping them in a bath of chrome plating solution using the following procedure:

1. String connectors on a wire.
2. Prepare a chrome plating solution consisting of 20 to 24 ounces of concentrated chromic acid per gallon of water.
3. Dip connectors into chrome plating bath for 5 to 10 minutes.
4. Rinse connectors in fresh water, dry, and then apply a thin coat of oil.

d. WAVEGUIDES

The most common trouble encountered with waveguides is the presence of dirt and moisture. Any foreign matter inside a waveguide will upset the line constants, resulting in a mismatch. Hot splot along a run are often a definite indication that foreign material in the waveguide is causing an excessive dissipation of power in the form of heat. Scale deposits may form inside a waveguide if it is not properly weather sealed.

It is not possible to determine the condition of a waveguide with a megger. An excellent means of determining waveguide condition is to measure the standing-wave ratio (SWR) of the line. To obtain particulars on SWR testing, check either the EIMB Radar Handbook, NAVSHIPS 0967-000-0020; the equipment technical manual; or the EIMB Test Methods and Practices Handbook, NAVSHIPS 0967-000-0130.

To determine if arcing is being caused by foreign matter in a waveguide, simply listen along the waveguide run while its associated equipment is radiating. If arcing is noted, the appropriate section(s) of waveguide should be dismantled and cleaned in accordance with the cleaning procedures outlined in the EIMB Installation Standards Handbook, NAVSHIPS 0967-000-0110 or MIL-HDBK-216.

When reassembling waveguide, exercise care to insure that all flanges are clean, properly mated, and that all gaskets are in place. All bolts should be drawn up tightly and evenly. Waveguide hangers should exert a firm pressure on the waveguide without distorting it. The waveguide should always be installed with a lining of insulation material such as sheet rubber or other non-absorbent insulating material between the waveguide and hanger or use Plastisol-dipped (or equivalent) hangers to prevent galvanic or electrolytic action.

When a waveguide is continually collecting moisture inside, it is permissible to drill a small hole at the lowest point of the waveguide on the LONG dimension. Make certain that all drilling chips and burrs are removed from the waveguide interior.

Some waveguides have dehydrator plugs installed at various points. These dehydrator plugs contain a moisture absorbing material, called a desiccator, along with an indicator. These plug indicators must be checked periodically. The indicator is blue when dry; when it becomes moist, it turns pink and means the dehydrator plug should be replaced.

6-4 FUSES AND CIRCUIT BREAKERS

Fuses and circuit breakers are protective devices whose primary purpose is to disconnect individual circuits, components, or equipments from a power source when a potentially damaging fault occurs in the unit. This fault may be either a moderate overload or a short circuit which, because of the heating effect of electric current, can create a fire hazard in the wiring system or otherwise damage the equipment.

a. FUSES

Fuses are made in two major styles; the plug type which is rated from 0- to 30 amps in circuits where the voltage does not exceed 125 volts to ground; and the cartridge type, which is rated up to 600 amps in circuits up to 600 volts.

The fuses commonly used in electronic equipment are known as normal lag, quick acting, and time delay. These names indicate the speed at which the fuses interrupt the current in a circuit.

To prevent equipment failures caused by faulty fuses, the following precautions should be observed:

1. Fuses should be kept tight to prevent oxidation.
2. Proper contact must be made between fuse and clip.
3. If oxidation is noted, it should be removed by light filing, and the clips should be readjusted to fit tightly against the fuse.

When a fuse or fuse element does blow, care must be taken to replace it with a properly rated fuse or element. An improper replacement will either damage the equipment or curtail its operation.

b. CIRCUIT BREAKERS

Circuit breakers, like fuses, are used to protect either circuits or equipments. In addition, circuit breakers can also be used as switches. As a protective device, a circuit breaker should be able to carry rated current indefinitely and to trip with a definite time delay characteristic when an overload occurs. As a switching device, it should be able to make and break rated current without excessive arcing.

Circuit breakers should be inspected regularly for pitting and corrosion. The contacts should be dry cleaned periodically with an approved dry cleaning solvent such as P-D-680 or inhibited methyl chloroform and dried immediately. A small piece of chamois on a strip of bakelite makes a convenient cleaning and drying tool. Never use paper, cloth, or any other shredding material.

To clean flat surfaces, a burnishing tool or crocus cloth is the only suitable tool. All pits and corrosion should be removed from the contact surfaces.

Extreme care must be exercised when making circuit breaker adjustments and double check all adjustments that are made to ensure proper operation.

6-5 SHOCK-MOUNTS

Anti-vibration and shock-mount devices are relatively simple in their design and construction and required little maintenance. Conditions of service and age and the condition of the equipment differ from ship to ship. Consequently, it is impracticable to provide a rigid schedule of tests and inspections. However, certain general precautions must be taken and observed by those who use and service the equipment. These general precautions and a list of do's and don'ts are as follows:

1. Do keep all fastening devices, such as threaded bolts, nuts, screws, studs, thread-locking devices and such, secure and in place.
2. Do not install a rigid connection between the foundation and the framework of equipment which is supported by resilient members of a shock mount. Such a connection destroys the effectiveness of the mount and may result in serious damage to the equipment mounted on it.
3. Do not paint the surface areas of the resiliency, deterioration, and premature failure of the resilient member of the shock mount.
4. Prevent oil, solvent, and any other types of organic substance from coming in contact with, or wetting, the rubber material.
5. Do not make changes in or alterations to spring type shock mounts if such changes or alterations will decrease the original clearances provided.
6. In some cases, adjusting screws or shims are provided to restor the original clearances. In such cases, refer to applicable technical manuals or manufacturer's data sheets before making any adjustments.
7. Inspect shock mounts for visible signs of deterioration. Shock mounts should be inspected at least once every six months, and those showing signs of deterioration should be replaced. If deterioration occurs too soon, refer to steps 3 and 4.
8. Do not mount or stack additional components on shock-mounted equipment. The added weight may make the whole unit incapable of withstanding shock.
9. Inspect the mounting clips, heat dissipating and retention devices, and such for signs of deterioration and loose associated hardware.
10. Use flexible braided ground straps on equipment mounted on sound isolation mounts. Make certain that no ground strap installed impairs maximum excursion of any installed mounts.
11. Install ground straps so that they can be readily inspected or replaced. In attaching the straps, make certain that the equipment is not damaged and that its watertight integrity is not impaired.
12. Remove all paint and dirt from surfaces at the points of ground strap contact before installation. Failure to do so could result in an improper or incomplete electrical connection between the equipment and the ship structure.

Since most component parts and equipment are tested and subjected to vibration and mechanical shock by the manufacturer or by Naval development laboratories, in accordance with Military Specifications, maintenance of anti-vibration and shock-mount devices by electronics technicians consists primarily of corrective and preventive maintenance. All personnel concerned must be aware that improperly applied maintenance techniques often result in needless equipment failure. Take time, be precise, and always maintain a scheduled inspection period to ensure that all anti-vibration and shock-mount devices and their associated mounting hardware are secure and in place.

6-6 SCREW AND THREAD FASTENERS

When engaged in the servicing and repair of electronic equipment, maintenance personnel often encounter broken or stripped stud bolts, machine screws, and other threaded fastener devices. In such cases, a screw extractor tool especially designed for this purpose should be used to prevent damage to the internal threaded surface from which the broken item is removed.

To remove a broken stud, first drill the stud as in Figure 6-1. The drill should be about 3/4 the size of the stud diameter. After drilling, insert the extractor and tap it lightly into position, being careful not to strike it too hard; a heavy blow would probably cause the extractor to break.

After setting the extractor, place a wrench on the square shank of the extractor. Then, holding the wrench so as to maintain a downward pressure, commence to gently turn the wrench in a counter-clockwise direction. The stud should start turning with the extractor. Continue turning until the broken part is extracted from the tapped hole. If the stud refuses to turn with the extractor, stop, apply

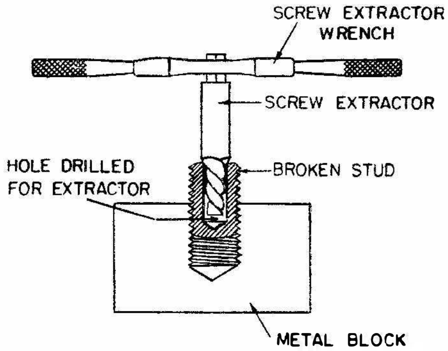


Figure 6-1. Using the Screw Extractor

penetrating oil to the threads, wait a few minutes, and try again, being careful not to exert excessive pressure on the extractor as this may cause the extractor to break.

There are cases when a screw extractor is not always available. In such a case, a broken stud often can be removed by sawing a screwdriver slot in the broken end of stud shank with a hacksaw and then remove the broken stud with a screwdriver. In other cases, if the broken stud protrudes sufficiently above the surface, it can be removed by using a small stillson wrench. If difficulty is encountered in this removal procedure, and the stud does not respond to a resonable pull on the wrench, apply penetrating oil to the threads and strike the broken stud shank lightly with a hammer. The broken stud should now turn freely from the tapped hole.

When replacing a broken or stripped fastener device, employ a screw pitch gage designed to determine the thread pitch, and a screw gage designed to determine the diameter of machine screws smaller than 1/4-inch. These tools will assist in the proper selection of replacement items. They will thus prevent inadvertent replacement of a broken or stripped fastening device with a replacement device having the improper screw pitch or diameter.

6-7 RELAYS AND SWITCHES

Inspect relays to ensure that they are securely mounted, contacts are free of pits, springs have sufficient tension, the armature does not stick, and that there are no signs of overheating or corrosion. Armature action of relays may be checked by operating the relay manually. Contact surfaces can be examined with the aid of a flashlight and mirror. Avoid bending relay springs and do not open sealed relays.

Inspect switches for loose mountings and connections. Examine switch contacts for dirt, pitting, and corrosion. Switch action should be tested to see that it operates without binding. In gang and wafer switches, ensure that the movable blade makes good contact with the stationary member and that the stationary contact leaves spread as the movable blade slides into them. Some switches have contacts that are impossible to reach without damaging the switch assembly, therefore these switches should be checked for defective mechanical action and looseness of mountings and connections.

Clean the exteriors of relays and switches carefully by blowing away the dust with approximately 5 lbf/in^2 of air pressure. If the connections are dirty, clean them with trichlorethylene. If it is necessary to remove covers from relays or switches, make certain that no dirt, lint, or other undesirable material is present that might get into the contacts. Dust and lint may also be removed from a relay or switch with a soft-bristled brush.

Contacts of relays used in computers are divided into groups for cleaning purposes. They are the hard-surfaced contacts, made of palladium or platinum, and the soft-surfaced contacts made of either silver or silver plated. Cleaning of hard-surfaced contacts may be done, when necessary, by using a flat-bladed burnishing tool as follows:

1. Clean the burnishing blade by wiping it with a lint-free cloth moistened with trichlorethylene.

2. Insert blade between contacts and then move blade two or three times between the contacts to brighten them. Open contacts can be pressed gently together with the finger or an orange stick to apply pressure against the blade of the burnisher. Closed contacts will usually apply enough pressure against the blade, therefore, open the relay manually and insert the blade between the contacts to be cleaned, release the relay armature and burnish.

> CAUTION: Avoid excessive burnishing. When too much of the contact metal is removed, the contact movement is altered and readjustment is necessary. Separate contacts carefully, when necessary, and use care never to bend the springs.

3. If burnishing in step 2 does not correct the contact trouble, deposit a few drops of trichlorethylene, with a toothpick, on the contacts. Before the solvent has a chance to dry, add a few more drops to flush away dirt loosened by the first application.

4. Allow the solvent to dry on the contacts.

5. Burnish contacts as in step 2 to remove any remaining residue. Always burnish the contacts after cleaning with trichlorethylene.

Solid-silver contacts may be cleaned by inserting a strip of hard surfaced bond paper between the contacts and then withdrawing the paper while pressing the contacts lightly together. Repeat with fresh strips of paper until the contact surfaces are clean. If this does not adequately clean the contacts, apply trichlorethylene as described in step 3 above, and again polish them with a paper strip.

Silver-plated relay contacts are ordinarily not cleaned. If such maintenance is necessary, they are cleaned in the same manner as for solid-silver contacts. Extreme care must be taken not to wear away the thin silver plate.

> CAUTION: Never use newspaper or any soft paper, emery cloth, or highly abrasive material such as coarse sandpaper to clean relay or switch contacts.

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