ELECTRONICS TECHNICIAN 3&2 VOL. 1

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10196

Although the words "he", "him", and "his", are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Electronics Technician 3 & 2, Volume 1,* NAVEDTRA 10196.

PREFACE

This Rate Training Manual and Nonresident Career Course (RTM/NRCC), *Electronics Technician 3 & 2,* NAVEDTRA 10196 (of which this is volume 1 of three volumes), is intended to serve as an aid for personnel who are seeking to acquire the theoretical knowledge and operational skills required of candidates for advancement to the rate of Electronics Technician Third and Second Class.

This volume contains information on aids to maintenance and the use of test equipment.

This training manual and nonresident career course was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Naval Education and Training Command. Special credit is given to the following commands for their reviews during the preparation of the manual: Naval Telecommunication Command Headquarters, Washington, D.C.; Naval Electronics System Command, San Diego, California; Service School Command, Great Lakes, Illinois; Electronics Technician Class "C" School, Fleet Training Center, Norfolk, Virginia; Service Schools Command, San Diego, California; and the Combat Systems Technical Schools Command, Mare Island, California.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER 1

AIDS TO MAINTENANCE

Maintenance may be defined as the function of retaining equipment in, or restoring it to, an operational condition. This includes many operations such as servicing, repair, modification, modernization, overhaul, rebuilding, testing, inspecting, and providing spare parts. Maintenance of electronics equipment is divided into two main categories—preventive maintenance and corrective maintenance.

Preventive maintenance consists of the accomplishment of those maintenance actions deemed necessary to maintain uninterrupted operation within design specifications, and to reduce or eliminate failures, thus prolonging the useful life of the equipment. If these actions are performed on a regular periodic basis, the maintenance is referred to as planned/preventive maintenance.

Corrective maintenance (or repair) is the correction of damage to equipment so as to restore it to an operational condition. This includes the isolation of trouble (troubleshooting), replacement of defective parts, and the readjustment and/or realignment of equipment to bring it up to a satisfactory operating level. Corrective maintenance may also be classified as class A, B, or C maintenance.

Class A maintenance (rebuilding or restoring) is the act of overhauling, repairing, modifying (field changing) and/or restoring a specific electronic set, group, unit, assembly, or subassembly so that it meets its most recent equipment design and technical specifications, and is essentially as good as new equipment.

Class B maintenance (overhaul) is the act of repairing and/or modifying a specific electronic set, group, unit, assembly, or subassembly so as to restore its operating characteristics to the extent required to meet its most recent design and technical specifications.

Class C maintenance is the act of repairing on board ship a specific electronic set, group, unit, assembly, or subassembly to correct those deficiencies specified by a particular job order or work request.

Maintenance may also be referred to as operational, technical, and tender/yard maintenance.

Operational maintenance consists of inspection, cleaning, lubrication, and servicing, and may also consist of adjustments and minor parts replacement not requiring high technical skill or internal alignment.

Technical maintenance consists of replacement of parts, subassemblies, or assemblies, and the alignment, testing, and adjustment of equipment. This type of maintenance requires skill and detailed knowledge of the equipment.

Tender/yard maintenance is maintenance which requires a major overhaul or complete rebuilding of assemblies, subassemblies, or parts.

In Department of Defense maintenance publications, the terms organizational, field, and depot maintenance are substituted for operational, technical, and tender/yard maintenance.

The job of a technician encompasses a large area of responsibility relating to maintenance. To meet this responsibility, numerous aids have been provided to assist the technicians in their assignments.

In the following paragraphs some of these aids will be discussed, explaining their contents and/or use. There are additional aids that can be used by the technician, however an explanation of all of these would be too lengthy. Therefore, only those normally encountered will be discussed in this chapter.

EQUIPMENT TECHNICAL MANUALS

Equipment technical manuals include information essential to the proper installation, operation, and maintenance of the equipments to which they apply. There are various types of technical manuals (all of which contain essentially the same types of information) in different formats and arrangements. Electronics equipment technical manuals that you will be using (fig. 1-1) include the conventional manuals which are divided into sections or chapters, each containing specific related information, and the Symbolic Integrated Maintenance Manual (SIMM) or Functionally Oriented Maintenance Manual (FOMM) which incorporate new concepts in presenting technical data. SIMM is used in this manual to identify both SIMM and FOMM manuals.

Other types of technical manuals which you may encounter include interim and temporary manuals which precede the approved military manuals, and the manufacturer's technical manuals which may be issued in place of the standard military manuals.

CONVENTIONAL MANUALS

The most common conventional equipment technical manuals are the 6- and 8-part manuals. Their organization and a description of the material contained in these manuals are presented in the following paragraphs.

The 6-Part Technical Manual

Front Matter

1. General Information
2. Installation
3. Operation
4. Troubleshooting—combines functional description and troubleshooting chapters
5. Maintenance—combines corrective maintenance, preventive maintenance, and alignment chapters
6. Parts List

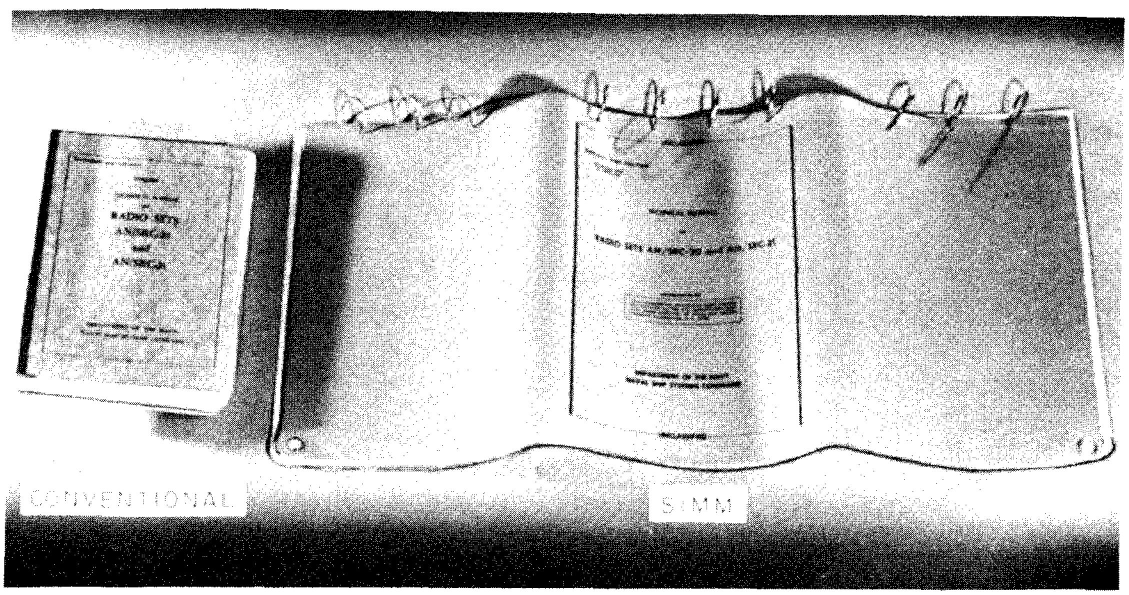

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Figure 1-1.—Equipment technical manuals.

The 8-Part Technical Manual

Front Matter

1. General Information
2. Operation
3. Functional Description
4. Scheduled Maintenance
5. Troubleshooting
6. Corrective Maintenance—includes alignment
7. Parts List
8. Installation

Front Matter

This chapter will be found in each volume of a multivolume technical manual and contains the following information:

A COVER and a TITLE PAGE which lists the equipment or system nomenclature, the security classification, publication number, volume number (if required), and the command in charge of the equipment. In addition, the TITLE PAGE includes an approval date and, if needed, a change number and date.

A FORWARD which explains the content, usage, and intent of the manual.

A LIST OF EFFECTIVE PAGES (table 1-1) which lists all pages of the manual and indicates the change status of each page.

A CHANGE RECORD which is to be filled in with information concerning the changes entered in the manual, such as the change number, the person making the change, and the date.

An INDEX containing: a Table of Contents, listing the number and title of the chapters, sections, and main paragraphs; a List of Illustrations, listing the number, title, and page number of each figure; a List of Tables, listing the number, title, and page number of each table.

In multivolume manuals, Volume I contains a complete index covering all volumes. The other volumes contain only their own indexes.

A DESCRIPTION OF CODES AND SYMBOLS which are particular to that technical manual, including how to interpret the symbols used.

General Information

This chapter provides a functional description of the equipment or system to allow command personnel and other users to easily and rapidly determine the intended use, capabilities, limitations, and relationships of the units and contains the following:

An INTRODUCTION which provides an explanation of the purpose, scope, supersedure data, and applicability of the manual, including

Table 1-1.—List of effective pages showing changes

PAGE NUMBERS	CHANGE IN EFFECT	PAGE NUMBERS	CHANGE IN EFFECT
Title Page	2	3-6B	1
A	2	3-7 & 3-8	Orig
B & C	Orig	4-1 thru 4-4	Orig
i	2	4-4A	2
ii thru vii	Orig	5-1 thru 5-18	Orig
1-0 thru 1-5	Orig	5-18A	1
2-0 thru 2-17	Orig	6-0 thru 6-20	Orig
3-0 thru 3-6	Orig	7-1 thru 7-4	1
3-6A	2	i-1 thru i-3	2

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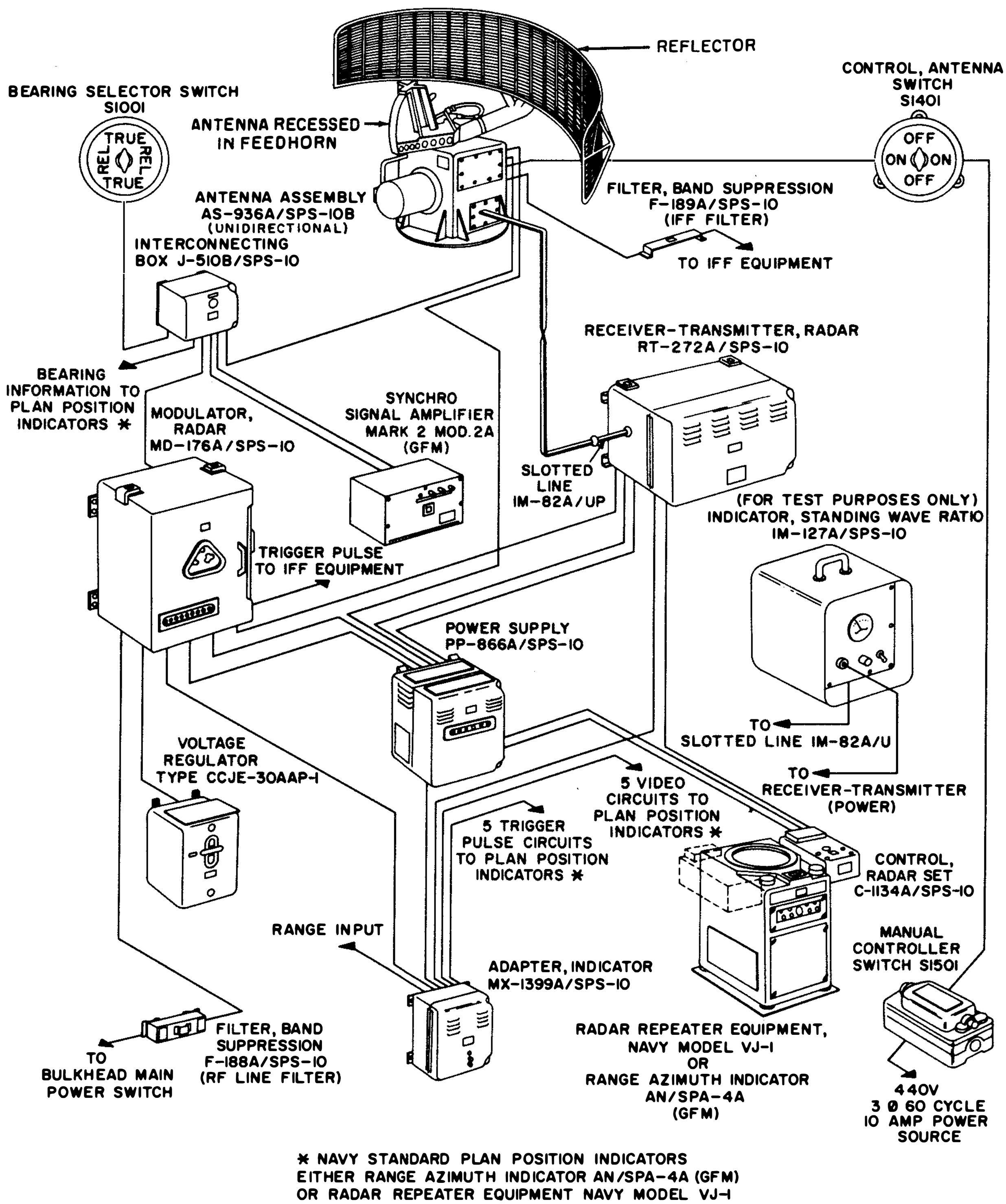

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Figure 1-2.—Equipment illustration showing relationship of all units.

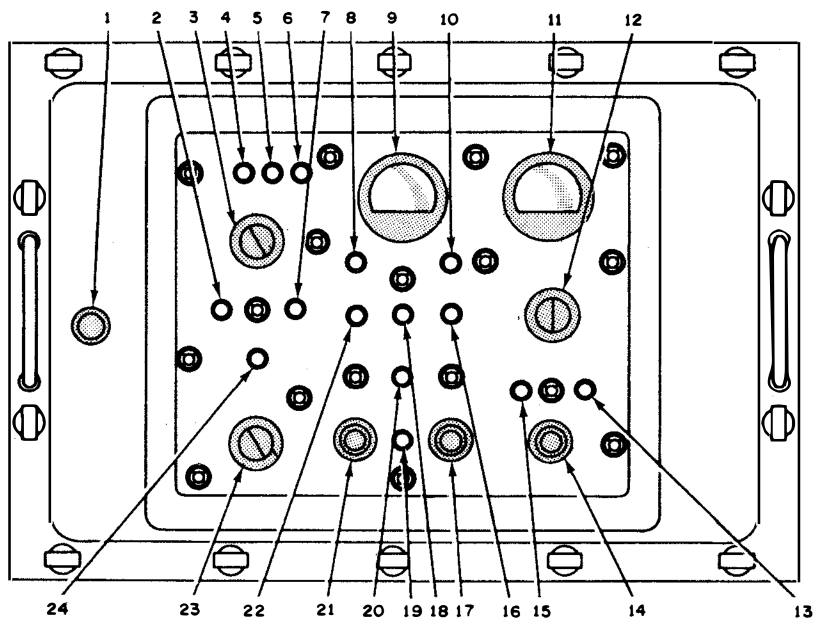
the models, serial numbers, and configurations of the equipment covered.

A GENERAL or EQUIPMENT DESCRIPTION which briefly and nontechnically describes the intended use, capabilities, and limitations. The RELATIONSHIP OF UNITS is a pictorial illustration (fig. 1-2) of all the units of a set or system showing the basic interconnections between the units and other equipment.

The REFERENCE DATA, which includes Nameplate Data, Functional Characteristics, Capabilities and Limitations, Rated Outputs, and Environmental Characteristics. EQUIPMENT, ACCESSORIES AND DOCUMENTS SUPPLIES which lists all equipment, test equipment, publications, and accessories required but not supplied. A table of FIELD CHANGES AND FACTORY CHANGES, which lists the changes that apply to that equipment, and whether they were accomplished.

Operation

This chapter contains routine and emergency operating instructions, safety precautions, operating limits, complete starting and stopping instructions, and any instructions required by the operator to prepare the equipment for use. An INTRODUCTION describes the operator's relationship to the equipment and identifies the units having controls and indicators which the operator uses. A DESCRIPTION OF CONTROLS AND INDICATORS includes names, positions, and operating functions of each control (fig. 1-3) and the normal operating condition of each indicator.



1. PHONE BUZZ buzzer
2. POWER INTERLOCKS lamp
3. POWER switch
4. STDBY lamp
5. READY lamp
6. TEST lamp
7. CW ILLUMINATOR INTERLOCKS lamp
8. RF POWER DRIVE lamp
9. RF POWER meter
10. RF POWER RADIATED lamp
11. DEVIATION meter
12. DEVIATION switch
13. FM NOISE ALARM lamp
14. NME RESET button
15. AM NOISE ALARM lamp
16. ILLUMINATOR STATUS NO GO lamp
17. RADIATE OFF button
18. ILLUMINATOR STATUS MARGINAL lamp
19. RADIATE lamp
20. HT MODE lamp
21. RADIATE ON button
22. ILLUMINATOR STATUS FAULT lamp
23. DIRECTOR LOUVERS switch
24. DIRECTOR LOUVERS OPEN lamp

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Figure 1-3.—Equipment controls and indicators.

RADIO RECEIVER R-XXX/URR
NAVSHIPS

INSTALLATION STANDARDS SUMMARY

Input Voltage ____________________ Vac
Input Frequency ____________________ Hz
(When reference standard tests are made)

Date ____________________
Serial Number of Model ____________________
Installed in (ship or station) ____________________
Length of transmission line ____________________

Record on this summary sheet the test indications which have been obtained during the installation verification test.

Paragraph No.	Ref. Std.	Paragraph No.	Ref. Std.
8-10	a. ______ Check	8-46	a. ______ μV
			b. ______ μV
8-21	a. ______ Vdc		c. ______ Check
	b. ______ Vdc		d. ______ μV
	c. ______ Vdc		e. ______ μV
	d. ______ Vdc		f. ______ μV
		8-51	a. ______ Sec
8-33	a. ______ Check		b. ______ Check
	b. ______ Check		c. ______ Check
	c. ______ Check		d. ______ Hz
	d. ______ Check		e. ______ Hz
			f. ______ Check
			g. ______ Check

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Figure 1-4.—Installation standards summary sheet.

The OPERATING PROCEDURES include Operator Turn-on, Modes of Operation, Operation Under Interfering Conditions, Operator Turn-off, Emergency Operation, and Emergency Turn-off.

The OPERATOR'S MAINTENANCE contains Operating Checks and Adjustments, Preventive Maintenance, and Emergency Maintenance. In some technical manuals this chapter is in a separate volume to allow it to be kept near the equipment for easy reference.

Installation

This chapter contains all the information required for the installation of the equipment, such as site selection, unpacking and handling, clearances, and recommendations for reduction of electromagnetic interference. In addition, this chapter contains tests and test procedures required to demonstrate that the equipment is capable of satisfying operational requirements. It also contains an INSTALLATION STANDARDS SUMMARY SHEET (fig. 1-4), which is used to record the results of the installation verification tests.

Functional Description

This chapter provides a detailed analysis of the principles of operation of the overall equipment and its major functions, including supporting functions such as power, cooling, and control. OVERALL FUNCTIONAL BLOCK DIAGRAMS (fig. 1-5) show all the major functions of the equipment by means of blocks

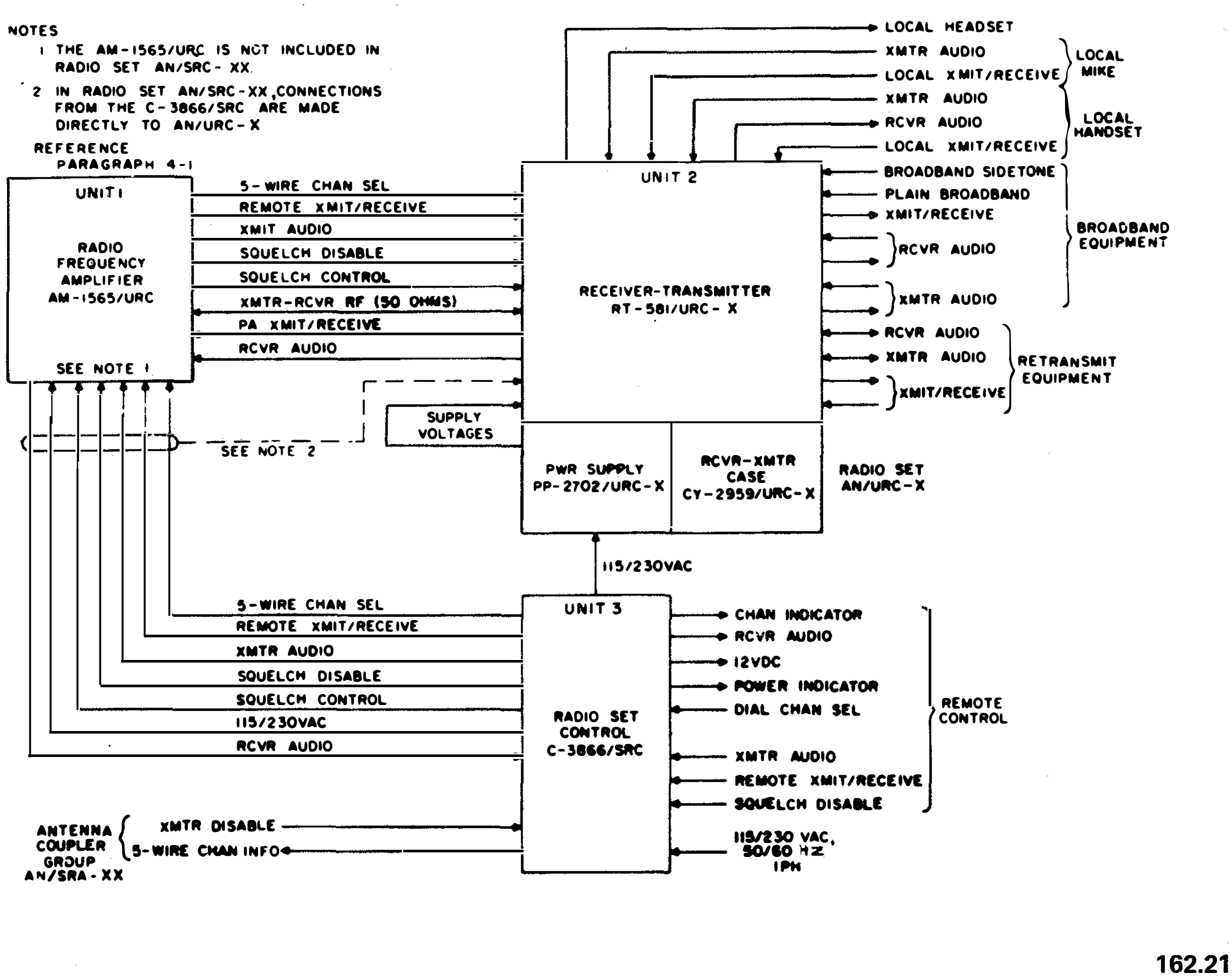

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Figure 1-5.—Overall functional block diagram.

which represent individual units or assemblies. Each block is identified by name, nomenclature, and number. Connecting lines and arrowheads show the direction of signal flow. Inputs and outputs are titled and waveforms may be included. Each of the major functions of the equipment is described on a separate FUNCTIONAL BLOCK DIAGRAM (fig. 1-6), which depicts the development of each function from input to output in detail. The electrical connections and functions of a specific circuit arrangement are shown by the SIMPLIFIED SCHEMATIC DIAGRAM (fig. 1-7).

The reference designation prefix 3A1A2, shown on figure 1-7, identifies the unit, assembly, and subassembly associated with the parts shown on the schematic. Reference designations are discussed in chapter 1 of *Volume 3, Electronics Technician 3 & 2.*

Other diagrams include PIPING DIAGRAMS, that show the interconnections of components by piping, tubing, or hoses, and MECHANICAL DIAGRAMS, that show the operational sequence and arrangement of mechanical devices.

Troubleshooting

This chapter contains all information and instructions necessary to locate troubles and conduct tests on each component, assembly, or subassembly of the equipment.

The INTRODUCTION explains the approach and logic of the troubleshooting principles and data and their relationship to each other.

The TROUBLESHOOTING INDEX (table 1-2) lists all equipment and functions with references to the appropriate procedures and diagrams that can be used to troubleshoot a specific function.

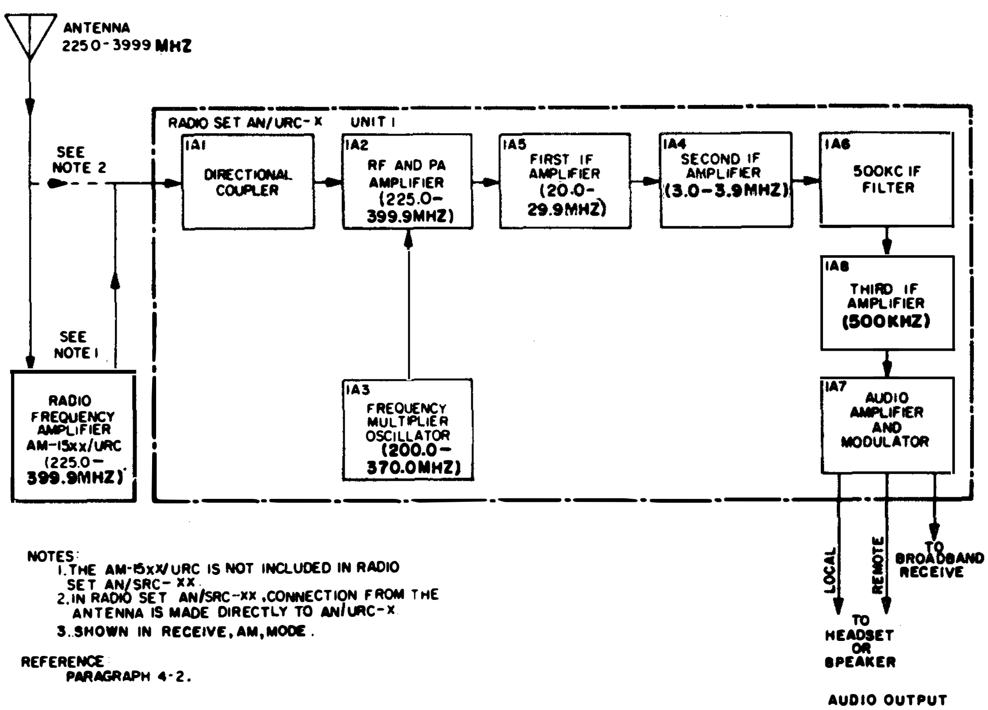

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Figure 1-6.—Functional block diagram.

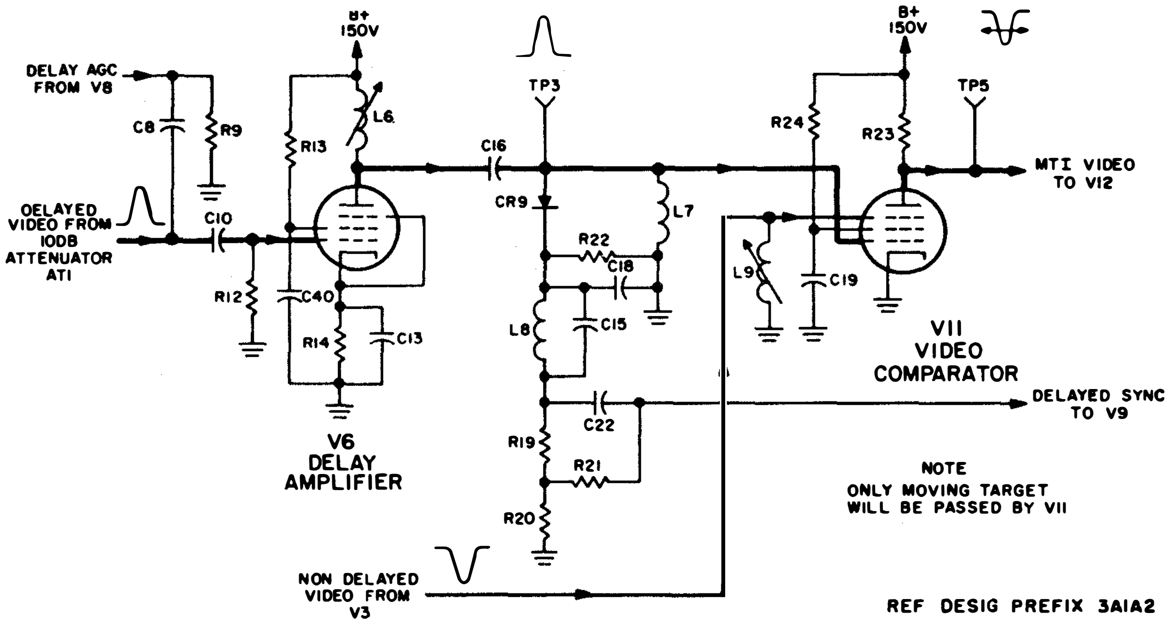

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Figure 1-7.—MTI comparator, simplified schematic diagram.

Table 1-2.—Troubleshooting Index

FUNCTIONAL AREA	TROUBLE SHOOTING PARAGRAPH	TROUBLE SHOOTING DIAGRAM	FUNCTIONAL DESCRIPTION PARAGRAPH	ALIGNMENT/ ADJUST PARAGRAPH
AC Power	5-3	5-8	3-9a	6-105, 6-106
DC Power	5-4	5-19	3-9b	6-107 through 6-110, 6-127
Keying	5-5	5-24	3-13	6-22
Receive RF	5-8	5-1	3-4	6-112 through 6-115
System Channel and Frequency Selection	5-9	5-16	3-10, 3-12	6-121

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RELAY, LAMP, and PROTECTIVE DEVICE INDEXES (table 1-3) list all relay coils, indicator lamps, and protective devices with the item reference designation, function name, voltages, ratings, and a reference to the troubleshooting diagram.

The MAINTENANCE TURN-ON PROCEDURE (table 1-4) lists the step-by-step procedure to energize the equipment with the correct indication for each step and the troubleshooting or corrective action for out-of-tolerance observations.

SIGNAL FLOW DIAGRAMS (fig. 1-8, foldout at the end of the chapter) are detailed block diagrams which illustrate the functional development of each equipment output from its origin to its measurable output. These diagrams also include test points, test parameters, schematic diagram references, adjustments, controls, switches, mechanical couplings, and that data required for test equipment setup.

CONTROL DIAGRAMS (fig. 1-9) are used to indicate all control circuits and group them according to their common characteristics.

Table 1-3.—Relay, lamp, and protective device indexes

RELAY INDEX

REFERENCE DESIGNATION	FUNCTIONAL NAME	ENERGIZING VOLTAGE	TROUBLE-SHOOTING DIAGRAM (FIG. NO.)
6A4K9	HV Door Interlock	115 Vac	5-21
6A4K10	Cabinet Interlock	28 Vdc	5-22
6A4K11	Buzzer Relay	28 Vdc	5-22

INDICATOR LAMP INDEX

REFERENCE DESIGNATION	FUNCTIONAL NAME	ENERGIZING VOLTAGE	TROUBLE-SHOOTING DIAGRAM (FIG. NO.)
9A8DS15	HV INTERLOCK CONFIDENCE-VSWR TRIP-OUT	28 Vdc	5-22
9A8DS16	HV INTERLOCK CONFIDENCE-HVPS	28 Vdc	5-22

CIRCUIT BREAKER AND FUSE INDEX

REFERENCE DESIGNATION	FRONT PANEL MARKING	RATING		CIRCUIT PROTECTED	TROUBLE-SHOOTING DIAGRAM (FIG. NO.)
		VOLTS	AMPS		
9A8F1	KLYSTRON FILAMENT FUSE ALARM 5 AMP	250	5	Klystron filament control circuit and filament trans-former 9A1T106.	5-32
14A2F1	CONTROL	125	3	Voltage sensor bridge pow-er supply consisting diodes 13A2CR1 through CR4.	5-2

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Table 1-4.—Maintenance turn-on procedure

STEP	OBSERVE	REFERENCE
1. Preliminary Procedure.		
a. Position the following switches on rear deck assembly 1A210A1 as indicated. Switch — Position POWER — OFF BATTLE SHORT — OFF STOW — BRAKES APPLY		
b. Position POWER switch on console, 1A220A20 (see figure 5-2) to OFF.		
c. Check to ensure that all chassis or subassemblies in the four compartmenta of electronic rack assembly, 1A70 are in the retracted position and all covers are secured.	Covers Secured	
d. Remove all obstructions from the rotational paths of the director main antenna assembly.	Director Clear	
2. Power Off.		
a. At power control panel perform the following.		
(1) Check convenience lamp indicators.	Lighted	Schematic, figure 5-233
e. At track meter panel, 1A340-02, check COOLANT FAILURES lamp.	Extinguished (Depress RESET button if lamp is lighted)	Relay diagram, figure 5-77, SH 4(4B)

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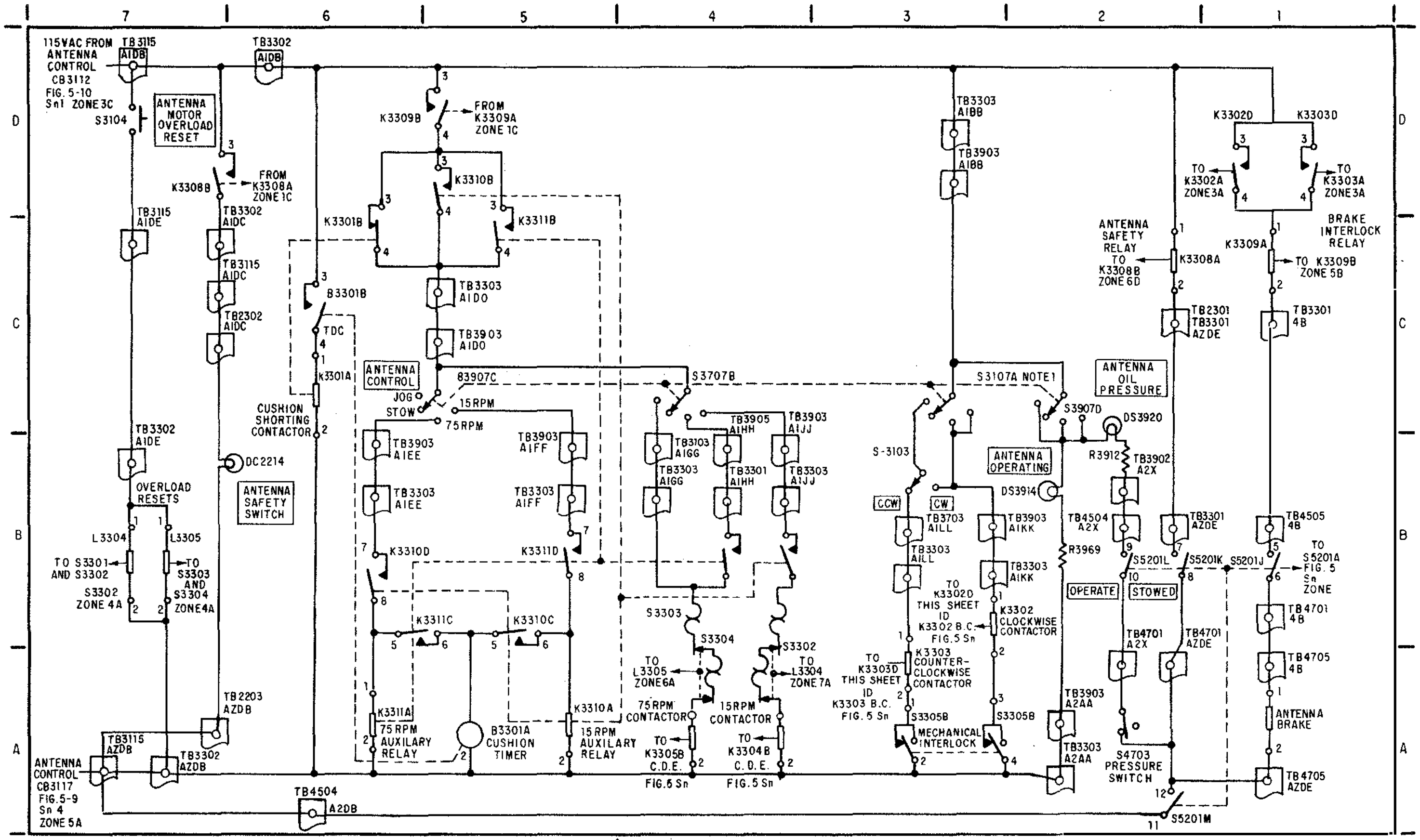
POWER DISTRIBUTION DIAGRAMS (fig. 1-10, foldout at the end of the chapter) depict the distribution of power from the equipment input to the various modules and subassemblies of the equipment. PIPING DIAGRAMS are included for fluid cooling, air, gas, and hydraulic systems as needed.

MAINTENANCE SCHEMATIC DIAGRAMS (fig. 1-11, foldout at the end of the chapter) completely cover the equipment. These include unit-to-unit interconnection diagrams, intra-unit interconnection diagrams, and unit, assembly, and subassembly schematic diagrams.

Scheduled Maintenance

This chapter contains preventative maintenance procedures and performance test



WARNING

DANGEROUS VOLTAGES ARE PRESENT EVEN THOUGH CONDITIONS OF NOTES A AND B ARE MET.

GENERAL NOTES

A. SWITCHES AND RELAY CONTACTS SHOWN IN STOW MODE OF OPERATION.
B. SWITCHES 83907 AND 85201 ARE SHOWN IN A STOW CONDITION.
C. 83907 IS LOCATED AGAINST THE FRONT PANEL.

PART LOCATION INDEX

Ref Des	Zone	Ref Des	Zone	Ref Des	Zone
B3301A	5A	K3311D	5B	TB2302-A1DC	6C
B3301B	6C	K3311E	4B	TB2303-A2DB	6A
D82214	6B	L3304	7A	TB3115-A1DB	7D
D83914	2B	L3305	6A	TB3115-A1DC	6C
D83920	2B	L4701	1A	TB3115-A1DE	7C

Figure 1-9.—Control diagram.

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instructions to be accomplished on a scheduled basis. NOTE: The scheduled maintenance instructions in this chapter are canceled when PMS is implemented for the appropriate equipment aboard your ship or station.

The sections in this chapter include: the INTRODUCTION, which explains the purpose, scope, and arrangement of the scheduled performance tests and preventive maintenance procedures; the PREVENTIVE MAINTENANCE PROCEDURES, which include the information required to inspect, clean, and lubricate the equipment; and the SCHEDULED PERFORMANCE TESTS, which contain step-by-step procedures necessary to verify that the equipment is operating within standards in all modes of operation.

Corrective Maintenance

This chapter contains the instructions required to remove, repair, adjust, and reinstall the circuit elements and mechanical items. Exploded and sectional views and parts placement diagrams are provided as necessary. Information on the use of special tools and special test equipment are also included.

Alignment

This chapter provides information for the complete alignment of the system or equipment. It includes all inputs, point of input injection, results expected, point of measurement, and test equipment required.

Parts List

This chapter lists and identifies all repair parts including the attaching hardware.

The INTRODUCTION explains the scope and arrangement of the parts list, and includes the models and serial numbers of the equipments covered.

The LIST OF MAJOR UNITS lists the units comprising the equipment. The units are listed by unit numbers in numerical order.

The PARTS LISTS are divided and arranged by major units in numerical sequence. Maintenance parts for each unit are listed alphanumerically and are widely used following the unit designation, for example:

Unit (Cabinet parts)	1 1AT1 1B1 1C1 1CR1 1R1 etc.
Assembly (Assembly parts)	1A1 1A1AT1 1A1B1 1A1C1 1A1CR1 1A1R1 etc.
Subassembly (Subassembly parts)	1A1A1 1A1A1AT1 1A1A1B1 1A1A1C1 1A1A1CR1 1A1A1R1 etc.
Unit	2 etc.

The LIST OF MANUFACTURERS contains the names, addresses, and code symbols of all manufacturers supplying equipment.

Security Classification

The security classification of the technical manual is printed at the top and bottom of the front and back covers and the title page. If the manual is classified (confidential, secret, etc.) the classification is also printed at the top and bottom of every page in the manual, in accordance with OPNAV Instruction 5510.1 series.

CHANGES

Changes in equipment design, alignment procedures, and maintenance procedures will require that the technical manual be changed to keep pace.

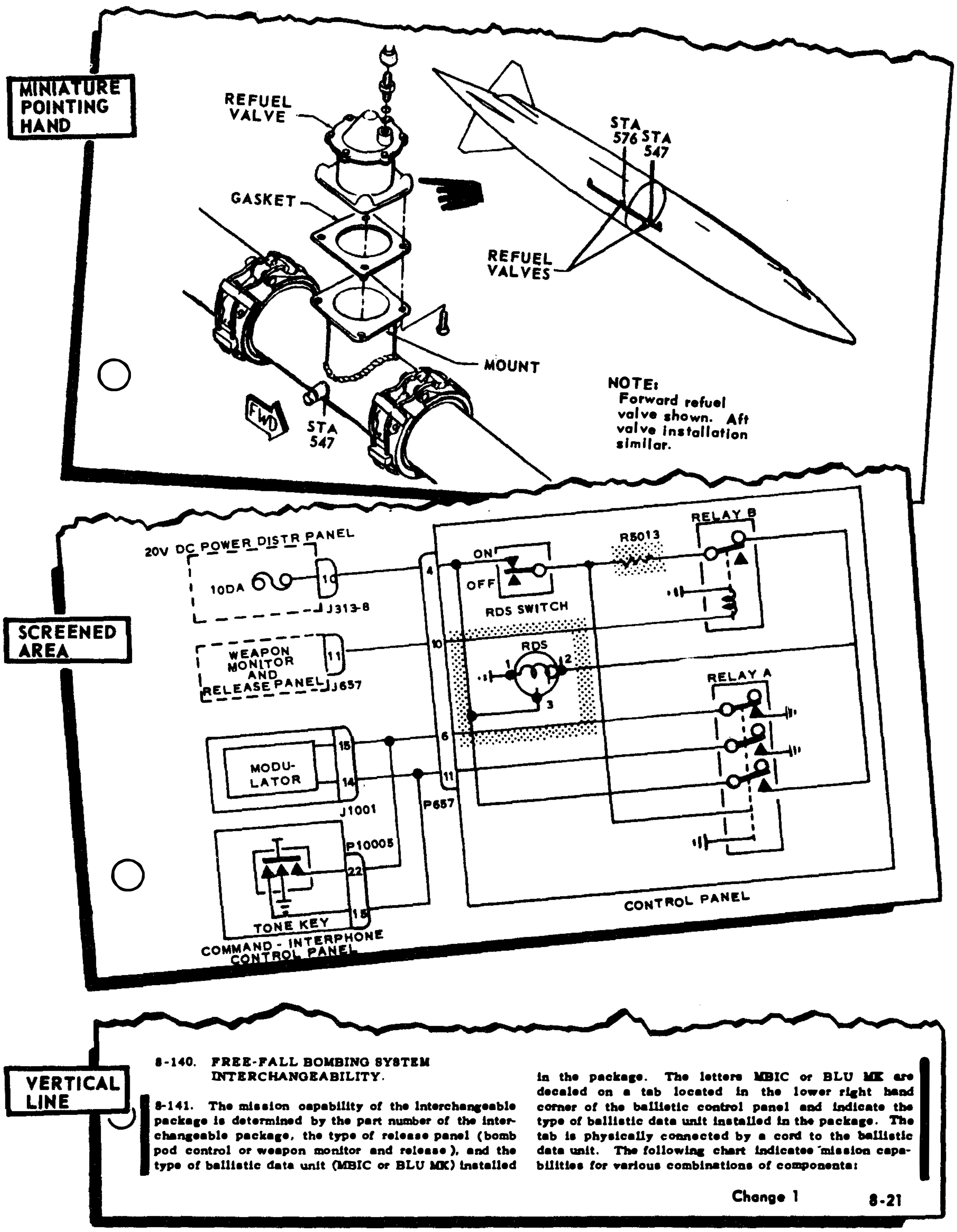

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Figure 1-12.—Sample of change symbols.

There are two types of changes: temporary changes which are often listed in the EIB and major changes which are issued by the command in charge of the equipment or by the manufacturer. These changes consist of various types: pen and ink, where the technician writes in the change; paste in, where a new item is placed over the old item; and complete pages, where the old page is removed from the book and the new pages are inserted.

New pages will frequently have the changed section marked by a symbol. Refer to figure 1-12 for an example of these symbols.

The miniature pointing hand denotes the changed part on a pictorial diagram. The screened area encloses a changed circuit or part on a schematic diagram. Vertical lines enclose changes in the text.

All corrections and changes must be made in the manuals. If corrections are not made, much time may be lost in attempting to repair an equipment by use of an obsolete schematic diagram. Upon completion of the change, the Change Record in the Front Matter must be filled in to indicate that the manual has been updated. The CHANGE INSTRUCTION (fig. 1-13) explains the purpose of the change, the coverage of the change, specific instructions for the insertion of the change, and the effective date of the change. After the changes have been made to the manual, the change instruction is inserted in the manual immediately behind the front cover, and before all previous changes.

SIMM MANUALS

Although the SIMM manual (fig. 1-1) is prepared to fulfill the same purpose as conventional manuals, it is constructed differently and uses different methods of organizing and presenting the information. The SIMM manual is organized on a functional basis in three major groupings: the hardware group, the major functions group, and the overall equipment function group.

The hardware group (the lowest group) includes all major hardware assemblies. Each of these hardware assemblies is further subdivided into subassemblies. Separate diagrams, text, part location and identification information with related maintenance and troubleshooting data are included for each assembly and subassembly.

The major functions group arranges the assemblies and subassemblies according to major functions such as transmitting, receiving, displaying data, etc.

The highest group ties the major functions together to represent the overall equipment function.

For example, in the case of radio set AN/SRC-20, 21, the hardware group consists of the RF Amplifier (AM-1565/URC), radio set (AN/URC-9), and the Radio Set Control (C-3866/SRC). The major functions group includes the transmitting function, the channel and frequency select function, and the power distribution function. The overall equipment function is a UHF transceiver capable of sending and receiving amplitude modulated voice and CW signals.

The SIMM Manual presents the necessary data for the installation, operation, and maintenance of electronics equipment by the use of various diagrams and charts. These are the blocked schematic, blocked text, precise access block diagram, overall functional block diagram, Maintenance Dependency Chart, and parts data chart.

The Blocked Schematic Diagram

The BLOCKED SCHEMATIC diagram (fig. 1-14) identifies each circuit element (switch, resistor, capacitor) or functional entity (amplifier, oscillator) according to its functional level. This diagram distinguishes between the functions and hardware by using shaded areas of blue and gray. Blue shaded areas indicate functional groupings of components or circuits. Darker shades of blue indicate circuits within the functional circuits. Each area of blue includes all circuit elements that are involved in accomplishing the circuit function. These areas are called functional entities. Gray shaded areas indicate physical packaging of equipment. Darker shades of gray indicate subpackaging within the lighter shades of gray. These shades of blue and gray are not shown in the illustrations used in this manual.

Note in figure 1-14 that the parts that work together to perform a basic function (such as

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Interim Change T-1 NAVSHIPS 0967-173-6011

INSTRUCTION SHEET

Interim Change T-1 to Technical Manual for Teletypewriter Set AN/UGC-16 NAVSHIPS 0967-173-6011 (formerly NAVSHIPS 94104)

General Instructions:

This interim change revises the manual to reflect the equipment changes made by Field Change 5-AN/UGC-16. When this change is included in the manual, the manual shall cover the equipment as though Field Change 5, NAVSHIPS 0967-173-6050, has been accomplished on the equipment. This change does not supersede any other changes or corrections.

Maintenance support activities shall make this change in the technical manual immediately but shall keep the superseded data intact for support of equipments that have not been modified.

Holders of equipment accompanied by technical manuals shall not make this change in the manual until accomplishment of the field change referenced above.

Insert this interim change in the manual immediately after the front cover preceding the title page, prior changes, or interim corrections in effect.

Specific Instructions:

1. Remove the following pages and insert the corrected T-1 pages:

REMOVE	INSERT
8-16	8-16 T-1
8-18	8-18 T-1

2. Add the following page:

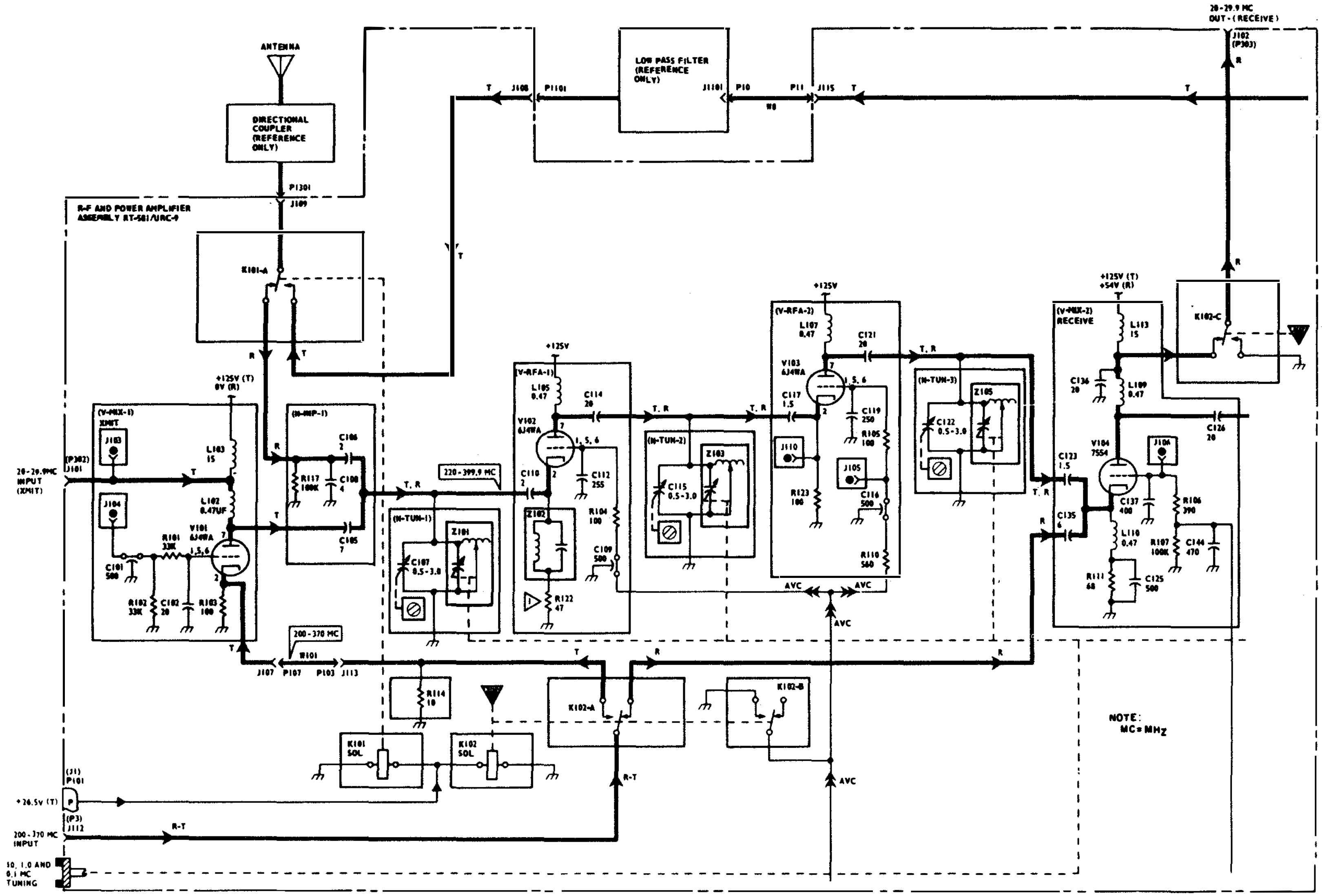
Insert 6-2A between pages 6-2 and 6-3.

DATED: 1 July 1969

UNCLASSIFIED

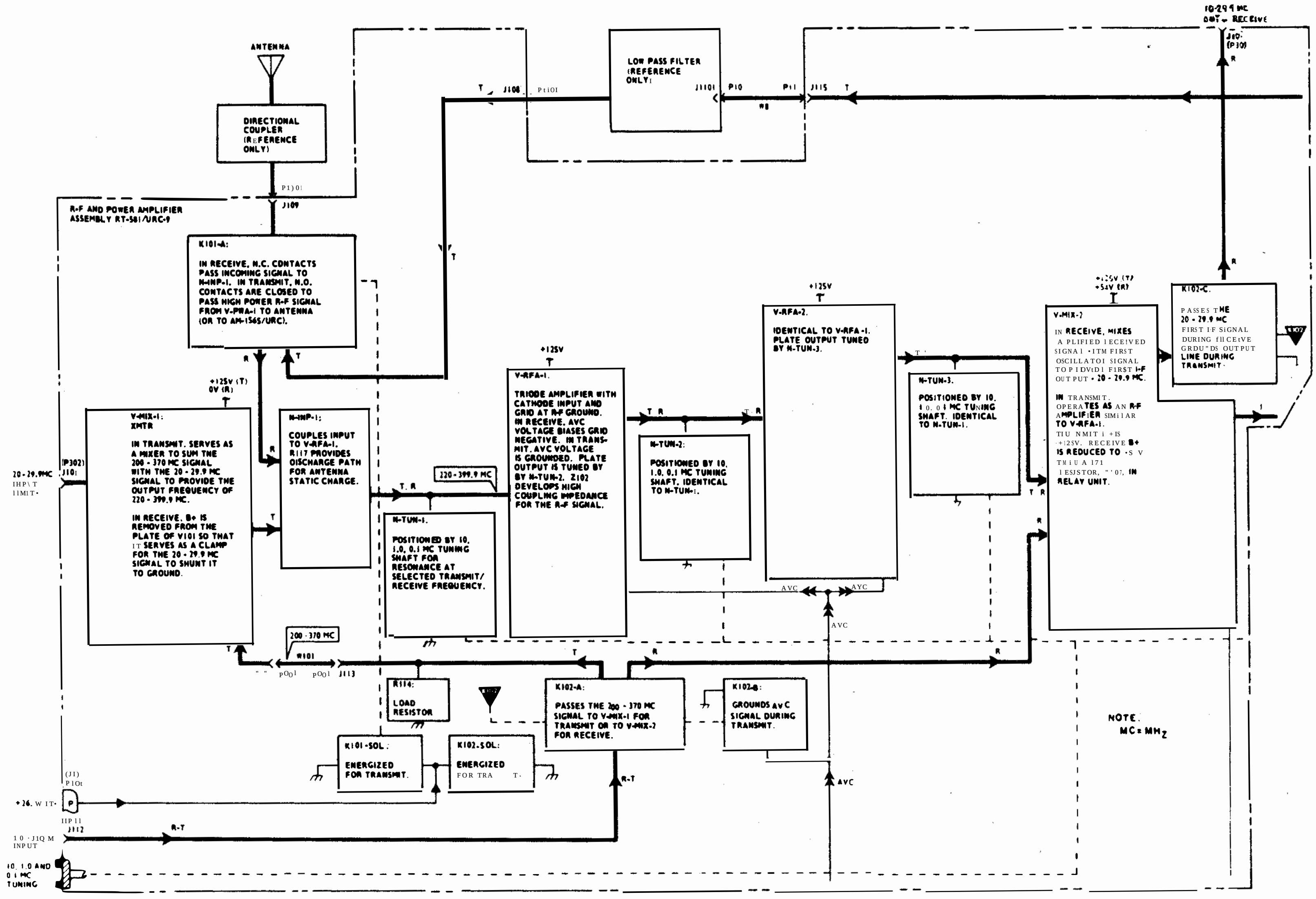
162.150

Figure 1-13.—Sample of instruction sheet of temporary and permanent changes.



162.151

Figure 1-14.—Blocked schematic.



162.152

Figure 1-15.—Blocked text.

amplifying, generating, gating, etc.) are blocked together. These blocks are shaded and coded with a mnemonic code which ties them to the identical blocks on other diagrams. The mnemonic code is an aid placed in the shaded area. Figure 1-14 shows this code located in the upper left of the block in parentheses. The code is used as an aid to the memory. This allows the technician to readily determine precisely what parts work together to perform a particular function. This is a marked improvement over the schematics in conventionally prepared manuals in which the parts that work together are, in many cases, not readily apparent. The technician, in this case, has to rely on his training, experience, and knowledge of the equipment to find the parts that work together.

The Blocked Text Diagram

The BLOCKED TEXT diagram (fig. 1-15) is blocked off and shaded identically to the respective blocked schematic diagram. In lieu of parts in the blocks, however, the blocked text describes what action takes place within the particular block.

Precise Access Block Diagram

The PRECISE ACCESS BLOCK diagram (PABD, fig. 1-16) shows all the circuits and hardware assemblies that make up a major function. It identifies the assemblies and depicts the nature and direction of signal flow through the assemblies. Shading is done in the same manner as on the blocked schematic. The PABD also serves as an interconnection diagram, as the signal paths are shown as they pass in and out of each assembly, drawer, and cabinet.

In order to present the various functional entities that make up a major function on a single page, the PABD uses three basic symbols: the triangle, trapezoid, and square.

The triangle represents a circuit that changes the voltage or power level of an incoming signal such as voltage or power amplifiers, cathode followers, etc. These circuits always contain active elements.

The trapezoid depicts a circuit which generates a signal or processes an incoming signal in some manner other than a changing voltage or power level. Examples are oscillators, multivibrators, and mixers. These circuits always contain one or more elements which may be active (electron tube or transistor) or passive (semiconductor diode).

The rectangle represents a circuit that is made up of purely passive elements, such as resistors, capacitors, and inductors.

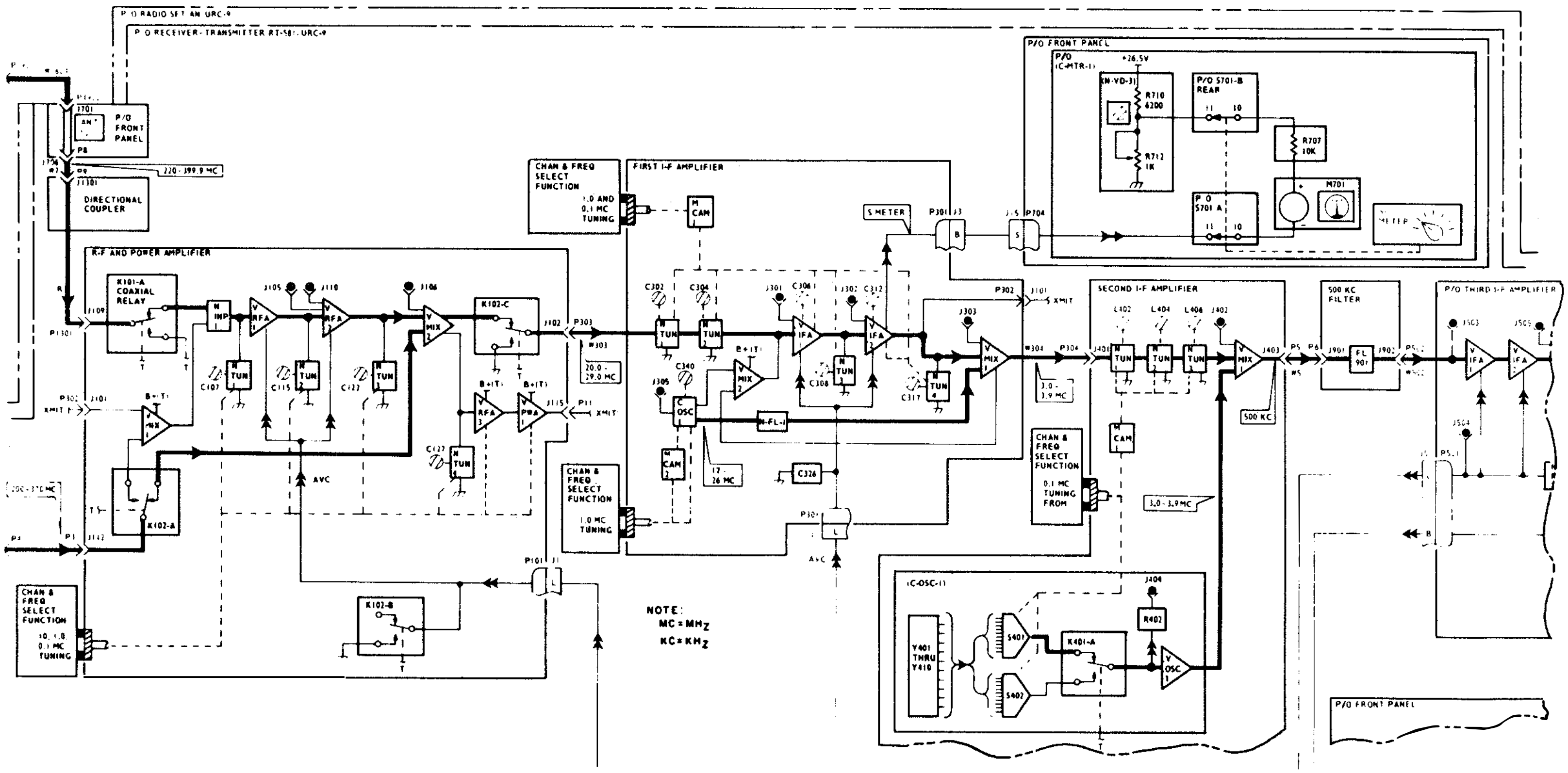
Like the blocked schematic, the PABD is augmented by an identically blocked and shaded facing page of blocked text (fig. 1-17).

Overall Block Diagram

The OVERALL BLOCK diagram (fig. 1-18) shows and describes the relationships between the major functions, thus presenting the overall equipment function. The SIMM overall block diagram differs from those in the conventional manuals in that the SIMM diagram shows cable connections, intraconnections, and graphic representations of certain controls and electronic parts. The function relating to each block is included in the block and shaded gray. Again, the relationship of the gray functional blocks to the hardware is shown by the blue of the hardware area.

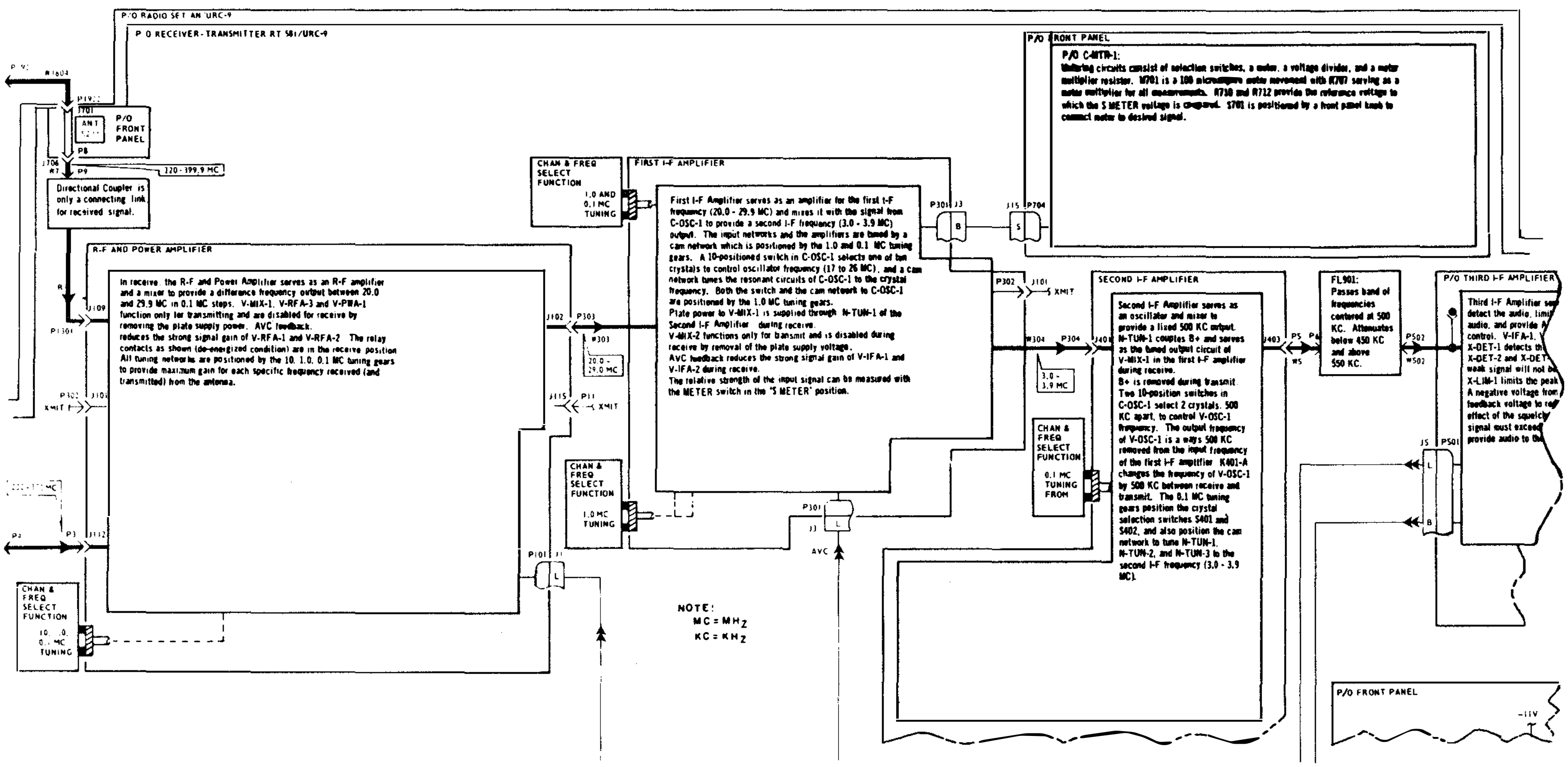
Maintenance Dependency Chart

The SIMM manual uses a new approach to the task of troubleshooting. By analogy, if a lamp is to light (Event), its switch must work, and it must be connected to a 115-V a.c. receptacle. In the simplest form of SIMM language, this analogy and its equivalent equipment statement, "if a specified source of energy is available, and a particular functional part is working, an event will occur," can be shown by the SIMM expression of a rectangle,



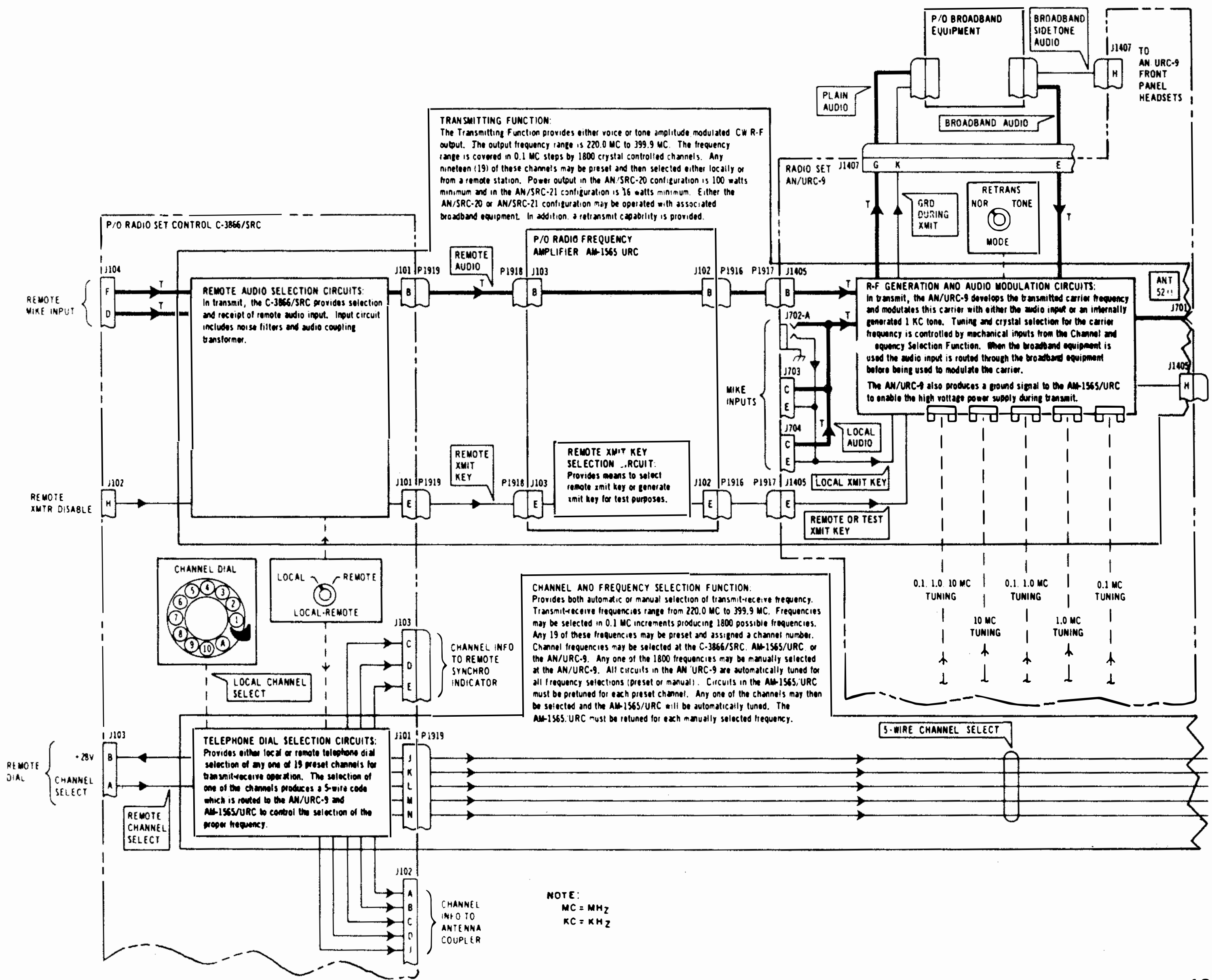
162.153

Figure 1-16.—Precise access block diagram (PABD).



162.154

Figure 1-17.—Precise access block diagram text.



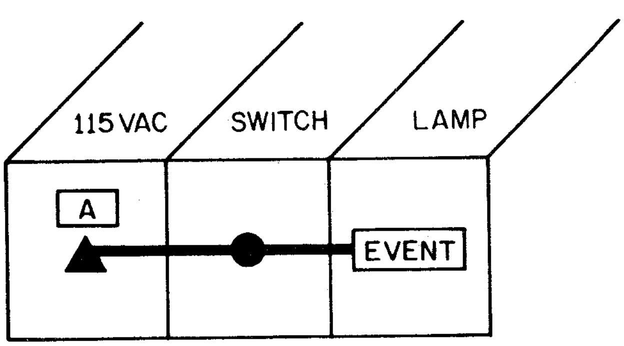
162.155

Figure 1-18.—Overall block diagram.

dependency triangle, dot, and rectangle connected in series as shown in figure 1-19.

The dependency triangle, the dot, and the rectangle are the basic symbols used in the SIMM approach to troubleshooting. They represent dependency upon the functional part or circuit, and event, respectively. Every piece of equipment in its normal operation has many events. Many of these events are determined by the particular mode of operation or switch position the equipment operator selects. Each event depends upon a source of energy or the normal occurrence of another event in addition to the normal operation of a part, a circuit, or a series of parts or circuits. Often, one part or circuit might be involved in the occurrence of more than one event. In practice, the technician is taught to troubleshoot by looking for the fault between the last good event and the first bad event. The entire relationship between an equipment's operation, its event, its functioning parts and circuits, and the dependencies which make the events occur are presented on a Maintenance Dependency Chart.

The MAINTENANCE DEPENDENCY CHART (fig. 1-20) is a symbolic representation of signal flow through the equipment. The chart presents events, as they occur, in a scheme that points out the interdependent relationship between the functional entities in the equipment, with the dependency relationship clearly outlined. The format used combines turn-on and checkout procedures with fault



162.156

Figure 1-19.—Simplified Maintenance Dependency Chart.

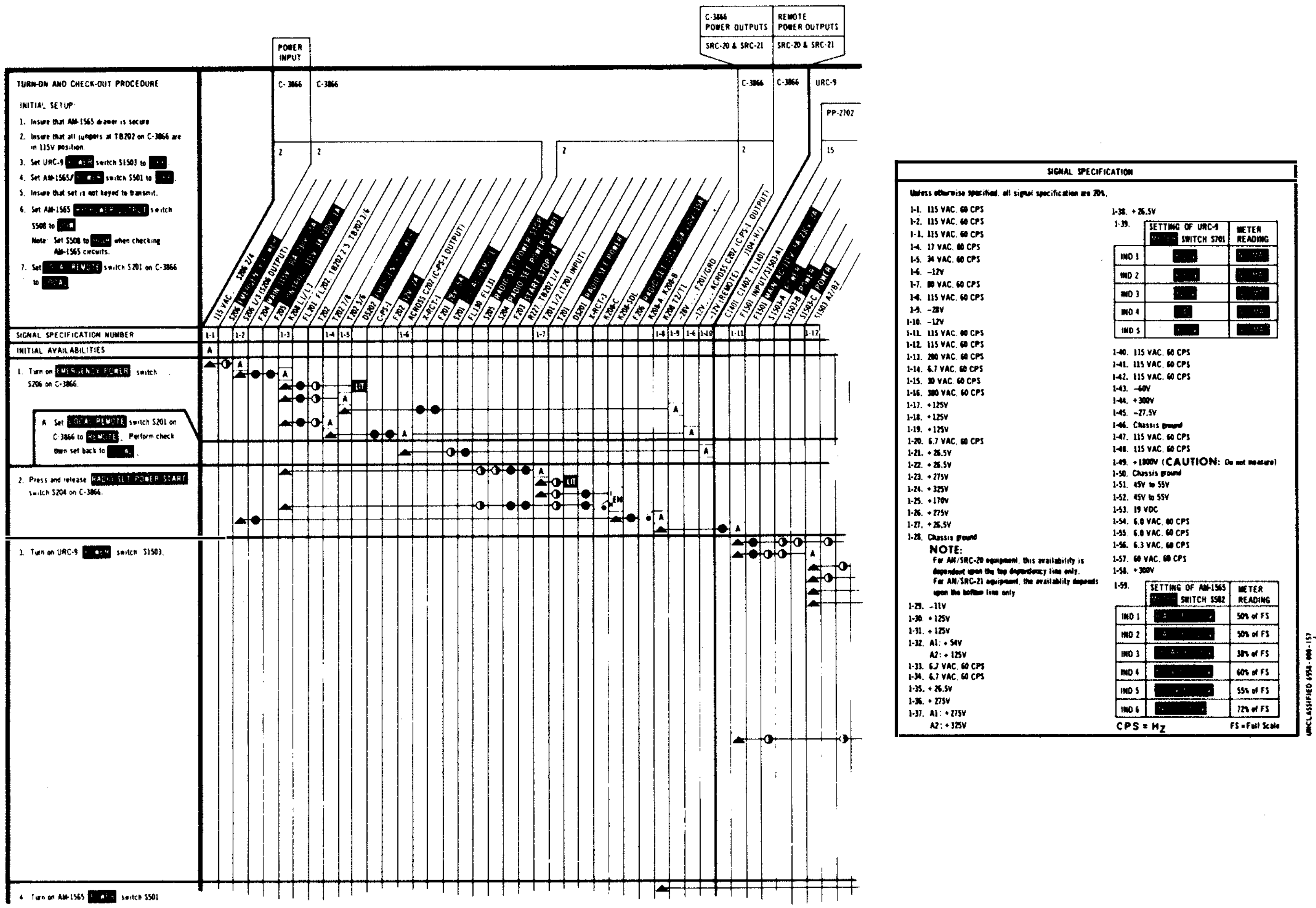
isolation. Through the use of the chart, fault isolation may be obtained at any level down to the circuit stage. The chart then provides direct access to a schematic for a detailed diagnosis or to a component replacement procedures. The chart is composed of four parts: the procedure column (on the left), the heading (across the top), the body, and the notes and specifications (on the right).

The procedures column specifies the operator actions required to turn on and check out the equipment. The turn-on procedure must be performed in the order given, top to bottom, since each step is dependent upon the proper execution of the preceding step. The checkout steps, indicated by the lettered steps within the numbered step (as shown by letter A in step 1 of fig. 2-20), provide a means of checking portions of the equipment that are not checked out under normal operating conditions.

Checkout steps need not be performed, and it is not necessary to perform them in any sequence. However, if they are performed, they must be performed with the equipment set up for the proper turn-on steps, i.e., if checkout step A is performed, it is necessary to complete turn-on steps 1 through 3. Checkout steps may also provide a means of exercising certain self-test features of the equipment.

The heading (fig. 1-20) uses alphanumeric or symbol designators to identify the action indicators, available test points, circuit elements, functional entities, and functional devices, i.e., P1307-A/B, K10-A, T1. The physical location of the indicators or entities is identified at the top of the column heading, including a reference to the schematics. Indicators that are recognizable from outside the equipment (front panel indicators, front panel test points) are shown in solid black background with white lettering. The signal specification numbers, located in the box at the base of the column heading are keyed to the notes and specifications located to the right of the chart. The signal specification number references the specification or description of an event that should be present at the check point.

The body of the chart contains symbols that are divided into three general categories: Events, Dependencies, and Function Symbols.



162.157

Figure 1-20.—Maintenance Dependency Chart (MDC).

An event is either an action that can be detected by sight or sound (a motor running, lamp lighting, meter indicating) or is an availability of a signal that can be determined by a measurement. As shown in figure 1-19, the Action Event symbol is a rectangular area which encloses an indication of the action. There are three types of Action Event symbols used to represent the degree to which the event is accessible: (1) External, (2) Internal, and (3) Indirect.

LIT A front panel indicator or an event recognizable from outside the cabinet. (black background)

LIT Internal test points that are readily accessible. (gray background)

EN A circuit point at which a measurement might at some time be made. This point is not necessarily readily accessible. (white background)

Abbreviations used to indicate Action Events are listed below:

- EN —Energized (Relay and Contactors)
- LIT —Lighted (Lights, Filaments, VR Tubes)
- RUN —Run (A motor is operating.)
- TD —Time Delay (A time-delay sequence is initiated.)
- IND —Indication (A meter is energized and is displaying a voltage or current.)
- OUT —Lamp is not Lit.
- NA —Not Available (A specified voltage, current, or signal is not available.)
- DE —De-energized (A relay is de-energized.)

The Availability Event symbol is a rectangular area with the letter A inside as shown below. The "A" denotes Availability and indicates that a voltage, signal or other data is present at a specified value. The Availability symbol represents a special type of event that requires an externally applied multimeter or oscilloscope or other test equipment to determine if the proper voltage or signal is available.

A

Availability Event Symbol

This symbol is used to show the technician where in the circuit he can expect a voltage, current, or waveform to exist to prove that an event has happened elsewhere or that events should be happening which are dependent upon a signal at the particular point of availability. The background shading of this symbol also indicates the accessibility of the point in the equipment.

The Dependency symbol is a black triangle as shown below.

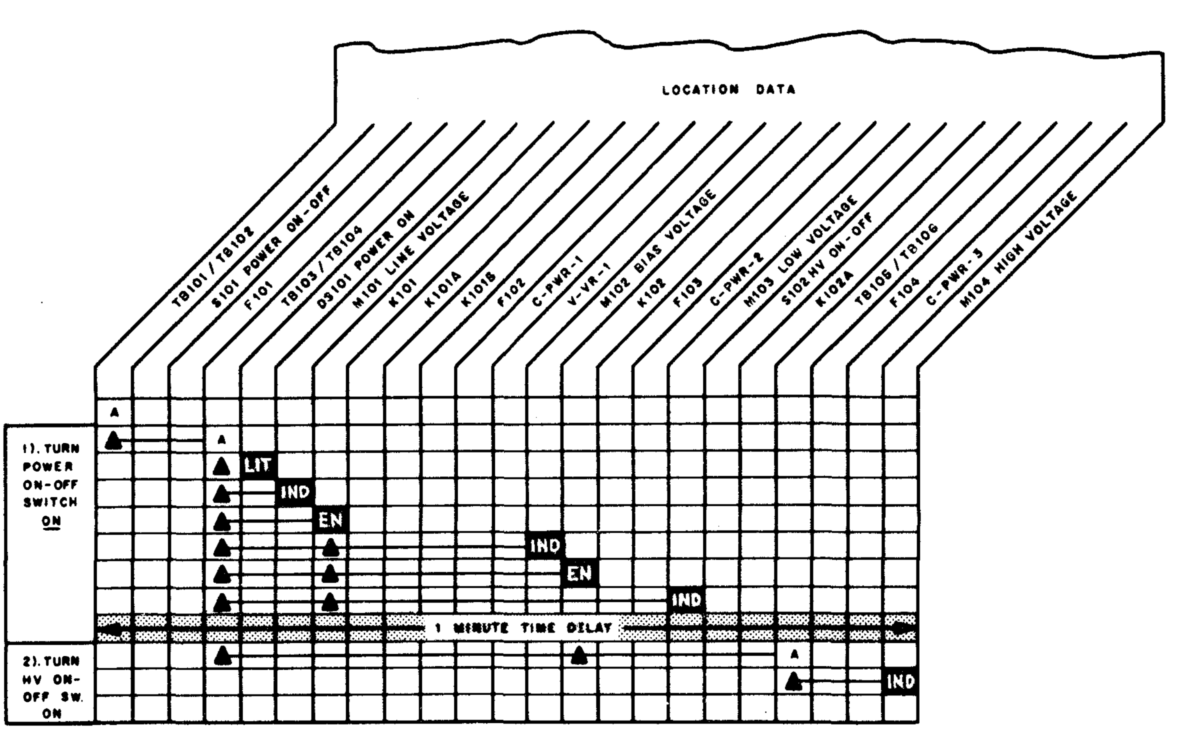
▲

Dependency Symbol

The black triangle means that the event on the same horizontal line is dependent upon occurrence of the Action or Signal Availability Event directly above the triangle in the same vertical column.

The Dependency symbol is used to show dependency on the Maintenance Dependency Chart. It is not an EVENT symbol but shows the dependency relationships between series or parallel circuit branches. The Dependency symbol is the only symbol that shows connection or relationship in the vertical direction. Figure 1-21 shows the Action Event, Availability Event, and Dependency symbols on a Maintenance Dependency Chart.

Function symbols represent a circuit or a circuit element and are identified at the top of the vertical column. These symbols are used to show relationship and connecting links between other symbols along a horizontal circuit path. The symbols take several forms to describe different conditions but the circuit elements they represent must be operating properly or be "good" before any action on the line can occur. Such symbols represent fuses, relay contacts, power supplies, switches and circuit breakers,



162.158

Figure 1-21.—Action Event, Availability Event, and Dependency symbols on the MDC.

oscillator stages, amplifier stages, etc. The Function symbols used in Maintenance Dependency Charts are shown below:

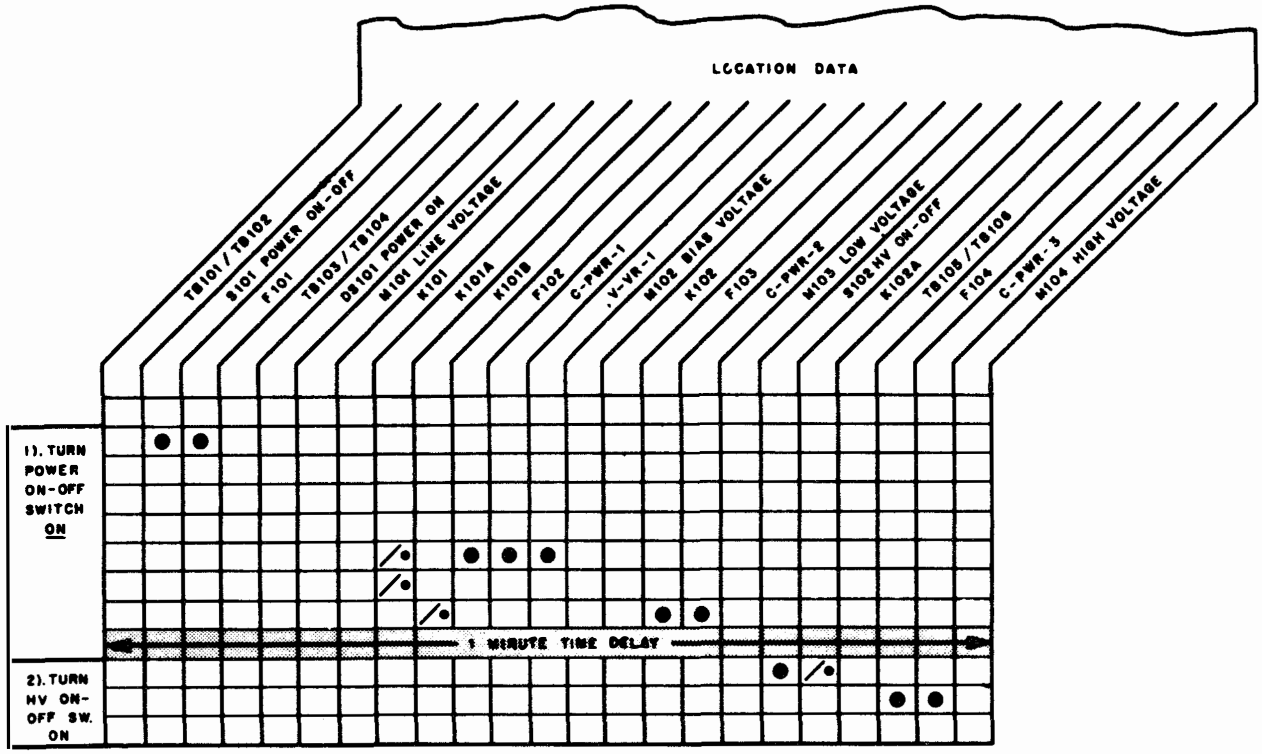
- ● The functional entity or circuit element shown in the column heading above the symbol must be "good" for an Action or an Availability Event shown on the same horizontal line to occur.
- /● The relay contacts provide continuity only when the relay coil is energized.
- ●/ The relay contacts provide continuity only when the relay coil is not energized.
- ◑ One aspect of the circuit or circuit element is proven good by the occurrence of an Action or Availability Event in the same line. (This symbol does not prove a functional entity or a circuit element wholly good.)

Figure 1-22 shows the use of some Function symbols on the Maintenance Dependency Chart.

To use the Maintenance Dependency Chart for troubleshooting, assume that in figure 1-23 black dots (●) represent the basic circuits (oscillator stages, amplifier stages, etc.) or circuit elements (relay contacts, relay coils, switches, etc.) employed to provide an action [LIT] at the end of the event line. The black triangle (▲) is a dependency marker.

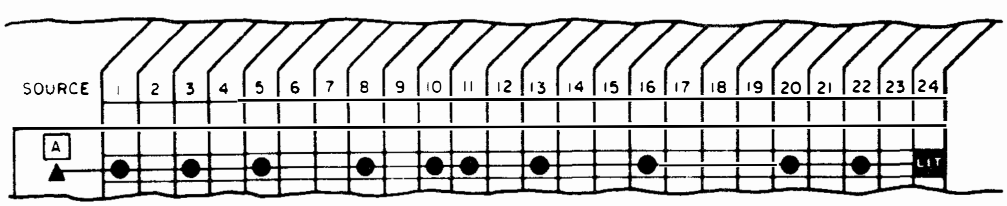
The action [LIT] is dependent upon an availability of a power source at the [A] block and on the proper operation of each of the circuits or circuit elements (●) represented along the event line. If the lamp which indicates the action fails to light, any item along the event line, as well as the source [A], is suspected.

In the case of multiple event lines, many entities listed in the heading are common to more than one event line while others are unique to a single line.



162.159

Figure 1-22.—Function symbols on the MDC.

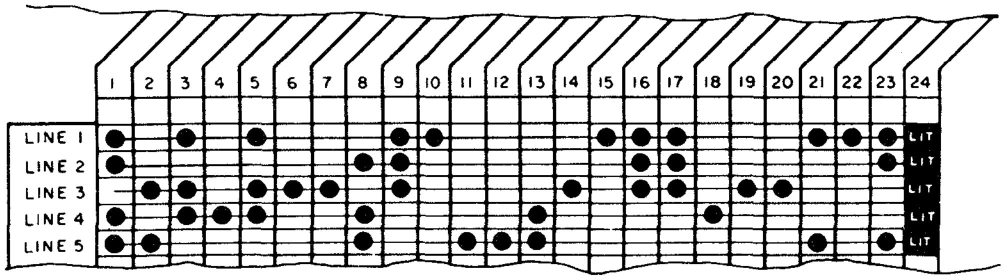


162.160

Figure 1-23.—Single event line.

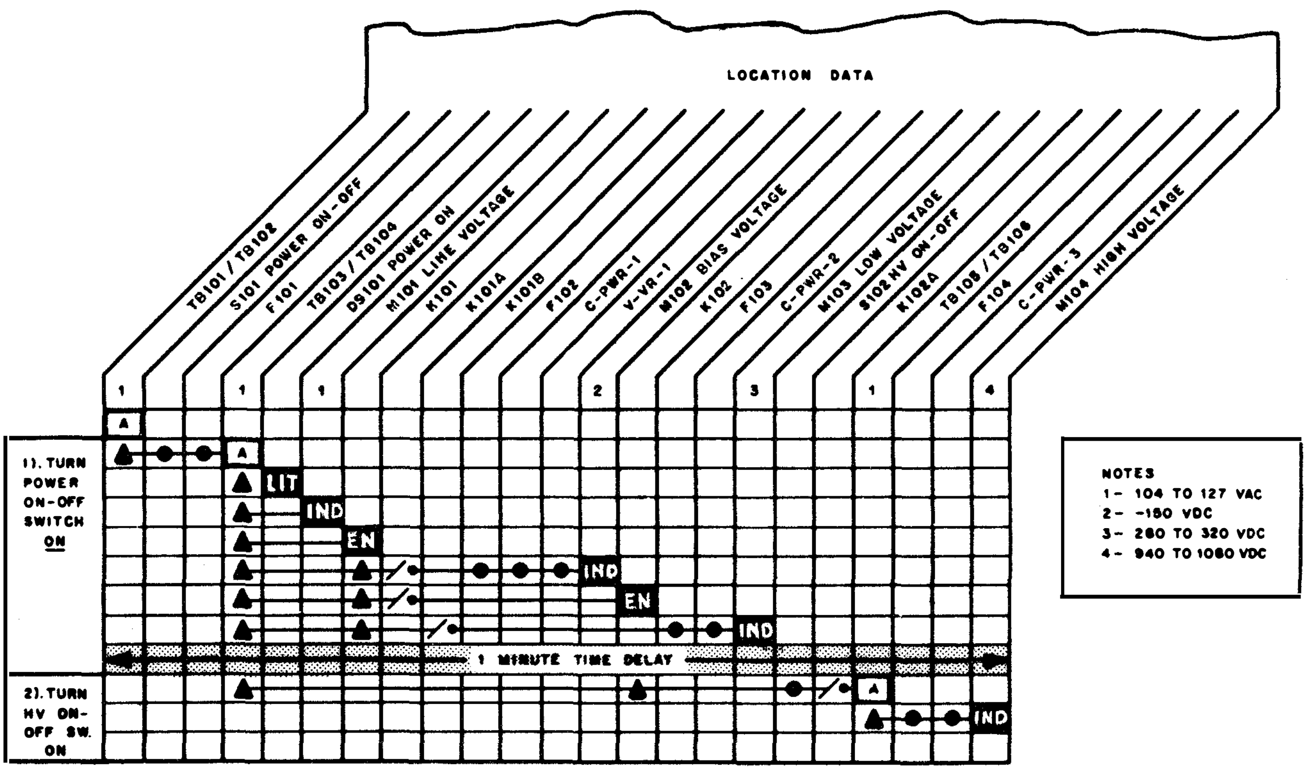
In figure 1-24 assume that the lamp does not light on line 4 but does light on lines 1, 2, 3, and 5. It becomes readily apparent that the circuit and circuit element represented by the black dots in columns 4 and 18 are the only ones that can be suspect as faulty since they are unique to line 4. All items represented by dots in the other columns are common to lines 1, 2, 3, or 5, and are proven good because the indicators at the end of the event line light.

Examination of the Partial Maintenance Dependency Chart in figure 1-25 will show that there are 10 events, which occur as indicated by the white and black rectangles. You will note that there is only one event on each horizontal



162.161

Figure 1-24.—Multiple event lines.



162.162

Figure 1-25.—Partial MDC.

line. The Availability [A] at TB101/TB102 is termed the Input Event, and the other events are dependent events, i.e., dependent upon the Input Event. You will also note that Availabilities are usually specified at important junction points.

To show how this chart reads, the fact that M102 indicates -150 VDC proves:

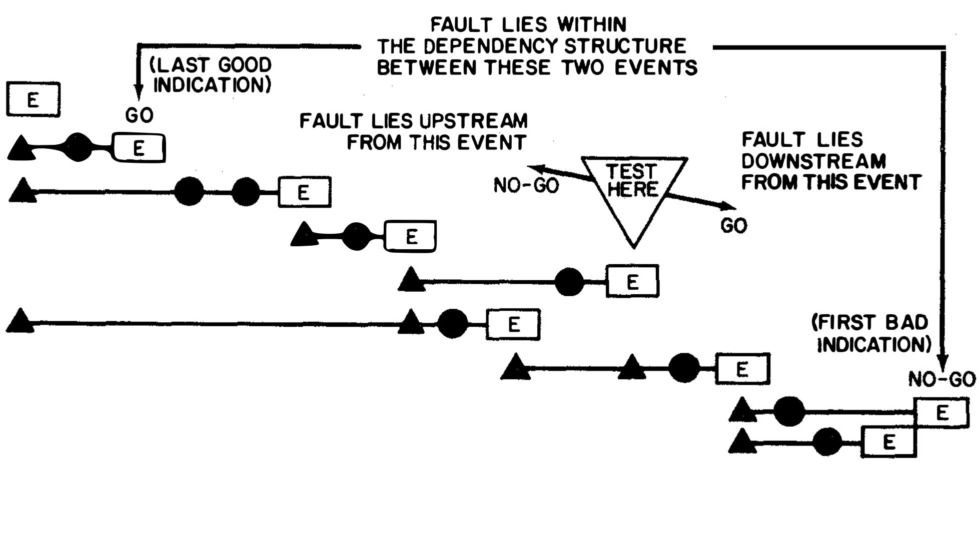
1. V-VR-1 is good.
2. C-PWR-1 is good.
3. F-102 is good.

4. Contacts K101A are providing continuity.
5. K-101 is energized.
6. The correct voltage is available at TB103/104.
7. F101 is good.
8. S101 is good.
9. The input voltage is available.

The chart in figure 1-26 illustrates the fault isolation process on a Maintenance Dependency Chart. The technician simply makes note of the equipment's front panel indicators which have "out-of-spec" indications. The events are then marked for reference, and the first bad indication and the last good indication of the dependency structure are established. The dependency structure between these two events contains the faulty element. To further narrow the area of concern, split-half diagnostics are used. The next event to be tested is located midway within the dependency structure defined by the last good and first bad indications. This event should be chosen for its ease of access as indicated by the Event symbol's background. If the event is GO, the fault lies within the dependency structure downstream from the event. If the event is NO-GO, the fault lies upstream from the event. This procedure is repeated until a single dependency line is isolated whose Input Event is good and whose Output Event is bad. The fault lies on this line, and the functional entity identified by the dot contains the fault.

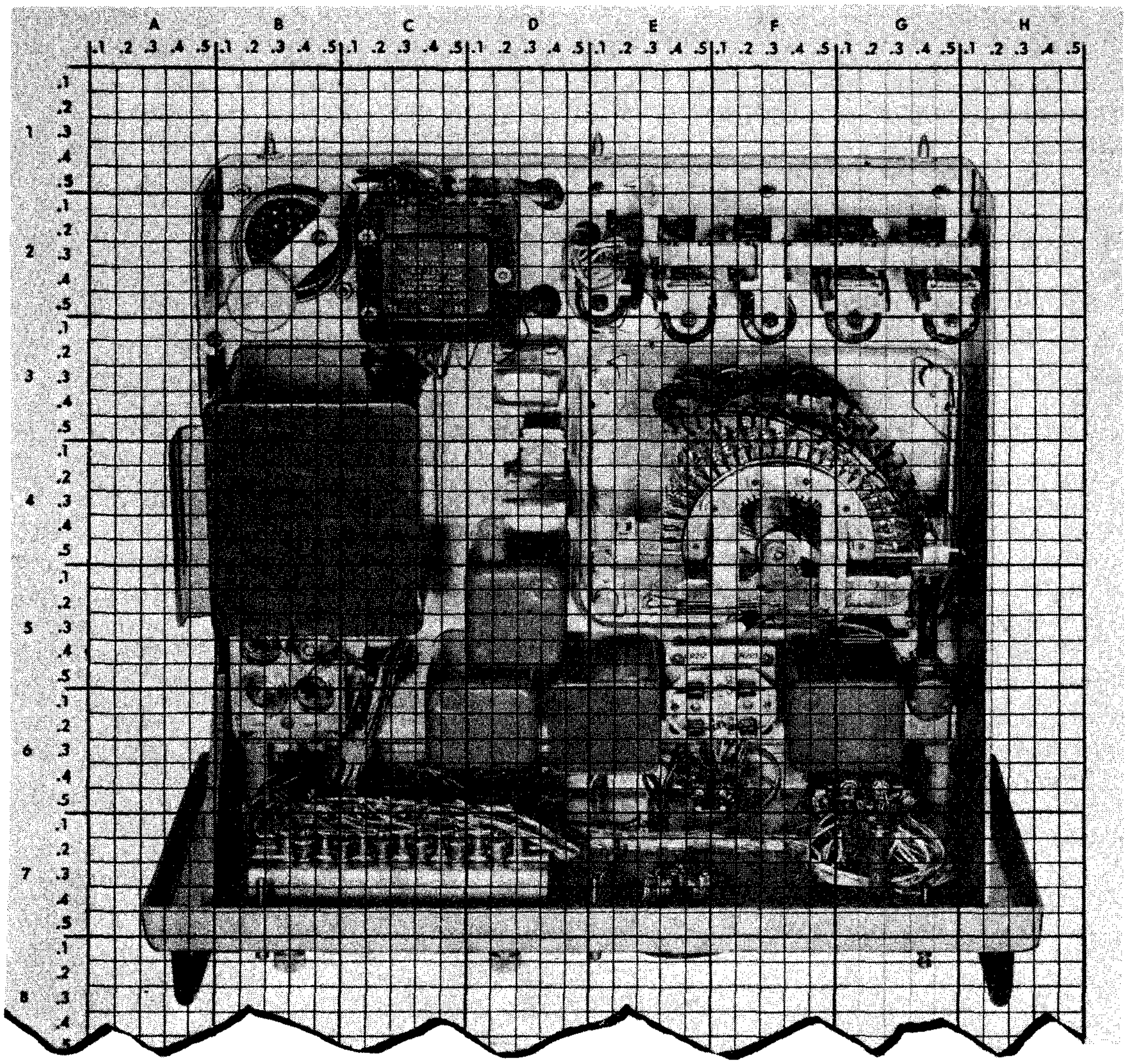
An important rule in using the Maintenance Dependency Charts is—if an event is proven good for one Dependent event, it is proven good for all dependent events. In a like manner, if a functional entity or circuit element has been proven good in connection with an event, then it is good in connection with all other events with which it is associated.

Isolation of a faulty functional entity or circuit element alone is important; also, knowledge of the physical location of the suspected circuit is important. Accordingly, along the top of the Maintenance Dependency Chart the assembly and the cabinetry in which the suspect circuit or circuit element is located is also indicated. Information and details on the suspect circuit or element can be readily ascertained by using the Functional Index to locate the data package for the assembly containing the suspect item. The suspect item's location can be determined (insofar as the assembly and cabinet are concerned) from the Maintenance Dependency Chart. Knowing the piece of hardware in which the assembly and its suspect items is contained, one can find all



162.163

Figure 1-26.—Fault isolation.



SLIDE MOUNTED ASSEMBLY

REF DESIG	LOCATING COORD	NAME AND DESCRIPTION	REF DESIG
C201	C.2/5.3	CAPACITOR, SPRAGUE ELECTRONIC CO. PART NO. 186P10504T15	R216
C202	D.3/4.4	CAPACITOR, MIL TYPE CL53CF132UP3	R217
C203	D.3/3.3	CAPACITOR, MIL TYPE CL53CF132UP3	R218
			R219
CR201	F.2/6.1	DIODE, MIL TYPE IN538	R220
CR202	F.2/6.2	DIODE, MIL TYPE IN538	R221
CR203	E.5/6.1	DIODE, MIL TYPE IN538	R222
CR204	E.5/6.2	DIODE, MIL TYPE IN538	R223
CR205	B.2/6.1	DIODE, MIL TYPE IN249B	R224
CR206	B.2/5.4	DIODE, MIL TYPE IN249B	R225
CR207	B.4/5.4	DIODE, MIL TYPE IN249B	R226
CR208	B.4/6.1 (H)	DIODE, MIL TYPE IN249B	R227
CR209	[illegible]	TYPE IN	

Figure 1-27.—Parts data.

162.164

pertinent data in the assembly data packages listed in the index.

Parts List and Functional Index

Another one of the principal features of SIMM is its method of indexing. Each hardware assembly (unit, major assembly, and subassembly, as required) is fully treated in a four-part data package. All data packages are arranged so that the same type of information is located in the same sequence in every package. Each package includes a parts list and parts location illustrations (fig. 1-27); blocked text; blocked schematic; and related technical maintenance data. All information at the hardware assembly level is provided in four pages or less. Hence, the index for assemblies lists only four page numbers for each assembly. Indexing the higher level PABDs and text, the system block diagram, the functional coverage page, the instructional page (how to use the manual), the maintenance dependency charts, and installation and operation information by page number is the only other requirement. This eliminates the need for long lists of contents, illustrations, and tables. The indexing of an SIMM manual (fig. 1-28) permits the finding of pertinent information in seconds.

Improvements

As this training manual goes to press, various improvements are being made to the SIMM technical manual. Current SIMM manuals will use a keyed-text technique instead of the blocked-text. In the keyed-text, the text material is arranged in tabular format and keyed to the diagram by circled numbers as shown by figure 1-29. This method of presentation permits significantly more text material to be presented than the blocked-text method. In addition to the schematic diagrams, the keyed-text will also be used with the precise access block diagrams (called functional block diagrams), and the overall block diagram (called the functional description diagram).

Another area of the manual to be improved is the Maintenance Dependency Chart. Instead of only one MDC for each major function, future manuals will have additional MDCs for the functional block and schematic diagrams. MDCs will also be provided with an acetate or Mylar overlay so that the technician can use a grease pencil to mark his progress when troubleshooting. Also, the manual will be smaller than the 15″ x 35″ shown in figure 1-1. New SIMM manuals will be 11″ x 27″. This gives them a folded dimension of 9″ x 11″, which is the same size as conventional manuals.

REFERENCE STANDARDS BOOK

The Reference Standards Book includes: (1) Reference Standards Tests, (2) Reference Standards Summary Sheets, and (3) Performance Standards Sheets. When these three items are contained in a single publication, they constitute a Reference Standards Book for a particular equipment or system.

Reference Standards Tests 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 in order to ascertain equipment readiness at any given time. The Reference Standards Tests are accompanied by blank spaces (fig. 1-30) 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 Reference Standards Tests are scheduled on a routine basis such as daily, weekly, and monthly. These tests are superseded and canceled when the PMS (Planned Maintenance System) is implemented. Reference Standards Books are to be retained on board ships, however, even after PMS has been installed, in order that technical data on installed equipments will be available for ready reference.

Two identical Reference Standards Summary Sheets precede the front matter of a newly issued Reference Standards Book. The Reference Standards Summary Sheets provide

FUNCTIONAL INDEX

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Manual Description		3
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Operating Instructions & Turn-on and Checkout Chart		5
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	Receiving Function Blocked Text	8
	Receiving Function Precise Access Block Diagram	9
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	Transmitting and Receiving Functions Maintenance Data	12
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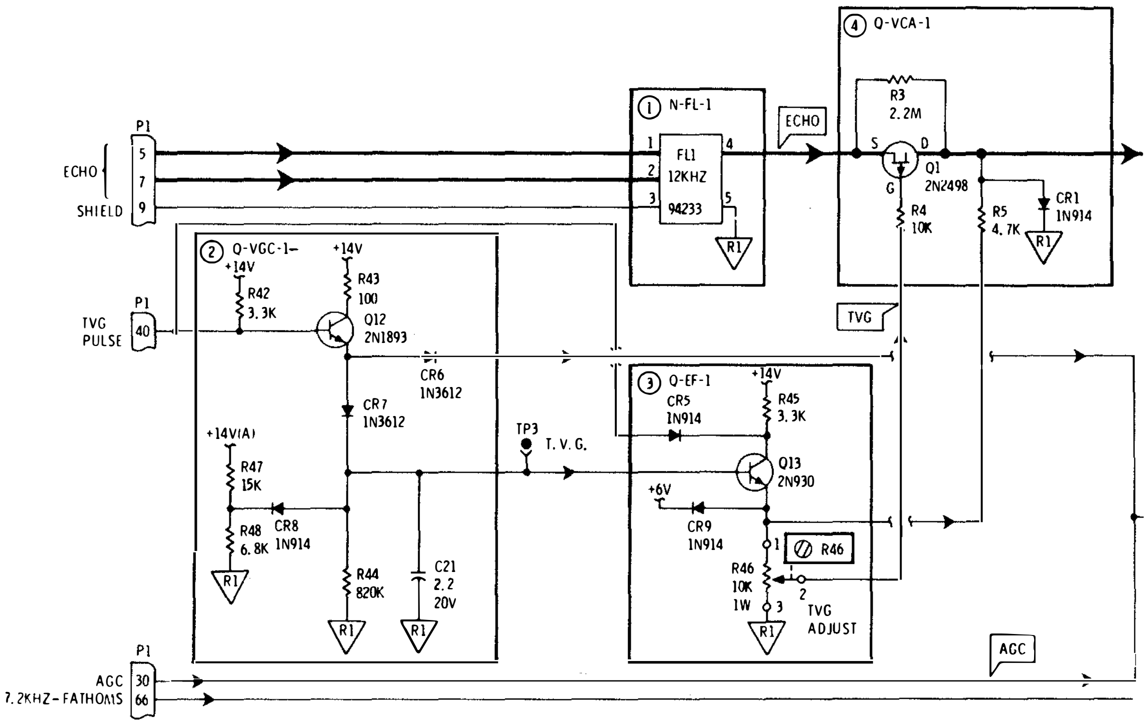
ASSEMBLY DATA

ASSEMBLY NOMENCLATURE	PARTS DATA PAGE	BLOCKED TEXT PAGE	BLOCKED SCHEMATIC PAGE	MAINTENANCE DATA PAGE
Radio Frequency Amplifier AM-1565/URC				
200 Series: Power Amplifier 400 Series: Servo Amplifier	21	22	23	24
500 Series: Front Panel and Autopositioner	25	26	27	28
Radio Set AN/URC-9 (RT-581/URC-9 and PP-2702/URC-9)				
100 Series: R-F and Power Amplifier 200 Series: Frequency Multiplier Oscillator	29	30	31	32
300 Series: First I-F Amplifier 400 Series: Second I-F Amplifier	33	34	35	36
500 Series: Third I-F Amplifier 600 Series: Relay-Filter Assembly	37	38	39	40
700 Series: Front Panel	41	42	43	44
800 Series: Audio Amplifier and Modulator 900 Series: 500 kHz Filter 1000 Series: Centrifugal Fan 1100 Series: Low-Pass Filter	45	46	47	48
1200 Series: Frequency Selector	49	50	51	52
1300 Series: Directional Coupler 1500 Series: Power Supply (PP-2702/URC-9) 1600 Series: Broadband Sidetone Amplifier	53	54	55	56 (Includes URC-9 Intracabling Diagram)
Radio Set Control C-3866/SRC				
100 Series: Case 200 Series: Slide Mounted Assembly	57	58	59	60

*Includes power schematic for AM-1565/URC

162.165

Figure 1-28.—Functional index.

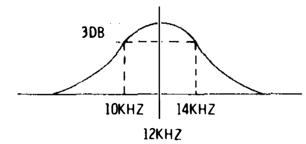


1A4A1 RECEIVER ASSEMBLY

AMPLIFIES THE LOW LEVEL RECEIVED ECHO. CONVERTS THE TVG PULSE (TIME VARIABLE GAIN) INTO A DECREASING EXPONENTIAL VOLTAGE TO BLANK THE RECEIVER AT TRANSMIT TIME AND ALLOW IT TO RECOVER SLOWLY. AGC IS ALSO PROVIDED TO REDUCE THE GAIN OF THE RECEIVER WHEN THE NOISE LEVEL HAS INCREASED (NOISE CAUSED BY RECEIVED ACOUSTIC ENERGY OTHER THAN THE ECHO).

① N-FL-1 FILTER

PROVIDES IMPEDANCE MATCHING BETWEEN THE FILTER IN THE TRANSMIT-RECEIVE NETWORK AND THE INPUT AMPLIFIER. HAS A CENTER FREQUENCY OF 12KHZ WITH A BANDPASS 2KHZ EITHER SIDE OF CENTER (3DB POINTS).



FILTER INPUT IMPEDANCE IS 120 OHMS, OUTPUT IMPEDANCE IS 240 OHMS.

② Q-VGC-1 VOLTAGE GAIN CONTROL

EMITTER FOLLOWER CONFIGURATION. NORMALLY BIASED OFF, CONDUCTS UPON RECEIPT OF TVG PULSE. DIVIDER R47 AND R48 ALONG WITH DIODE CR8 LIMIT THE TVG VOLTAGE AT TP3 TO APPROXIMATELY +3.8V. THE TVG PULSE HAS THE SAME PULSE WIDTH AS THE TRANSMIT PULSE AND IS APPLIED TO C11 THRU CR6.

③ Q-EF-1 EMITTER FOLLOWER

COUPLES TVG PULSE TO Q-VCA-1. AMPLITUDE CONTROLLED BY R46 IN EMITTER CIRCUIT.

④ Q-VCA-1 VOLTAGE CONTROLLED ATTENUATOR

ACTS AS VARIABLE RESISTOR BETWEEN OUTPUT OF N-FL-1 AND INPUT TO Q-AMP-1. PINCHED OFF BY THE POSITIVE TVG VOLTAGE APPLIED TO GATE DURING TRANSMIT TIME.

162.179

Figure 1-29.—Blocked schematic with keyed text.

QUARTERLY STEPS Q1 thru Q8

NAVSHIPS 94715.42

AN/WRR-2, -2A
AN/FRR-59, -59A

OPERATING CONDITIONS AND CONTROL SETTINGS:

Equipment in full operation and conditioned for A1 reception.
O. L. THRES: OFF

STEP NO.	ACTION REQUIRED	READ INDICATION ON	REFERENCE STANDARD
Q1	Record over-all sensitivity of Mode A1 at low end of 2-4 mc band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	*PROCEDURE: Connect signal generator to the ANT IN jack (J957). Adjust generator for a 2-mc unmodulated signal and set output at 5 μv. Set BAND selector to 2-4. Tune receiver to 2 mc and adjust the ANT COMP and HF ADJ controls for maximum indication on the RESONANCE meter. Reduce generator output to zero and adjust RF GAIN for a -2 db indication on the LINE A OUTPUT meter. Set generator output to 5 μv and adjust generator frequency for a maximum indication on the RESONANCE meter. Readjust generator output for a +18 db indication on the LINE A OUTPUT meter. Record the generator output in microvolts.		
Q2	Repeat for high end of band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Tune receiver to 4 mc and repeat step Q1.		
Q3	Record over-all sensitivity of Mode A1 at low end of 4-8 mc band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Set BAND selector to 4-8. Tune receiver to 4 mc and repeat step Q1.		
Q4	Repeat for high end of band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Tune receiver to 8 mc and rcpeat step Q1.		
Q5	Record over-all sensitivity of Mode A1 at low end of 8-16 mc band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Set BAND selector to 8-16. Tune receiver to 8 mc and repeat step Q1.		
Q6	Repeat for high end of band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Tune receiver to 16 mc and repeat step Q1.		
Q7	Record over-all sensitivity of Mode A1 at low end of 16-32 mc band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Set BAND selector to 16-32. Tune receiver to 16 mc and repeat step Q1.		
Q8	Repeat for high end of band.	Signal Generator AN/URM-25	______ μv (1.5 max.)
	PROCEDURE: Tune receiver to 32 mc and repeat step Q1.		

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Figure 1-30.—Sample page from Reference Standards Book (Reference Standards Tests).

blank spaces for maintenance personnel to record the results of all Reference Standards Tests. After the sheets are filled in, one is retained in the book and the second is submitted to NAVSHIPS for evaluation.

A Performance Standards Sheet (fig. 1-31) lists the capability of a particular equipment or system. The sheet also lists the measurements that can be performed to determine if the equipment is operating at its designed capability.

6 April 1972 NAVSHIPS 94715.32 AN/WRR-2, -2A AN/FRR-59, -59A

PERFORMANCE STANDARD SHEET
for
RADIO RECEIVING SETS AN/WRR-2, -2A, AN/FRR-59, -59A

TABLE I - OPERATIONAL PERFORMANCE
The many variables involved, such as radio propagation conditions at the time of the test, power output of the transmitter being received and the type of antenna installation, preclude definitive predictions of operation ranges. To achieve optimum reliable ranges, frequency selection should be made in accordance with DNC-14, as corrected by half-hourly radio propagation predictions given over WWV and WWVH.

NOTE: KC = KHz

TABLE II - STANDARDS FOR EQUIPMENT MEASUREMENT

MEASUREMENT	STEP	STANDARD
Bandwidth (IF, 1.0 KHz)	Q19 and Q20	0.8 KHz min. (at 6 db) 2.4 KHz min. (at 60 db)
Receiver Sensitivity (Sr)	Q1 thru Q8	1.5 μv max.
Performance Figure (PF)*	Calculate	1.5 max.

* PF = Sr (μv)

Total time required to perform Table II measurements - 1 hour.

All steps refer to tests in the Reference Standards Book, NAVSHIPS 94715.42

This Performance Standards Sheet supersedes NAVSHIPS 93550.32

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Figure 1-31.—Performance standards sheet.

A Performance Standards Sheet is used by maintenance personnel to determine the overall operation of an equipment by test results from the Reference Standards Book with the data given on the Performance Standards Sheet. This sheet is usually the first page in a newly issued Reference Standards Book.

NAVAL SHIPS' TECHNICAL MANUAL (CHAPTER-400)

PURPOSE

The purpose of the *Naval Ships' Technical Manual,* Chapter 400, is to provide the major policies and instructions pertaining to the proper handling of electronic work and electronic material under the cognizance or technical control of both the Naval Sea Systems Command (NAVSEA) and Naval Electronic System Command (NAVELEX). Chapter 400 replaced the old Chapter 9670 of the *Naval Ships' Technical Manual.*

SCOPE

Chapter 400 provides major policies and instructions pertaining to maintenance of electronic equipment and safety information aboard active and reserve ships. Subordinate policies and instructions required to implement the policies and instructions of this chapter are contained in the *Electronics Installation and Maintenance Book* (EIMB). The EIMB and other pertinent publications are briefly described in this chapter.

ELECTRONICS INSTALLATION AND MAINTENANCE BOOK (EIMB)

The *Electronics Installation and Maintenance Book* (EIMB) is the medium for collecting, publishing, and distributing, in one convenient documentation source, safety information, maintenance policies and philosophies, installation standards and practices, and overall electronic equipment and material handling procedures required by Chapter 400 of the *Naval Ships' Technical Manual.* The EIMB is organized into a series of individual handbooks as follows.

GENERAL EIMB HANDBOOK

This handbook provides data pertaining to administration, supply, publications, and safety matters, and contains the subject index for information contained in the other handbooks.

INSTALLATION STANDARDS EIMB HANDBOOK

This handbook promulgates approved standards, techniques, and practices for the installation of electronic equipment aboard ships.

ELECTRONIC CIRCUITS EIMB HANDBOOK

This handbook provides the theory of operation and circuit description of basic vacuum tube and semiconductor circuits.

TEST METHODS AND PRACTICES EIMB HANDBOOK

This handbook provides electronic technicians with reference information on the fundamentals of test methods and basic measurements, step-by-step procedures for testing typical electronic circuits and equipment, and functional descriptions of the theory of operation of the test equipment used and circuits tested.

REFERENCE DATA EIMB HANDBOOK

This handbook contains an encyclopedic presentation of useful and informative definitions, abbreviations, formulas, and other general data related to electronic installations and maintenance.

EMI REDUCTION EIMB HANDBOOK

This handbook contains techniques and procedures for the elimination or reduction of electromagnetic interference created by ownforces electromagnetic radiating devices.

GENERAL MAINTENANCE EIMB HANDBOOK

This handbook contains routine maintenance concepts, techniques, and procedures common to all electronic and electrical equipment.

EQUIPMENT-ORIENTED EIMB HANDBOOKS

For the basic equipment category, each of the six handbooks contains: general servicing information; servicing information for specific equipments; a Field Change Identification Guide (FCIG) which provides field change information for all equipments of the basic equipment category; and functional descriptions common to the equipment of the basic equipment category. The six equipment-oriented handbooks are as follows:

1. Communications
2. Radar
3. Sonar
4. Test Equipment
5. Radiac
6. Countermeasures

ELECTRONICS INFORMATION BULLETIN (EIB)

The *Electronics Information Bulletin* (EIB) is a biweekly, authoritative publication containing advance information of field changes, installation techniques, maintenance notes, beneficial suggestions, and technical manual corrections and distribution. Articles of lasting interest are later transcribed into the EIMB. All EIB articles including those under the cognizance of NAVELEX, have been authenticated and are authoritative in nature. Accordingly, reference may be made to a particular issue as the authority for adoption of ideas contained therein.

A library of the EIBs is maintained aboard ship for ready reference to the technician and all new EIBs are normally routed to personnel concerned to insure necessary articles are acted upon by appropriate personnel.

The use of the EIMB and the EIB are great assets to the technician. The information contained in these publications will enable the technicians to stay current with changes to equipment and procedures allowing for a higher degree of professionalism in the performance of their duties.

MAINTENANCE MATERIAL MANAGEMENT SYSTEM

The growing complexity of weapons systems and the advanced age of many ships and their equipment have produced problems in maintaining optimum operational readiness of the fleet. The Maintenance and Material Management (3-M) System is designed to overcome these problems by providing for orderly scheduling and accomplishment of maintenance and for reporting maintenance related information.

Objectives of the 3-M System are to achieve uniform maintenance standards and procedures, effectively utilize available manpower and material, document maintenance requirements and accomplishments, improve maintainability and reliability of equipments and systems, and identify the cost of maintenance in terms of manpower, material, and money and reduce these costs through effective management.

The two principle components of the 3-M System are the Planned Maintenance System and the Maintenance Data Collection System.

PLANNED MAINTENANCE SYSTEM

The Planned Maintenance System (PMS) is the tool used for planning, scheduling, and managing men, material, and time to accomplish required preventive maintenance on shipboard equipment, such as weapons systems, ordnance equipment, machinery, and electrical and electronic systems and components. The PMS defines uniform maintenance standards and prescribes simplified maintenance procedures.

The PMS, when installed, supersedes all previous maintenance systems or programs. If there is a difference between maintenance requirements of the PMS and other technical publications or programs (*NavShips' Technical Manual,* manufacturers' technical manuals, POMSEE, etc.), the Planned Maintenance System requirements take precedence. However, the PMS does not yet cover all shipboard equipment requiring periodic maintenance. Such equipment will continue to be maintained in accordance with existing instructions.

Objectives

Basically, the purpose of the PMS is to standardize maintenance requirements on a fleetwide basis, thereby improving equipment readiness and, consequently, fleet operational readiness. Equipment downtime is reduced to the minimum, as are the costs of maintenance in money and manhours.

Specific objectives of the PMS are as follows:

1. Simplify complex maintenance procedures and make them easily identified and managed.
2. Define preventive maintenance required, schedule and control its performance, describe methods and tools to be used.
3. Provide for the detection and prevention of impending casualties.
4. Forecast and plan material and manpower requirements.
5. Plan and schedule maintenance tasks.
6. Estimate and evaluate material readiness.
7. Detect areas needing improved personnel training and maintenance techniques.

Some of the benefits of the PMS are:

1. Increased Reliability and Economy: The performance of regular planned maintenance improves equipment reliability and achieves economy by reducing the need for major corrective maintenance.
2. Better Planning: The PMS makes possible more efficient programming of work. Changes in ship operating schedules are readily accommodated.
3. Improved Documentation: Simplified records improve maintenance management.
4. Improved Morale: The increased clarity, convenience, and flexibility of the system, along with the reduction in frustrating equipment breakdowns and irregular hours of work, help prevent morale breakdown of maintenance personnel and enhance the feeling of effectiveness on the part of officers and enlisted personnel.
5. Training: The PMS is an excellent aid for on-the-job training and for qualifying personnel in personnel advancement requirements (PARs).

As with most programs, there are limitations to the Planned Maintenance System. The PMS does not automatically produce good results—professional guidance and supervision of inexperienced personnel are essential. The PMS is not a substitute for technical ability—training in corrective maintenance procedures is required. Because of the wide scope of the PMS, occasional errors can be expected.

MAINTENANCE DATA COLLECTION SYSTEM

The Maintenance Data Collection System (MDCS) provides a means for recording information concerning preventive and corrective maintenance actions. Much of the recorded information is in the form of coded data elements which standardize the data and facilitate its processing and use.

Through the MDCS, management personnel of the systems commands are able to gather maintenance information related to equipment reliability, costs of repairs, manhours expended for maintenance, and the quality of parts. This information is used for improving equipment design and logistic support and for preparing annual budgets.

Function

Routine maintenance reporting is accomplished on a multi-purpose form. This form also is used in reporting the completion or deferral of maintenance actions, or to request assistance. Data collected includes initial discovery of a malfunction, cause of the failure, manhours expended to restore the equipment to normal operation, delays incurred, reasons for the delays, repair parts and materials used, and the rate of the person performing the maintenance.

Work center supervisors submit completed documents to the maintenance data collection center (MDCC) daily. MDCC personnel review the documents for accuracy and completeness and forward them to the type commander keypunch activity at least weekly. After keypunching, the data is forwarded to the Maintenance Support Office (MSO). The MSO provides data monthly to requesting activities, such as NavShips, where the data is analyzed to identify maintenance and logistic support problems.

Analyzation of the data provides more accurate accounting of parts costs, manhours, and maintenance deferrals (for lack of necessary parts, need for technical assistance, etc.). Additionally, specific problems are identified and corrective action initiated. A study of the thousands of reports submitted monthly, for example, may reveal the fact that inferior material was used in the manufacture of certain valves, resulting in excessive breakdowns of a particular type of pump. Steps can then be taken to correct the deficiency.

Although the MDCS, utilizing automatic data processing equipment, is a major tool for identifying and correcting fleet maintenance problems, it is dependent upon the accuracy and completeness of submitted reports. Maintenance personnel must actively support and use the MDCS in order to gain all possible benefits from the system.

The 3-M System is covered under OPNAV Instruction 4790.4, which sets the guidelines for the 3-M System. The information is divided into three separate volumes covering specific areas of the system. These volumes are used in the fleet and are readily available to users. The following is a brief description of each volume.

Volume One

This volume is directed to all users as an overall introduction to the 3-M organization including responsibilities, training, and reports available from the system. It also deals specifically with the Planned Maintenance System (PMS). This volume should be used in the preparation of all PMS materials and should be used to clarify any questions about PMS.

Volume Two

Volume two is also directed to all users and contains the information for the Maintenance Data Collection System (MDCS). This volume should be used in the preparation of all documents that pertain to the Maintenance Data Collection System and should be used to clarify any questions about the system.

Volume Three

Volume three contains information pertaining to the Intermediate Maintenance Activity (IMA) Maintenance Management System and is used by those activities supported by an automated data processing facility.

For the preparation of documents and reports these manuals should be consulted and any changes made to the system will be reflected as they become effective.

The PMS and MDCS are discussed in *Military Requirements for PO 3 & 2,* NAVEDTRA 10056-D.

LEVELS OF EQUIPMENT MAINTENANCE

Three levels (or echelons) of equipment maintenance that will be performed within the Navy are prescribed by NAVMATINST 4700.4. The definitions of these three levels of equipment maintenance are included in the following subsections.

ORGANIZATIONAL MAINTENANCE

Organizational maintenance is that maintenance which is the responsibility of and is performed by a using organization on its assigned equipment. Its phases normally consist of the inspecting, servicing, lubricating, adjusting, and replacing of parts, minor assemblies, and subassemblies. This normally includes shipboard maintenance of its own equipment, mobile or portable (van), unit or aircraft squadron maintenance, including scheduled preventive maintenance.

INTERMEDIATE MAINTENANCE

Intermediate maintenance is that maintenance which is the responsibility of and is performed by designated maintenance activities for direct support of using organizations. Its phases normally consist of calibration; repair or replacement of damaged or unserviceable parts, components, or assemblies; the emergency manufacture of non-available parts; and providing technical assistance to using organizations. This normally includes maintenance performed by aircraft carriers, tenders in support of other ships, airwing/group maintenance departments, aircraft maintenance departments, public works centers, public works departments, public works transportation centers, and shore activities officially designated as such.

DEPOT MAINTENANCE

Depot maintenance is that maintenance performed on material requiring major overhaul or a complete rebuild of parts, assemblies, subassemblies, or end items, including the manufacture of parts, modifications, testing, and reclamation as required. Depot maintenance serves to support lower categories of maintenance by providing technical assistance and performing that maintenance beyond their responsibility. Depot maintenance provides stocks of serviceable equipment by using more extensive facilities for repair than are available in lower level maintenance activities. This is normally that maintenance performed by the Naval Air Rework Facilities, Depot Field Teams, Naval Ammunition Depots, Naval Ordnance Stations, Naval Weapons Stations, Naval Torpedo Stations, Naval Construction Battalion Centers, Polaris Missile Facilities, contractor depot level rework activities, and at commercial facilities or Navy Shipyards (including Ship Repair Facilities) during availabilities designated "voyage repairs," restricted, technical, regular overhauls and the like.

PREVENTIVE MAINTENANCE

Preventive maintenance is the systematic accomplishment of actions deemed necessary to reduce or eliminate the occurrence of failures, and prolong the useful life of the equipment. All preventive maintenance actions are grouped into three basic categories: routine maintenance, testing, and adjusting. These categories are discussed briefly in the following subsections; however, a more useful knowledge of preventive maintenance can be acquired by understanding the programs which plan and schedule the routine maintenance, testing, and adjusting of equipment.

ROUTINE MAINTENANCE

Routine maintenance is the application of special procedures of inspection, cleaning, and lubrication of equipment. They are special procedures in that approved and standard methods are employed whenever such maintenance actions are performed. For example, certain approved methods have been developed for the cleaning and lubrication of ball bearings. Whenever a ball bearing requires lubrication, it must first be cleaned using approved methods and solvents, and must then be lubricated with the proper lubricant. Included with the lubricating instructions are lubrication charts which specify approved lubricants and their general usage. Such approved methods are routine in that they apply whenever ball bearings are lubricated and must be accomplished periodically.

Routine inspections include such actions as checking equipment ground straps for loose connections and broken or frayed straps, checking tightness of screws, bolts, and nuts, checking oil reservoirs for the proper quantity of oil, checking front panel indicators and illumination for burned-out bulbs, etc. Inspections of such require direct analysis and judgment by the person performing the check.

A source of routine inspection, cleaning, and lubrication procedures is contained in Section 3 of the General Maintenance EIMB, NAVSHIPS 0967-000-0160.

Testing

Testing of electronic equipment involves the use of calibrated instruments to monitor or record the electrical, mechanical, and chemical properties of functions of the equipment's circuits and other devices for comparison with established standards. By observing the responses and indications of the test instruments, and by comparing the information presented with established standards, it can be determined if the circuit or device is functioning as it should.

The difference between a test, as explained here, and an inspection, as explained in the preceding subsection, is that a test involves the use of an instrument to present information representing a form or function of energy not perceivable by the human senses and which could be hazardous to health. With the information presented by the instrument, a person can then make an examination and analysis. Inspections require direct examination by human senses, normally sight and touch.

Adjusting

Adjusting of electronic equipment is a broad term which encompasses all phases of (1) adjustments to rearrange or change a function or characteristic, (2) circuit alignment which adjusts two or more sections of a circuit or system so their functions are properly synchronized, and (3) circuit calibration by which circuits or instruments of a given accuracy standard are checked against standards of higher accuracy and then aligned or adjusted accordingly. Sometimes other terms (e.g., collimation) are used to indicate special adjusting techniques. Collimation is the precise alignment of the mechanical system of a radar antenna by comparison with an optical device aligned on known points in azimuth and elevation. It also applies to the process of making light rays or the paths of electrons or other particles in a beam parallel to, or concentric with, each other.

ELECTRONIC EQUIPMENT FIELD CHANGES

A Field Change is any modification or alteration made to an electronic equipment after delivery to the government. Recommendations for Field Changes may originate from any of several sources including the fleet, Naval shipyards, contractors, project managers, and equipment engineers.

Field Changes are developed for the purpose of improving performance, operational characteristics, maintenance, reliability, and safety features of equipment. They may be of such a nature as to require minor wiring or mechanical changes to an item of equipment and consist only of instructions for making the change. Other Field Changes may be more extensive, requiring circuit changes and the removal and/or substitution of parts. The nature of each Field Change issued is identified by a type and class designation operational category and an accomplishment priority.

Field Changes are mandatory and are to be accomplished on the equipment affected in accordance with the instructions contained in the Field Change bulletin at the earliest opportunity. Field Changes are issued in kits and are classified as type 1, 2, 3, or 4 as follows:

A type 1 Field Change kit includes all parts, materials, special tools, and instructions required to accomplish the change to the affected equipment and to revise existing equipment nameplates, publications, and charts.

A type 2 Field Change kit contains the instructions to accomplish the Field Change and to correct the related publications. The required parts are not included.

A type 3 Field Change kit includes the instructions to accomplish the change, and some of the parts, materials, and special tools required to accomplish the change and to revise the existing nameplates, publications, and charts.

A type 4 Field Change kit includes the instructions for accomplishing the change and for correcting the related publications. No parts or special tools are required.

Field Changes are further classified as class A, B, or C as follows:

A class A Field Change is a change approved for accomplishment by forces afloat or station personnel. No installation funding is required.

A class B Field Change is a change approved for accomplishment by Naval Shipyards, tenders, and repair facilities, without reference to the cognizant Systems Command, upon allocation of funds by the Type Commander.

A class C Field Change is a change normally requiring shipyard or other industrial assistance for accomplishment, and the cognizant Systems Command is obligated for funding.

When a Field Change is accomplished, record its completion on the Field Change Accomplishment Plate of the equipment affected, and on the appropriate MDCS Maintenance Data Form in accordance with OPNAV 4790.4.

REPORTING THE ACCOMPLISHMENT OF FIELD CHANGES

The accomplishment of a Field Change is considered complete only when the actions listed below have been performed, at which time its accomplishment must then be reported to certain cognizant activities.

1. The Field Change has been installed in the equipment in accordance with the Field Change instructions, and installation accuracy and completion have been verified.
2. The equipment has been tested for proper operation in accordance with the Field Change instructions, and proper operation has been verified.
3. The Field Change number has been stamped on the Field Change Accomplishment Plate located on the equipment.
4. If the Maintenance Data Collection System (MDCS) is implemented, the accomplishment of a Field Change must be reported on the Ship's Maintenance Action Form (2-KILO), OPNAV Form 4790/2K, in accordance with Volume 2 of the *Ship's 3-M Manual,* OPNAVINST 4790.4.

If MDCS is not implemented, notification of cognizant authority is completed by mailing the preaddressed postcard enclosed with the Field Change Bulletin.

ALTERATIONS TO SHIPS AND EQUIPMENT

An alteration to a naval ship is defined as any change in the hull, machinery, equipment, or fittings that involves a change in design, materials, number, location, or relationship of the component parts of an assembly regardless of whether it is undertaken separately from, identical to, or in conjunction with, repairs.

Alterations to naval ships, whether they be promulgated as Ship Alterations (SHIPALTS) or Ordnance Alterations (ORDALTS) by the Naval Sea Systems Command (NAVSEA), Special Project Alterations (SPALTS) by the Project Offices of the Systems Commands or, as designated by the Chief of Naval Material, or as any other Systems Command controlled alteration or modification (except electronic equipment Field Changes), are categorized by one of the following three terms.

Military Alteration

A military alteration is an alteration which changes or improves the operational or military characteristics of a ship.

Technical Alteration

A technical alteration is an alteration which does not affect the operational or military characteristics of a ship. In general, technical alterations concern matters of safety of personnel and equipment and effectiveness of equipment performance.

Alteration-Equivalent-to-Repair

An alteration-equivalent-to-repair (AER) is an alteration which meets one of the following conditions:

- The substitution, without change in design, of different materials which have prior approval of the cognizant Systems Command for similar use and which are available from standard stock.

- The replacement of worn or damaged parts, assemblies, or equipments requiring renewal by those of later and more efficient design previously approved by the cognizant Systems Command.

- The strengthening of parts which require repair or replacement in order to improve reliability of the parts and of the unit, provided no other change in design is involved.

- Minor modifications involving no significant changes in design or functioning of equipment, but considered essential to eliminate recurrence of unsatisfactory conditions.

AUTHORITY FOR THE APPROVAL AND AUTHORIZATION OF ALTERATIONS

The word "approve" used in connection with an alteration indicates an action of approval of a proposed change. Promulgation of an approved alteration constitutes authority to expend design resources to plan for the accomplishment, but does not constitute authority to procure material or accomplish the alteration. The word "authorize" is used to signify permission to proceed with the installation and the granting of funds for a particular ship during a particular availability.

Alterations affecting the military characteristics of a ship (i.e., military alterations) may be approved only by the Chief of Naval Operations who shall establish the priority for the accomplishment of such alterations by the Systems Commands concerned.

Alterations not affecting the military characteristics of a ship (i.e., technical alterations) may be approved and authorized for accomplishment by the Systems Command concerned without reference to the Chief of Naval Operations.

Alterations-equivalent-to-repairs may be approved and authorized for accomplishment by fleet type commanders to the extent that such authority has been delegated to them by the Systems Commands concerned.

SUPPLY

Although the supply department is responsible for supplies, the technician needs to know how to identify what is needed, how to write out the request, and how to report on the use of the supplies. The publications containing the stock numbers are maintained in the supply department; therefore, cooperation with supply personnel is essential in accomplishing assigned duties.

SUPPLY REQUISITION FORMS

Documenting material usage and cost data on maintenance transactions requires the joint effort of the ship's supply and maintenance personnel. NAVSUP Form 1250 and DD Form 1348 (discussed in *Military Requirements for PO 3 & 2,* NAVEDTRA 10056-D and Volume 2 of OPNAV 4790.4) are the source documents used to record material usage and cost data in support of maintenance actions. Supply personnel are expected to assist maintenance personnel whenever difficult or unusual documentation problems arise. Issues of materials which do not directly involve a maintenance action or minor consumables will not be reported in the MDCS.

When a repair part is needed before a specific maintenance action can be completed, the maintenance personnel aboard a non-mechanized ship use NAVSUP Form 1250 to request the issue of the part from the ship's supply department. Supply personnel issue the part, if it is in stock aboard ship. If it is not in stock, the information on the form is used by supply to order the part from off-ship sources.

When a repair part is required to complete a specific maintenance action aboard a mechanized ship, the maintenance personnel use DD Form 1348.

After appropriate action has been taken by the supply personnel, the requesting maintenance personnel receive a copy of the supply request along with the material. In cases where the material is not available on board, the supply document is marked NIS (not in stock) or NC (not carried), as appropriate, and the supply personnel take appropriate action to obtain the requested material.

There are numerous publications used with the supply system for the requisition of parts and tools and a knowledge of these is required to use the system to its full capability. These publications are discussed in *Military Requirements for PO 3 & 2,* NAVEDTRA 10056-D.

MANDATORY TURN-IN REPAIRABLES

Some of the repair parts used today are mandatory turn-in items. These parts are sent to a repair facility for repairs that are normally beyond the capabilities of the ship's force. When this is required, the supply system transports the broken repair part to the repair facility for repair.

Repair personnel will no doubt encounter the terms "mandatory turn-ins" and "repairables" in the process of obtaining replacement parts from supply. It will be helpful to understand the purpose of the program and the responsibilities of the repair personnel.

When any of the equipment fails, the technician's primary concern is to locate the trouble, correct it, and get the equipment "back on the line." In most instances this involves tracing the trouble to a defective part, obtaining the replacement part from the supply storeroom and installing it, and throwing away the defective part. When the defective part is expensive and repairable, the technician encounters the repairables program.

A large number of parts can be economically repaired when they fail. This results in savings of dollars and time since it is quicker and cheaper to repair an item than to contract for and buy a new one—provided that the old item is promptly returned in repairable condition. For the program to work as intended, repair personnel have certain responsibilities. At the time a request for a mandatory turn-in item is presented to supply, they must inform the requestor that the item is to be returned. At this point the technician's responsibilities begin. The technician must:

- Remove the defective part without damaging it.

- Provide adequate protection to the part so that it will not be further damaged before it is turned in to supply. The most effective way, for all concerned, is to place the defective part in the same container in which the replacement part was received.

- Resist the temptation to cannibalize the part for components which might possibly be used sometime in the future.

- Return the defective part to supply as soon as practicable.

When the required part is not in the storeroom, supply must then take appropriate action to obtain it. The failed part must still be returned and should be turned in prior to receiving the replacement part. This way the failed part can enter the repair cycle and be available for reissue that much sooner. The only exception should be when the failed part will permit limited or reduced operation of an equipment until the replacement is received.

TOOLS

Tools are designed to make a job easier and enable repair personnel to work more efficiently. Tools are a technician's best friend. If the tools are not used properly or cared for, their advantages will be lost. Without them technicians are as helpless as they would be without their eyes. In fact, they would be more helpless, for a blind technician, skilled in the use of good tools and having them available, can do more than the most expert mechanic without tools.

Regardless of the type of work to be done, technicians must have, choose, and use the correct tools in order to do their work quickly, accurately, and safely. Without the proper tools and the knowledge of how to use them, technicians waste time, reduce efficiency, and may even injure themselves.

THE MOST VALUABLE TOOLS IN THE WORLD

What would THE MOST VALUABLE TOOLS IN THE WORLD cost? These tools could help the technician grip, grasp, push, twist, and operate equipment. Furthermore, these remarkable tools could distinguish temperature variations and be sensitive to touch. It is impossible to purchase such tools . . . they are your HANDS.

These fabulous tools are subject to injury by being caught in machines, crushed by objects, or cut by a variety of sharp-edged tools such as chisels, knives, or saws. Additionally, the technicians' hands can be damaged by being burned, fractured, or sprained unless they are always alert.

Why? Because they cannot THINK for themselves. PROTECT THEM. They are invaluable. KEEP ALERT and THINK while working. THINK before making adjustments to machinery. Has the electric power been turned off? Are the required guards on the machinery? Is the object to be worked on properly secured and clamped?

Hands should be protected from injury as directed by the applicable safety instructions whenever tools are used. A technician would be working under severe handicaps without the full use of both hands. Make it a habit to FOLLOW ALL SAFETY RULES.

TEN SAFETY COMMANDMENTS

Obey the ten commandments of safety:

1. LEARN the safe way to do a job before starting.
2. THINK safety and ACT safety at all times.
3. OBEY safety rules and regulations–they are for your protection.
4. WEAR proper clothing and protective equipment.
5. CONDUCT yourself properly at all times–horseplay is prohibited.
6. OPERATE only the equipment authorized.
7. INSPECT tools and equipment for safe condition before starting work.
8. ADVISE your superior promptly of any unsafe conditions or practice.
9. REPORT any injury immediately to your superior.
10. SUPPORT your safety program and take an active part in safety meetings.

In addition to the above, there are other good tool habits which will help in performing your work more efficiently as well as safely.

TOOL HABITS

"A place for everything and everything in its place" is just common sense. Efficient, fast repair jobs are impossible if the tool needed is not in its proper place. The following rules, if followed, will make the job easier.

KEEP EACH TOOL IN ITS PROPER STOWAGE PLACE.–A tool is useless if it cannot be found. Return each tool to its proper place so that it will be available the next time it is needed.

KEEP ALL TOOLS IN GOOD CONDITION.–Protect them from rust, nicks, burrs, and breakage.

KEEP ALL TOOL ALLOWANCE COMPLETE.–If the technician is issued a tool box, each tool should be placed in it when not in use. If possible, the box should be locked and stored in a designated area. Note: Never leave the handbox adrift where it could become a missile and cause injury to personnel. An inventory list retained in the box and checked after each job will help keep track of the tools.

USE EACH TOOL ONLY ON THE JOB FOR WHICH IT WAS DESIGNED.–If the wrong tool is used to make an adjustment, the results will probably be unsatisfactory. For example, if a socket wrench is used that is a trifle too big, it will round off the corners of the wrench or nut. If this rounded wrench or nut is not replaced immediately the safety of the ship may be jeopardized in an emergency. Does this sound exaggerated? Remember . . . for want of a nail, a kingdom was lost.

KEEP ALL TOOLS WITHIN EASY REACH AND WHERE THEY CANNOT FALL ON THE FLOOR OR INTO MACHINERY.–Avoid placing tools anywhere above machinery or electrical apparatus. Serious damage will result if the tool falls into the machinery after the equipment is energized.

NEVER USE DAMAGED TOOLS.–A battered screwdriver may slip and spoil the screw slot, damage other parts, or cause painful injury. A gage strained out of shape will result in inaccurate measurements.

Remember, the efficiency of technicians and the tools they use are determined to a great extent by the way they keep their tools. Likewise, they are frequently judged by the manner in which they handle and care for their tools. Anyone watching a skilled technician at work notices the care and precision with which the tools of the trade are used.

The care of handtools should follow the same pattern as for personal articles; that is, always keep handtools clean and free from dirt, grease, and foreign matter. After use, return tools promptly to their proper place in the toolbox. Improve efficiency by organizing the tools so that those used most frequently can be reached easily without digging through the entire contents of the box. Avoid accumulating unnecessary junk.

COMMON HANDTOOLS

Common handtools are tools that are used most frequently in the performance of preventive and corrective maintenance. Common handtools include: screwdrivers, pliers, adjustable wrenches, setscrew wrenches, inspection mirrors, and mechanical fingers.

Screwdrivers

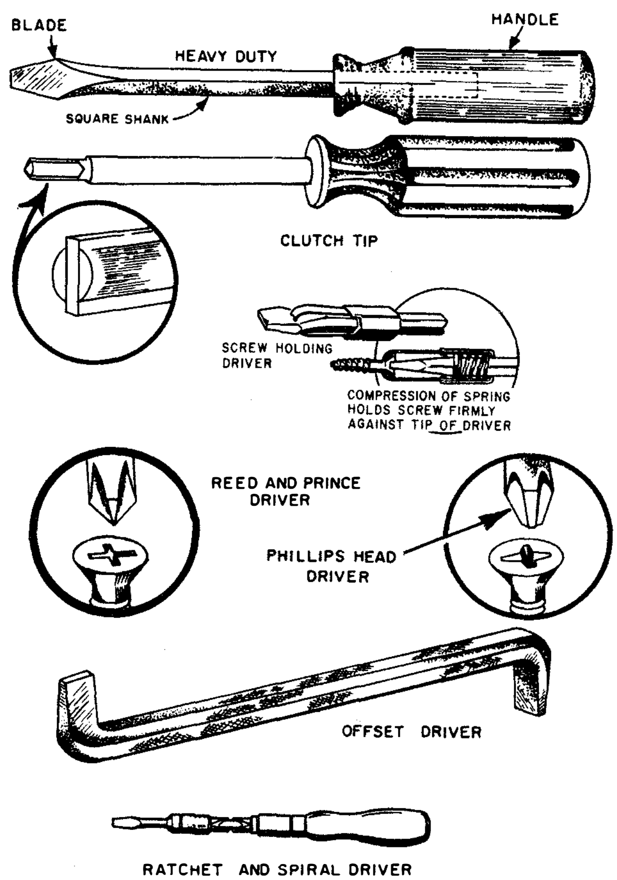
A screwdriver is one of the most basic handtools. It is also the most frequently abused of all handtools. It is designed for one function only–to drive and remove screws. A screwdriver should not be used as a pry bar, a scraper, a chisel, or a punch.

Standard

There are three main parts to a standard screwdriver. The grip is called the handle, the steel portion extending from the handle is the shank, and the end which fits into the screw is called the blade (fig. 1-32).

The steel shank is designed to withstand considerable twisting force in proportion to its size, and the tip of the blade is hardened to keep it from wearing.

Standard screwdrivers are classified by size, according to the combined length of the shank and blade. The most common sizes range in



1.14

Figure 1-32.–Screwdrivers.

length from 2 1/2 inches to 12 inches. There are screwdrivers smaller and larger for special purposes. The diameter of the shank, and the width and thickness of the blade are generally proportionate to the length, but, again, there are special screwdrivers with long thin shanks, short thick shanks, and extra wide or extra narrow blades.

Screwdriver handles may be wood, plastic, or metal. When metal handles are used, there is usually a wooden hand grip placed on each side of the handle. In some types of wood- or plastic-handled screwdrivers the shank extends through the handle, while in others the shank enters the handle only a short way and is pinned to the handle. For heavy work, special types of screwdrivers are made with a square shank. They are designed this way so that they may be gripped with a wrench, but this is the only kind on which a wrench should be used.

When using a screwdriver it is important to select the proper size so that the blade fits the screw slot properly. This prevents burring the slot and reduces the force required to hold the driver in the slot. Keep the shank perpendicular to the screw head (fig. 1-33).

Recessed

Recessed screws are now available in various shapes. They have a cavity formed in the head and require a specially shaped screwdriver. The clutch tip (fig. 1-32) is one shape, but the more common include the Phillips, Reed and Prince, and newer Torq-Set types (fig. 1-34). The most common type found is the Phillips-head screw. This requires a Phillips-type screwdriver (fig. 1-32).

Phillips Screwdriver

The head of a Phillips-type screw has a four-way slot into which the screwdriver fits. This prevents the screwdriver from slipping. Three standard-sized Phillips screwdrivers handle a wide range of screw sizes. Their ability to hold helps to prevent damaging the slots or the work surrounding the screw. It is a poor practice to try to use a standard screwdriver on a Phillips screw because both the tool and screw slot will be damaged.

Reed and Prince Screwdriver

Reed and Prince screwdrivers are NOT interchangeable with Phillips screwdrivers. Therefore, always use a Reed and Prince screwdriver with Reed and Prince screws and a Phillips screwdriver with Phillips screws, or a ruined tool or ruined screwhead will result.

How do you distinguish between these similar screwdrivers? Refer to figure 1-35.

The Phillips screwdriver has approximately 30-degree flukes and a blunt end, while the Reed and Prince has 45-degree flukes and a sharper, pointed end. The Phillips screw has beveled walls between the slots; the Reed and Prince, straight, pointed walls. In addition, the Phillips screw slot is not as deep as the Reed and Prince slot.

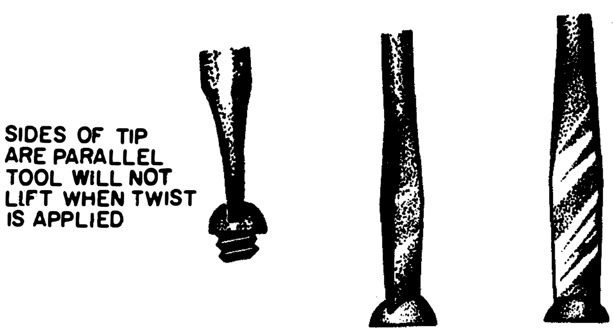


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Figure 1-33.—Positioning screwdrivers.

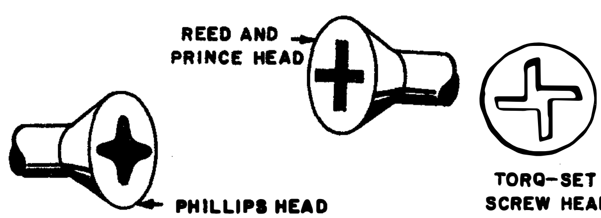

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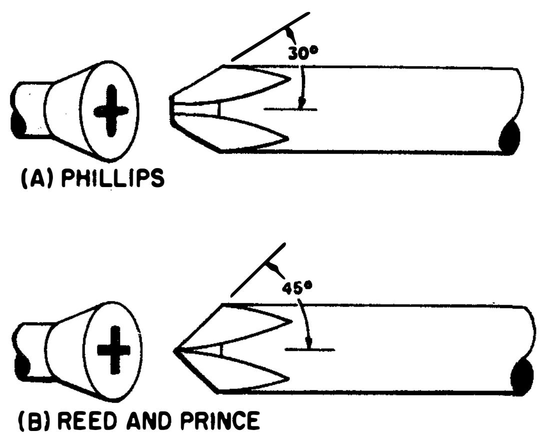
Figure 1-34.—Comparison of Phillips, Reed and Prince, and Torq-Set screwheads.



1.14
Figure 1-35.—Matching cross-slot screws and drivers.

Additional ways to identify the right screwdriver are as follows:

1. If it tends to stand up unassisted when the point is put in the head of a vertical screw, it is probably the proper one.
2. The outline of the end of a Reed and Prince screwdriver is approximately a right angle, as seen in the illustration.
3. In general, Reed and Prince screws are used for airframe structural applications, while Phillips screws are found most often in component assemblies.

"Torq-Set" Screws

"Torq-Set" machine screws (offset cross-slot drive) have recently begun to appear in new equipment. The main advantage of the newer type is that more torque can be applied to its head while tightening or loosening than any other screw of comparable size and material without damaging the head of the screw.

Torq-Set machine screws are similar in appearance to the more familiar Phillips machine screws.

Since a Phillips driver could easily damage a Torq-Set screwhead, making it difficult if not impossible to remove the screw even if the proper tool later is used, maintenance personnel should be alert to the differences (fig. 1-34) and ensure that the proper tool is used.

Offset Screwdrivers

An offset screwdriver (fig. 1-32) may be used where there is not sufficient vertical space for a standard or recessed screwdriver. Offset screwdrivers are constructed with one blade forged in line and another blade forged at right angles to the shank handle. Both blades are bent 90 degrees to the shank handle. By alternating ends, most screws can be seated or loosened even when the swinging space is very restricted. Offset screwdrivers are made for both standard and recessed head screws.

Ratchet Screwdriver

For fast, easy work the ratchet screwdriver (fig. 1-32) is extremely convenient, as it can be used one-handed and does not require the bit to be lifted out of the slot after each turn. It may be fitted with either a standard type bit or a special bit for recessed heads. The ratchet screwdriver is most commonly used by the woodworker for driving screws in soft wood.

SAFETY

- Never use a screwdriver to check an electrical circuit.

- Never try to turn a screwdriver with a pair of pliers.

- Do not hold work in your hand while using a screwdriver—if the point slips it can cause a bad cut. Hold the work in a vise, with a clamp, or on a solid surface. If that is impossible, always be safe by following this rule: NEVER GET ANY PART OF YOUR BODY IN FRONT OF THE SCREWDRIVER BLADE TIP. That is a good safety rule for any sharp or pointed tool.

PLIERS

Pliers are made in many styles and sizes and are used to perform many different operations. Pliers are used for cutting purposes as well as holding and gripping small articles in situations where it may be inconvenient or impossible to use hands. Figure 1-36 shows several different kinds.

The combination pliers are handy for holding or bending flat or round stock. The long-nosed pliers are less rugged, and break easily if used on heavy jobs. Long-nosed pliers, commonly called needle-nose pliers, are especially useful for holding small objects in tight places and for making delicate adjustments. The round-nosed kind are handy when it is necessary to crimp sheet metal or form a loop in a wire. The diagonal-cutting pliers, commonly called "diagonals" or "dikes", are designed for cutting wire and cotter pins close to a flat surface and are especially useful in the electronic and electrical fields. The duckbill pliers are used extensively in aviation areas.

Here are two important rules for using pliers:

1. Do not make pliers work beyond their capacity. The long-nosed kind are especially delicate. It is easy to spring or break them, or nick their edges. After that, they are practically useless.

2. Do not use pliers to turn nuts. In just a few seconds, a pair of pliers can damage a nut. Pliers must NOT be substituted for wrenches.

Slip-Joint Pliers

Slip-joint pliers (fig. 1-37) are pliers with straight, serrated (grooved) jaws, and the screw or pivot with which the jaws are fastened together may be moved to either of two positions, in order to grasp small- or large-sized objects better.

To spread the jaws of slip-joint pliers, first spread the ends of the handles apart as far as possible. The slip-joint, or pivot, will now move to the open position. To close, again spread the handles as far as possible, then push the joint back into the closed position.

Slip-joint combination pliers (fig. 1-38) are pliers similar to the slip-joint pliers just described, but with the additional feature of a side cutter at the junction of the jaws. This cutter consists of a pair of square-cut notches, one on each jaw, which act like a pair of shears when an object is placed between them and the jaws are closed.

The cutter is designed to cut material such as soft wire and nails. To use the cutter, open the jaws until the cutter on either jaw lines up with the other. Place the material to be cut as far back as possible into the opening formed by the cutter, and squeeze the handles of the pliers together. Do not attempt to cut hard material such as spring wire or hard rivets with the combination pliers. To do so will spring the jaws; and if the jaws are sprung, it will be

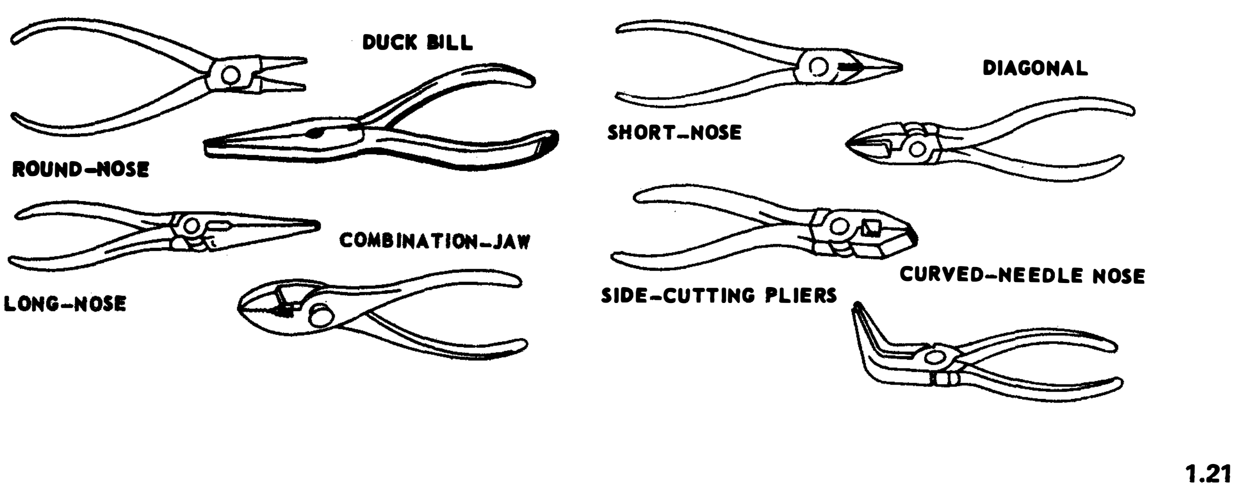


Figure 1-36.—Pliers.

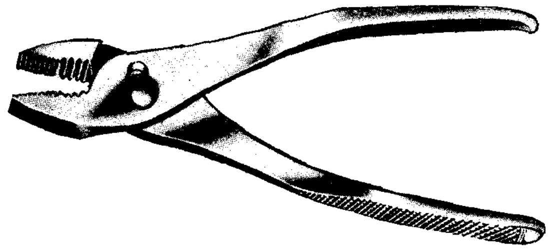


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Figure 1-37.—Slip-joint pliers.

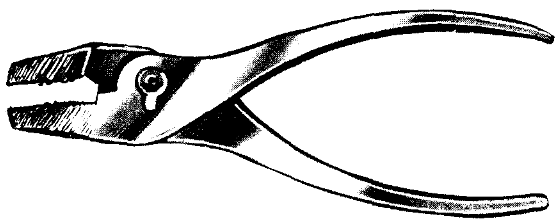

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Figure 1-38.—Slip-joint combination pliers.

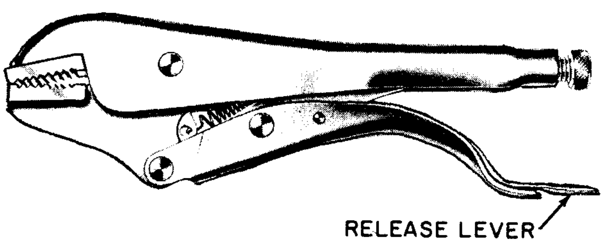

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Figure 1-39.—Vise-grip pliers.

difficult thereafter to cut small wire with the cutters.

Wrench (Vise-Grip) Pliers

Vise-grip pliers (fig. 1-39) can be used for holding objects regardless of their shape. A screw adjustment in one of the handles makes them suitable for several different sizes. The jaws of vise-grips may have standard serrations such as the pliers just described or may have a clamp-type jaw. The clamp-type jaws are generally wide and smooth and are used primarily when working with sheet metal.

Vise-grip pliers have an advantage over other types of pliers in that they can be clamped on an object and they will stay. This will leave your hands free for other work.

A technician uses this tool a number of ways. It may be used as a clamp, speed wrench, or portable vise, and for many other uses where a locking, plier-type jaw may be employed. These pliers can be adjusted in various jaw openings by turning the knurled adjusting screw at the end of the handle (fig. 1-39). Vise-grips can be clamped and locked in position by pulling the lever toward the handle.

CAUTION: Vise-grip pliers should be used with care since the teeth in the jaws tend to damage the object on which they are clamped. They should not be used on nuts, bolts, tube fittings, or other objects which must be reused.

Water-Pump Pliers

Water-pump pliers were originally designed for tightening or removing water-pump packing nuts. They are excellent for this job because they have a jaw adjustable to seven different positions. Water-pump pliers (fig. 1-40) are easily identified by their size, jaw teeth, and adjustable slip joint. The inner surface of the jaws consists of a series of coarse teeth formed by deep grooves, a surface adapted to grasping cylindrical objects.

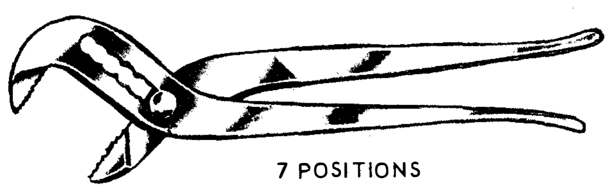

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Figure 1-40.—Water-pump pliers.

Channel-Lock Pliers

Channel-lock pliers (fig. 1-41) are another version of water-pump pliers easily identified by the extra long handles, which make them a very powerful gripping tool. They are shaped approximately the same as the pliers just described, but the jaw opening adjustment is effected differently. Channel-lock pliers have grooves on one jaw and lands on the other. The adjustment is effected by changing the position of the grooves and lands. The channel-lock pliers are less likely to slip from the adjustment setting when gripping an object. The channel-lock pliers will be used only where it is impossible to use a more adapted wrench or holding device. Many nuts and bolts and surrounding parts have been damaged by improper use of channel-lock pliers.

Diagonal Pliers

Diagonal-cutting pliers (fig. 1-36) are used for cutting small, light material, such as wire and cotter pins in areas which are inaccessible to the larger cutting tools. Also, since they are designed for cutting only, larger objects can be cut than with the slip-joint pliers.

As the cutting edges are diagonally offset approximately 15 degrees, diagonal pliers are adapted to cutting small objects flush with a surface. The inner jaw surface is a diagonal straight cutting edge. Diagonal pliers should never be used to hold objects, because they exert a greater shearing force than other types of pliers of a similar size. The sizes of the diagonal-cutting pliers are designated by the overall length of the pliers.

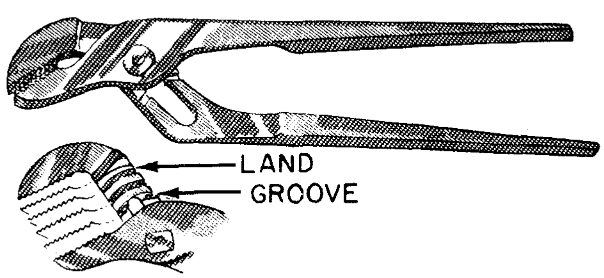

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Figure 1-41.—Channel-lock pliers.

Side-Cutting Pliers

Side-cutting pliers (sidecutters) are principally used for holding, bending, and cutting thin materials or small-gage wire. Sidecutters vary in size and are designated by their overall length. The jaws are hollowed out on one side just forward of the pivot point of the pliers. Opposite the hollowed-out portion of the jaws are the cutting edges (fig. 1-36).

When holding or bending light metal surfaces, the jaw tips are used to grasp the object. When holding wire, grasp it as near one end as possible because the jaws will mar the wire. To cut small-diameter wire the side cutting edge of the jaws near the pivot is used. Never use sidecutters to grasp large objects, tighten nuts, or bend heavy-gage metal, since such operations will spring the jaws.

Sidecutters are often called electrician or lineman pliers. They are used extensively for stripping insulation from wire and for twisting wire when making a splice.

Duckbill Pliers

Duckbill pliers (fig. 1-42A) have long wide jaws and slender handles. Duckbills are used in confined areas where the fingers cannot be used. The jaw faces of the pliers are scored to aid in

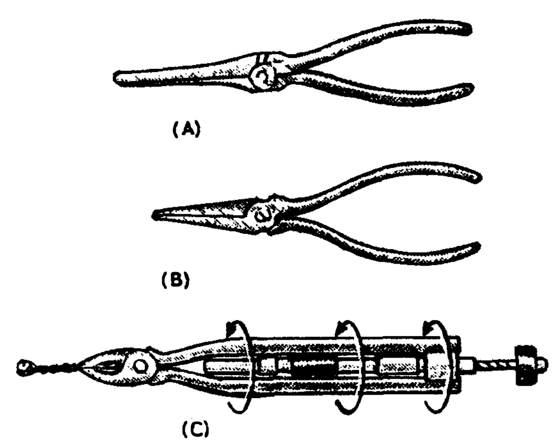

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Figure 1-42.—Pliers (A) Duckbill, (B) needle-nose, and (C) wire-twister.

holding an item securely. Duckbills are ideal for twisting the safety wire used in securing nuts, bolts, and screws.

Needle-Nose Pliers

Needle-nose pliers (fig. 1-42B) are used in the same manner as duckbill pliers. However, there is a difference in the design of the jaws. Needle-nose jaws are tapered to a point which makes them adapted to installing and removing small cotter pins. They have serrations at the nose end and a side cutter near the throat. Needle-nose pliers may be used to hold small items steady, to cut and bend safety wire, or to do numerous other jobs which are too intricate or too difficult to be done by hand alone.

NOTE: Duckbill and needle-nose pliers are especially delicate. Care should be exercised when using these pliers to prevent springing, breaking, or chipping the jaws. Once these pliers are damaged, they are practically useless.

Wire-Twister Pliers

Wire-twister pliers (fig. 1-42C) are three-way pliers which hold, twist, and cut. They are designed to reduce the time used in twisting safety wire on nuts and bolts. To operate, grasp the wire between the two diagonal jaws, and the thumb will bring the locking sleeve into place. A pull on the knob twirls the twister, making uniform twists in the wire. The spiral rod may be pushed back into the twister without unlocking it, and another pull on the knob will give a tighter twist to the wire. A squeeze on the handle unlocks the twister, and the wire can be cut to the desired length with the side cutter. The spiral of the twister should be lubricated occasionally.

Maintenance of Pliers

Nearly all sidecutting pliers and diagonals are designed so that the cutting edges can be reground. Some older models of pliers will not close if material is ground from the cutting edges. When grinding the cutting edges never take any more material from the jaws than is necessary to remove the nicks. Grind the same amount of stock from both jaws.

NOTE: When jaws on pliers do not open enough to permit grinding, remove the pin that attaches the two halves of the pliers so that the jaws can be separated.

The serrations on the jaws of pliers must be sharp. When they become dull, the pliers should be held in a vise and the serrations recut by using a small three-corner file.

Pliers should be coated with light oil when they are not in use. They should be stored in a toolbox in such a manner that the jaws cannot be injured by striking hard objects. Keep the pin or bolt at the hinge just tight enough to hold the two parts of the pliers in contact and always keep the pivot pin lubricated with a few drops of light oil.

Adjustable Wrenches

A handy all-round wrench that is generally included in every toolbox is the adjustable open-end wrench. This wrench is not intended to take the place of the regular solid open-end wrench. Additionally, it is not built for use on extremely hard-to-turn items. Its usefulness is achieved by being capable of fitting odd-sized nuts. This flexibility is achieved although one jaw of the adjustable open-end wrench is fixed because the other jaw is moved along a slide by a thumbscrew adjustment (fig. 1-43). By turning

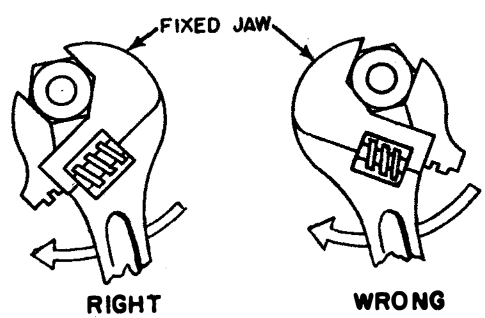

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Figure 1-43.—Proper procedure for pulling adjustable wrenches.

the thumbscrew, the jaw opening may be adjusted to fit various sizes of nuts.

Adjustable wrenches are available in varying sizes ranging from 4 to 24 inches in length. The size of the wrench selected for a particular job is dependent upon the size of nut or bolt head to which the wrench is to be applied.

Adjustable wrenches are often called "knuckle busters", because mechanics frequently suffer these consequences as a result of improper usage of these tools. To avoid accidents, follow four simple steps. First, choose a wrench of the correct size; that is, do not pick a large 12-inch wrench and adjust the jaw for use on a 3/8-inch nut. This could result in a broken bolt and a bloody hand. Second, be sure the jaws of the correct size wrench are adjusted to fit snugly on the nut. Third, position the wrench around the nut until the nut is all the way into the throat of the jaws. If not used in this manner, the result is apt to be as bloody as before. Fourth, pull the handle toward the side having the adjustable jaw (fig. 1-43). This will prevent the adjustable jaw from springing open and slipping off the nut. If the location of the work will not allow for all four steps to be followed when using an adjustable wrench, then select another type of wrench for the job.

Setscrew Wrenches (Allen and Bristol)

In some places it is desirable to use recessed heads on setscrews and capscrews. One type (Allen) screw is used extensively on office machines and in machine shops. The other type (Bristol) is used infrequently.

Recessed head screws usually have a hex-shaped (six-sided) recess. To remove or tighten this type screw requires a special wrench that will fit in the recess. This wrench is called an Allen-type wrench. Allen-type wrenches are made from hexagonal L-shaped bars of tool steel (fig. 1-44). They range in size up to 3/4 inch. When using the Allen-type wrench make sure you use the correct size to prevent rounding or spreading the head of the screw. A snug fit within the recessed head of the screw is an indication that it is the correct size.

The Bristol wrench is made from round stock. It is also L-shaped, but one end is fluted

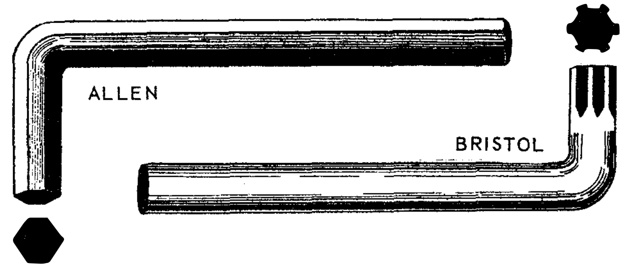

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Figure 1-44.—Allen- and Bristol-type wrenches.

to fit the flutes or little splines in the Bristol setscrew (fig. 1-44).

Inspection Mirror

There are several types of inspection mirrors available for use in maintenance. The mirror is issued in a variety of sizes and may be round or rectangular. The mirror is connected to the end of a rod and may be fixed or adjustable (fig. 1-45).

The inspection mirror aids in making detailed inspection where the human eye cannot directly see the inspection area. By angling the mirror, and with the aid of a flashlight, it is possible to inspect most required areas. A late-model inspection mirror features a built-in light to aid in viewing those dark places where use of a flashlight is not convenient.

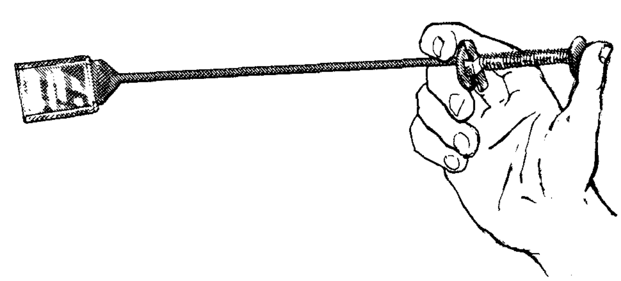

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Figure 1-45.—Adjustable inspection mirror.

Mechanical Fingers

Small articles which have fallen into places where they cannot be reached by hand may be retrieved with the mechanical fingers. This tool is also used when starting nuts or bolts in difficult areas. The mechanical fingers, shown in figure 1-46, have a tube containing flat springs which extend from the end of the tube to form clawlike fingers, much like the screw holder. The springs are attached to a rod that extends from the outer end of the tube. A plate is attached to the end of the tube, and a similar plate to be pressed by the thumb is attached to the end of the rod. A coil spring placed around the rod between the two plates holds them apart and retracts the fingers into the tube. With the bottom plate grasped between the fingers and enough thumb pressure applied to the top plate to compress the spring, the tool fingers extend from the tube in a grasping position. When the thumb pressure is released, the tool fingers retract into the tube as far as the object they hold will allow. Thus, enough pressure is applied on the object to hold it securely. Some mechanical fingers have a flexible end on the tube to permit their use in close quarters or around obstructions (fig. 1-46).

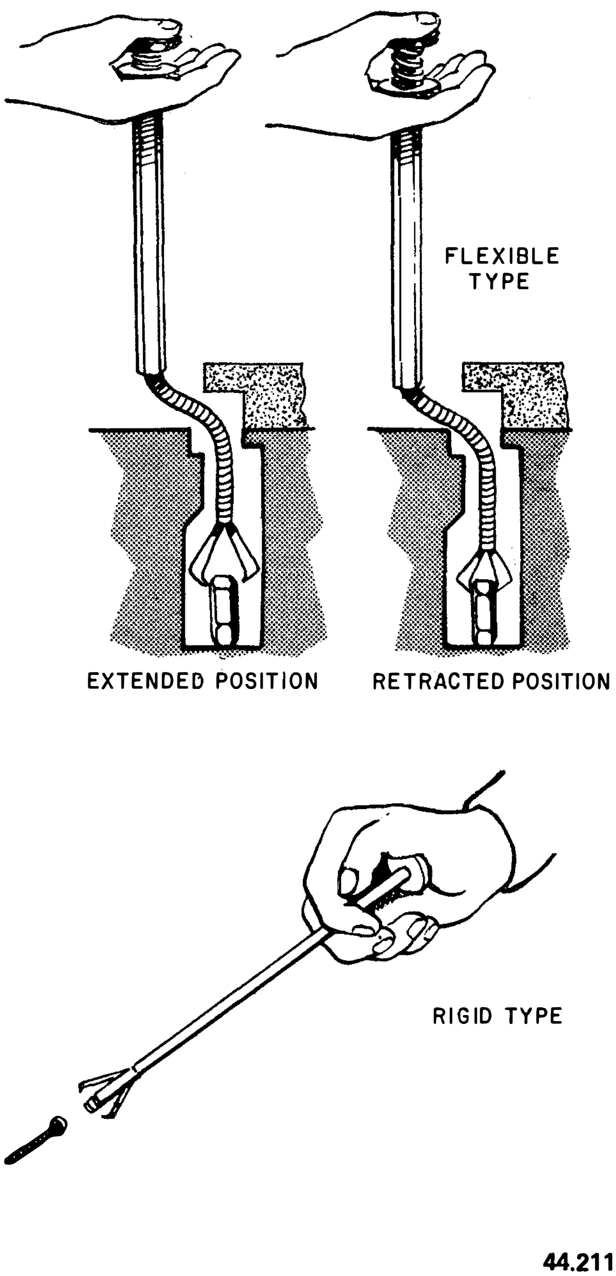

Figure 1-46.—Mechanical fingers.

NOTE: Mechanical fingers should not be used as a substitute for wrenches or pliers. The fingers are made of thin sheet metal or spring wire and can be easily damaged by overloading.

SPECIAL TOOLS

Special tools are tools that are not normally found in the common toolbox and are not used in everyday maintenance. These tools are normally located in the tool rooms and are checked out when required. There are times when special tools have to be checked out from other divisions or departments. When this happens there is one rule that should be remembered. Return borrowed tools in the same or better condition than when they were received. This will insure your reputation as a responsible person so that tools can be checked out again. Special tools require special attention and are usually expensive. Therefore, it is very important to treat these tools with care. Some special tools require calibration and rough use will nullify the purpose of that tool.

Torque Wrenches

Torque wrenches are a good example of special tools. There are times when, for engineering reasons, a definite force must be applied to a nut or bolt head. In such cases a torque wrench must be used. For example, equal force must be applied to all the head bolts of an engine or all the bearing hold-down bolts of an antenna. Otherwise, one bolt may bear the brunt of the force and ultimately cause engine or antenna failures.

The three most commonly used torque wrenches are the Deflecting-Beam, Dial-Indicating, and Micrometer-Setting types (fig. 1-47). When using the Deflecting-Beam and the Dial-Indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the Micrometer-Setting type, unlock the grip and adjust the handle to the desired setting on the micrometer-type scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth, steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value, which is indicated on the handle setting, a signal mechanism will automatically issue an audible click, and the handle will release or "break," and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.

Manufacturers' and technical manuals generally specify the amount of torque to be applied. To assure getting the correct amount of torque on the fasteners, it is important that the wrench be used properly in accordance with manufacturers' instructions.

Use that torque wrench which will read about mid-range for the amount of torque to be applied. BE SURE THAT THE TORQUE WRENCH HAS BEEN CALIBRATED BEFORE USING IT. Remember, too, that the accuracy of torque-measuring depends a lot on how the threads are cut and the cleanliness of the threads. Be sure to inspect and clean the threads. If the manufacturer specifies a thread lubricant, it must be used to obtain the most accurate torque reading. When using the Deflecting-Beam or Dial-Indicating wrenches, hold the torque at the desired value until the reading is steady.

Torque wrenches are delicate and expensive tools. The following precautions should be observed when using them:

1. When using the Micrometer-Setting type, do not move the setting handle below the lowest torque setting. However, it should be placed at its lowest setting prior to returning to storage.

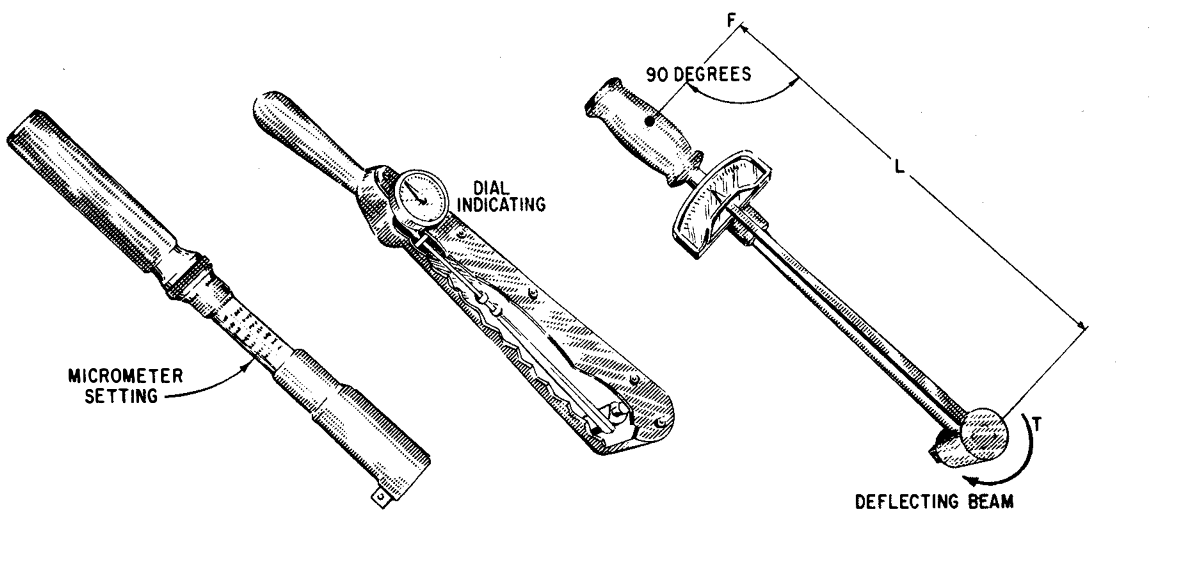

Figure 1-47.—Torque wrenches.

2. Do not use the torque wrench to apply greater amounts of torque than its rated capacity.

3. Do not use the torque wrench to break loose bolts which have been previously tightened.

4. Do not drop the wrench. If dropped, the accuracy will be affected.

5. Do not apply a torque wrench to a nut that has been tightened. Back off the nut one turn with a non-torque wrench and retighten to the correct torque with the indicating torque wrench.

6. Calibration intervals have been established for all torque tools used in the Navy. When a tool is calibrated by a qualified calibration activity at a shipyard, tender, or repair ship, a label showing the next calibration due date is attached to the handle. This date should be checked before a torque tool is used to ensure that it is not overdue for calibration.

One point to remember—always treat tools as if they are personal property and had to be paid for out of your own pocket.

PRIMARY AND SECONDARY POWER SYSTEMS

Normal, alternate, and emergency feeders from several switchboards are spaced as far apart as feasible to minimize the possibility of damage from a single hit to more than one feeder to a vital load. Cable runs are located so as to obtain the maximum possible protection on the ship's structure and armored envelope. However, only one power feeder is usually contained within the armored envelope, consistent with the desire to obtain maximum physical separation from the other power supplies.

The very basic typical a.c. power distribution system (fig. 1-48) shows the three different power inputs to the prime equipment and the two power inputs to the secondary equipment. For explanation of these systems assume that the A system is located in the forward section of the ship, system B is located in the aft section of the ship, and both A and B systems are identical. The C system is the emergency system. (A separate emergency system would also be used with the A system.) The B and C systems will be explained.

Ship's service generator #2 supplies power to switchboard #2. Switchboard #2 has numerous outputs; however, for simplicity, only four and the bus tie are shown. The normal paths are automatic bus transfer switch (ABT) #2, ABT #3A and ABT #3C. (The ABTs are switches that automatically switch to an alternate source of power when the normal supply of power is interrupted.) The output of ABT #2 is fed to distribution panel (D/P) #2. (Distribution panels allow numerous connections to a single power source.) The output of the distribution panel is fed to a power panel (P/P) which is normally located near the equipment space. The output of the power panel feeds power to the equipment.

The alternate power source for ABT #2 is from switchboard #1. Ship's service generator #1 can furnish power in case of a power failure of the ship's service generator #2. If generator #2 fails, ABT #2 automatically switches over to the alternate power thus keeping power to distribution panel #2 and the rest of the system. The A system is the alternate system for the B system and vice versa.

The bus tie is used to tie the two switchboards together so that one of the generators can be taken off line for maintenance.

For prime equipment that is necessary for the safety of the ship, an emergency power system is used. If both ship's service generators fail, power is still maintained.

Distribution panel #3, power panel #3, and the prime equipment in B of figure 1-48 receive power from ABT #3C as described earlier. ABT #3C receives its normal power input from switchboard #2. The alternate source is supplied through the emergency switchboard and ABT #3B. If the normal power fails, ABTs #3A and #3C would change over to their alternate power source. If the alternate power fails, ABT #3B would switch over to the emergency generator which automatically starts and supplies limited power to the critical circuits only.

As stated earlier, this is a very basic power distribution system used for explaining a very complicated system. It is very important to understand the primary power distribution used aboard your ship. This will enable you to work

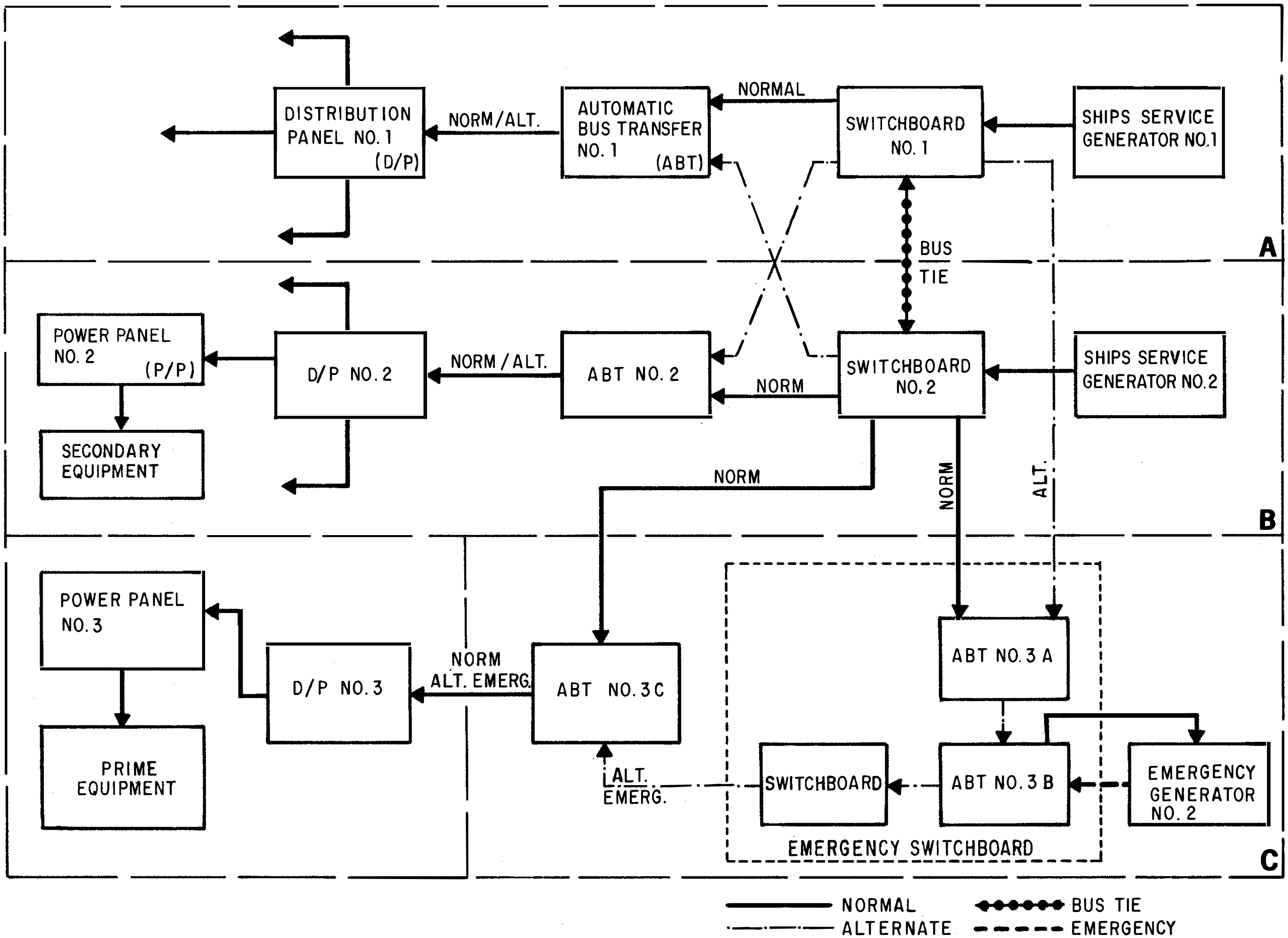

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Figure 1-48.—Typical ship a.c. power distribution.

with the electricians to solve problems that might arise during normal and emergency operations.

SAFETY PRECAUTIONS

Safety precautions relating to maintenance of electronics equipment are discussed in chapter 2 of *Basic Electronics, Vol. 1,* NAVPERS 10087-C, Chapter 400 of the *NAVSHIPS Technical Manual,* and the *Navy Electricity and Electronics Training Series (NEETS).* The following paragraphs review and build upon the material contained in these publications by discussing precautions when working aloft. Also presented are some of the important "DOs" and "DON'Ts" concerning safety for Electronics Technicians.

PRECAUTIONS WHEN WORKING ALOFT

Hazards while working aloft include death or injury from falling, asphyxiation from stack gasses, and electric shock (either from the equipment being worked on or from induced voltages in guy wires and other ungrounded conductive materials due to radiation from radio and radar antennas). Also included are overexposure to radiation from high-powered radar antennas, contact with rotating or oscillating antennas or other moving machinery, and overexposure to inclement weather conditions.

In addition to the danger from electric shock due to energized equipment and induced voltages, there may also be a shock hazard due to static charges. Static charges are caused by electrically charged particles that exist naturally in the air. Under certain conditions these charged particles will collect on metallic objects such as wire antennas and produce a shock hazard. Grounding the objects concerned will eliminate the hazard. Shocks from static charges will not cause direct harm to the individual, but any unexpected shock while aloft may cause a person to fall.

Before going aloft, permission must be obtained from the officer of the deck, and all transmitters and machinery in the vicinity of the work area must be secured and tagged. Permission must also be obtained from the engineer officer to ensure that boiler tubes will not be blown or boiler safeties set during the time the work is being done aloft. If in port or at anchor, permission must also be obtained from the OOD of any ships moored alongside. Notify these ships when work is completed.

An approved parachute-type safety harness (fig. 1-49) must be worn at all times when working aloft. (The lineman-type safety belt is no longer authorized for Navy use.) Safety harnesses must be checked periodically in accordance with the Planned Maintenance System. Tools to be used on the job should be placed in a canvas bag and hauled up with a line to the job location. To guard against dropping tools and seriously injuring someone, it is recommended that the tool being used be tied to the safety harness with a piece of line.

RADIOACTIVE ELECTRON TUBES

Electron tubes containing radioactive material are now commonly used. These tubes are known as TR, ATR, PRE-TR, spark-gap, voltage-regulator, gas-switching, and cold-cathode gas-rectifier tubes. Some of these tubes contain radioactive material and have intensity levels which are dangerous; they are so marked in accordance with Military Specifications.

So long as these electron tubes remain intact and are not broken, no great hazard exists. However, if these tubes are broken and the radioactive material is exposed, or escapes from the confines of the electron tube, the radioactive material becomes a potential hazard. The concentration of radioactivity in a normal collection of electron tubes in a maintenance shop does not approach a dangerous level, and the hazards of injury from exposure are slight. However, at major supply points, the storage of large quantities of radioactive electron tubes in a relatively small area may create a hazard. For this reason, personnel working with equipment employing electron tubes containing radioactive material, or in areas where a large quantity of radioactive tubes is stored, should read and become thoroughly familiar with the safety

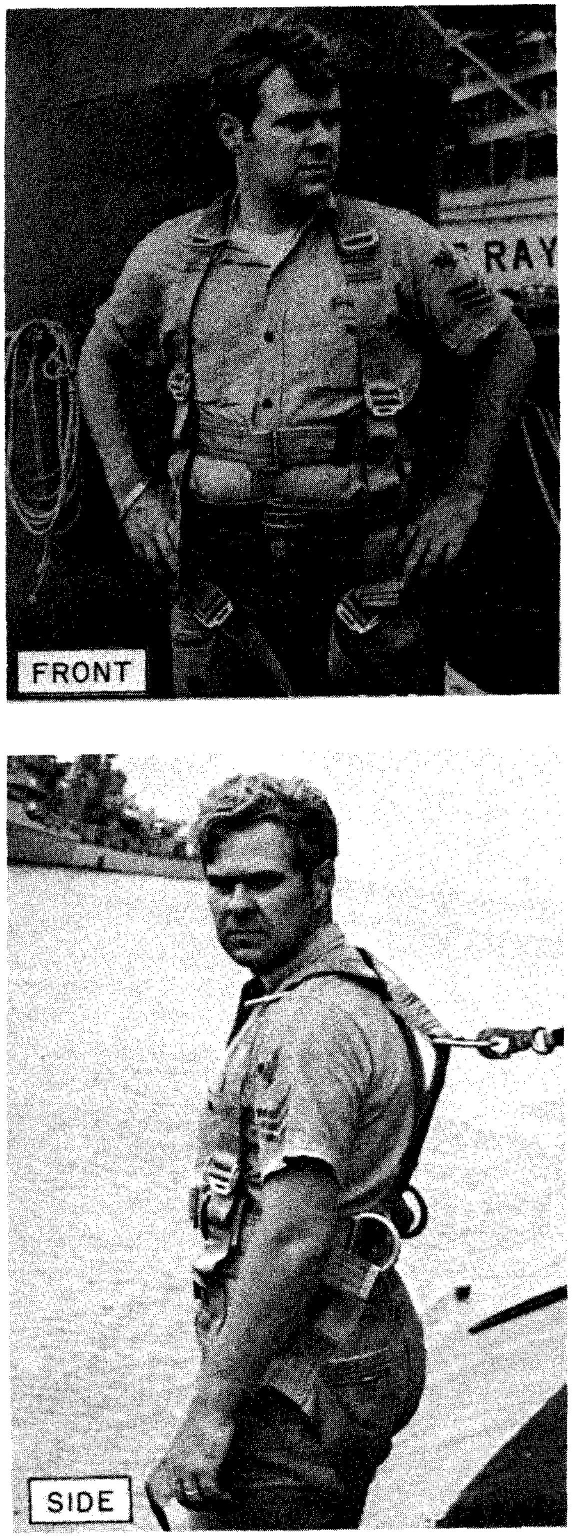

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Figure 1-49.—Parachute-type safety harness.

practices contained in the *Radiation, Health, and Protection Manual,* NAVMED P-5055. Strict compliance with the prescribed safety precautions and procedures of this manual will help to avoid preventable accidents, and to maintain a work environment which is conducive to good health.

The following precautions should be taken to ensure proper handling of radioactive electron tubes and safety of personnel:

1. Radioactive tubes should not be removed from cartons until immediately prior to actual installation.
2. When a tube containing a radioactive material is removed from the equipment, it should be placed in an appropriate carton to prevent possible breakage.
3. A radioactive tube should never be carried in one's pocket, or elsewhere on one's person in such a manner that breakage can occur.
4. If breakage does occur during handling or removing of a radioactive electron tube, notify the cognizant authority and obtain the services of qualified radiological personnel immediately.
5. Isolate the immediate area of exposure to protect other personnel from possible contamination and exposure.
6. Follow the established procedures set forth in NAVMED P-5055.
7. Do not permit contaminated material to come in contact with any part of a person's body.
8. Take care to avoid breathing any vapor or dust which may be released by tube breakage and secure the ventilation system.
9. Wear rubber or plastic gloves at all times during cleanup and decontamination procedures.
10. Use forceps for the removal of large fragments of broken radioactive tube. The remaining small particles can be removed with a vacuum cleaner, using an approved disposal collection bag. If a vacuum cleaner is not available, use a wet cloth to wipe the affected area. In this case, be sure to make one stroke at a time. DO NOT use a back-and-forth motion. After each stroke, fold the cloth in half, always holding one clean side and using the other for

the new stroke. Dispose of the cloth in the manner stated later.

11. No food or drink should be brought into the contaminated area or near any radioactive material.

12. Immediately after leaving a contaminated area, personnel who have handled radioactive material in any way should remove any clothing found to be contaminated. They should also thoroughly wash their hands and arms with soap and water, and rinse with clean water.

13. Immediately notify a medical officer if a wound is sustained from a sharp radioactive object. If a medical officer cannot reach the scene immediately, mild bleeding should be stimulated by pressure about the wound and the use of suction bulbs. DO NOT USE THE MOUTH. If the wound is of the puncture type, or the opening is small, make an incision to promote free bleeding, and to facilitate cleaning and flushing of the wound.

14. When cleaning a contaminated area, seal all debris, cleaning cloths, and collection bags in a container such as a plastic bag, heavy wax paper, or glass jar, and place in a steel can until disposed of in accordance with existing instructions. Using soap and water, decontaminate all tools and implements used to remove a radioactive substance. Monitor the tools and implements for radiation with an authorized radiac set; they should emit less than 0.1MR/HR at the surface.

CATHODE-RAY TUBES (CRTs)

Cathode-ray tubes should always be handled with extreme caution. The glass envelope encloses a high vacuum and, because of its large surface area, is subject to considerable force caused by atmospheric pressure. (The total force on the surface of a 10-inch crt is 3750 pounds, or nearly two tons; over 1000 pounds is exerted on its face alone.) Proper handling and disposal instructions for crts are as follows:

1. Avoid scratching or striking the surface.
2. Do not use excessive force when removing or replacing the crt in its deflection yoke or its socket.
3. Do not try to remove an electromagnetic type crt from its yoke until the high voltage has been discharged from its anode connector (hole).
4. Never hold the crt by its neck.
5. Always set a crt with its face down on a thick piece of felt, rubber, or smooth cloth.
6. Always handle the crt gently. Rough handling or a sharp blow on the service bench can displace the electrodes within the tube, causing faulty operation.
7. Safety glasses and gloves should be worn when handling crts.

CLEANING SOLVENT

The Navy does not permit the use of gasoline, benzine, ether, or like substances for cleaning purposes. Only nonvolatile solvents should be used to clean electrical or electronic apparatus.

In addition to the potential hazard of accidental fires, many cleaning solvents are capable of damaging the human respiratory system in cases of prolonged inhalation. The following is a list of "Do Nots" when using cleaning solvents.

1. DO NOT work alone in a poorly ventilated compartment.
2. DO NOT breathe directly the vapor of any cleaning solvent for a long time.
3. DO NOT spray cleaning solvents on electrical windings or insulation.
4. DO NOT apply solvents to warm or hot equipment, since this increases the toxicity hazard.

The following reminders are positive safety steps to be taken when cleaning operations are underway.

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 portholes and place wind scoops in them.
3. Place a fire extinguisher close by, ready for use.
4. Use water compounds in lieu of other solvents where feasible.

5. Wear rubber gloves to prevent direct contact.
6. Use goggles when a solvent is being sprayed.
7. Hold the nozzle close to the object being sprayed.

Inhibited methyl chloroform (1,1,1 trichloroethane) should be used where water compounds are not feasible. Methyl chloroform is toxic and should be used with care since concentrations of the vapor can be fatal. Methyl chloroform is an effective cleaner and safe when reasonable care is exercised. Care requires plenty of ventilation and observance of fire precautions.

For additional information on the safety precautions to be observed when using solvents, see Chapter 400 of the *NAVSHIPS Technical Manual.*

AEROSOL DISPENSERS

Deviation from prescribed procedures in the selection, application, storage, or disposal of aerosal dispensers containing industrial sprays has resulted in serious injury to personnel because of toxic effects, fire, explosion, and so on. Specific instructions concerning the precautions and procedures that must be observed to prevent physical injury cannot be given because there are so many types of industrial sprays available. However, all personnel concerned with the handling of aerosol dispensers containing volatile substances should clearly understand the hazards involved and the need to use all protective measures required to prevent personal injury. Strict compliance with the instructions printed on the aerosol dispenser will prevent many of the accidents which result from improper application, mishandling, or improper storage of industrial sprays used in the Naval service for electrical and electronic equipment.

SAFETY IS YOUR JOB–DO IT PROPERLY!

POINTS TO REMEMBER

Some important points to remember relating to safety are listed in the following paragraphs.

Remember to secure power from ALL sources, tag supply switches, and discharge all capacitors and other devices that may contain a stored electrical charge before working on electrical or electronics equipment.

For all the switches that YOU "tagged out" when securing power, YOU are personally required to untag them when YOU restore power.

Do not work on energized equipment unless in an emergency, and then only after obtaining permission from appropriate authority and taking special precautions. Voltages as low as 30 volts can be dangerous under certain conditions. Approximately 100 milliamperes through the heart area for one second can be fatal.

Do not use your fingers to test a "hot" circuit; use an approved meter. Do not hold test probes when measuring voltages over 300 volts. Do not work alone when working on energized circuits and equipments.

Use an approved fuse puller to remove and replace cartridge fuses. Do not short out, block open, or otherwise disable any interlock switch.

Observe all "high voltage," "RF radiation," and other types of safety warning signs. Ensure that the metal cases of portable test equipment and power tools are properly grounded. Do not use a power tool that has a frayed cord or damaged plug.

Take time to be safe–hurrying invites accidents.

ENVIRONMENTAL EFFECTS ON ELECTRONIC EQUIPMENT

It is beyond the scope of the chapter to present all the problems encountered from environmental conditions, because individual methods of installation and stowage of electronic equipment 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.

TEMPERATURE

Extremely low temperature may cause brittleness in certain types of metals, and loss of flexibility to rubber, insulation, and similar material. Extremely high temperatures 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.

The cooling or heating of air spaces surrounding the components of electronic equipment is generally accomplished and controlled by blowers, fans, hot oil, 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 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.

HUMIDITY

High humidity (prevalent in tropical climates) is the "arch enemy" of electronic equipment. Its resultant damage to equipment parts is caused by condensation and fungus growth, under conditions of both highly salt-laden moist air and high temperature. 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 equipment, 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 electronics technician will not always have on hand the suitable sealing compounds 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.

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, protected 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.

CORROSIVE ATMOSPHERE

The effect of a corrosive atmosphere on metal parts and insulation can cause serious damage to unprotected electronic equipment. For this reason, the technician should be cognizant of the harmful effects of all corrosive elements. The technician must be especially aware of the effects produced by salt spray or salt-impregnated air. To prevent corrosive effects, a regular periodic cleaning schedule for most equipment has been established by PMS. This schedule normally includes dusting and cleaning, lubrication of the 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, and salt-impregnation. Failure to adhere to this regular periodic cleaning schedule can lead to degradation and early equipment failure. In addition, all access doors and panels should be securely fastened and in place when maintenance work is not being performed on the equipment.

In the event that a piece of electronic equipment becomes soaked with salt water or oil, or acquires a thick coat of oily dirt, the following procedure may be used to clean the equipment:

1. De-energize the equipment.
2. Disconnect and remove the drawers or units which are to be cleaned.

3. Remove all tubes, subassemblies, assemblies, cover plates, plug-in cables, and any parts which could be affected by water.

4. Move all of the items to a place near a source of fresh water, such as a shower stall.

5. Liberally wash down the items with fresh water; for oil and greasy dirt, use an approved dry-cleaning solvent or a nonionic detergent.

6. Rinse thoroughly with fresh water and allow the excess water to drain off.

7. Use clean, low-pressure air to blow out as much of the water as possible.

8. Completely dry the parts using heat lamps, electrical heaters, hot-air blowers, or the galley ovens. Be careful not to overheat the parts.

9. Clean out all connectors with solvent and pipe cleaners.

10. After the parts are dry, make visual inspections and resistance tests to locate damaged parts. Replace parts as necessary.

11. Reassemble and reinstall all parts of the equipment, and make all required tests and alignments as indicated in the technical manual.

TEST DATA

GENERAL NOTES

A. Test Equipment Required
Signal Generator AN/USM-44 or equivalent
RF Millivoltmeter CCVO-31-DA or equivalent
20-db, 50ohm attenuator (part of Power Measuring Set AN/USM-177B)
6-db, 50-ohm attenuator Microlab Type AA-06N or equivalent
Multimeter AN/PSM-4B or equivalent
Oscilloscope AN/USM-1400 or equivalent

B. If necessary, refer to paragraph 5-6.7 for troubleshooting sequence and figure 5-15 for physical location of test points.

SPECIFIC NOTES

1. Make the following preliminary control settings:

UNIT	CONTROL	POSITION
Switch Box SAXXX/SP	STOW-OPERATE switch 17S1	OPERATE
Radio Frequency Transmission Line Line Switch SA-XXX/U	DUMMY-NORMAL 1A1S3	Dummy load position
Electron Tube Liquid Cooler HD-XXX/SP	POWER switch 10S1	ON

2. Monitor scope set-up:

POWER switch - ON
OPERATION switch - REMOTE
TRIGGER SELECT switch - EXT
DELAY MULTIPLIER switch - OFF
VERTICAL GAIN control - CAL position

3. Test Steps:
(For steps out of tolerance, refer to paragraph 5-6.7.)

TS1 Refer to note 1 before performing test, except ignore pulse generator cabinet settings. Open outer door of receiver. Then open inner door while holding MOMENTARY INTERLOCK BYPASS switch 4S2 closed: engage PULLOUT TO BYPASS INTLK switch 4S1 before releasing switch 4S2. Connect tee-adapter between 4A3P1 and 4A3CP1. Connect probe of rf millivoltmeter to open end of tee-adapter. At control monitor, successively select each of the 20 channels using CHANNEL SELECTOR switch 6A3S2. Input measured on rf millivoltmeter should be at least 0.7 volt rms for each channel.

TS2 Same as TS1, except connect tee-adapter between 9A1P5 and 4A1J5.

TS3 Refer to note 1 before performing test, except ignore pulse generator cabinet settings. Set up control-monitor cabinet monitor scope per note 2. Place CONTROL POSITION switch 6A3S6 in LOCAL position. Place MONITOR DISPLAY SELECTOR switch 6A1S1 in Dx BIAS PULSE position.

TS4 Refer to note 1 before proceeding. Connect sync input of Oscilloscope AN/USM-140D to a tee-ad adapter connected between 20A1A1P1 and 20A1A1J1 (A trigger). Connect oscilloscope probe to test point via tee-adapter.

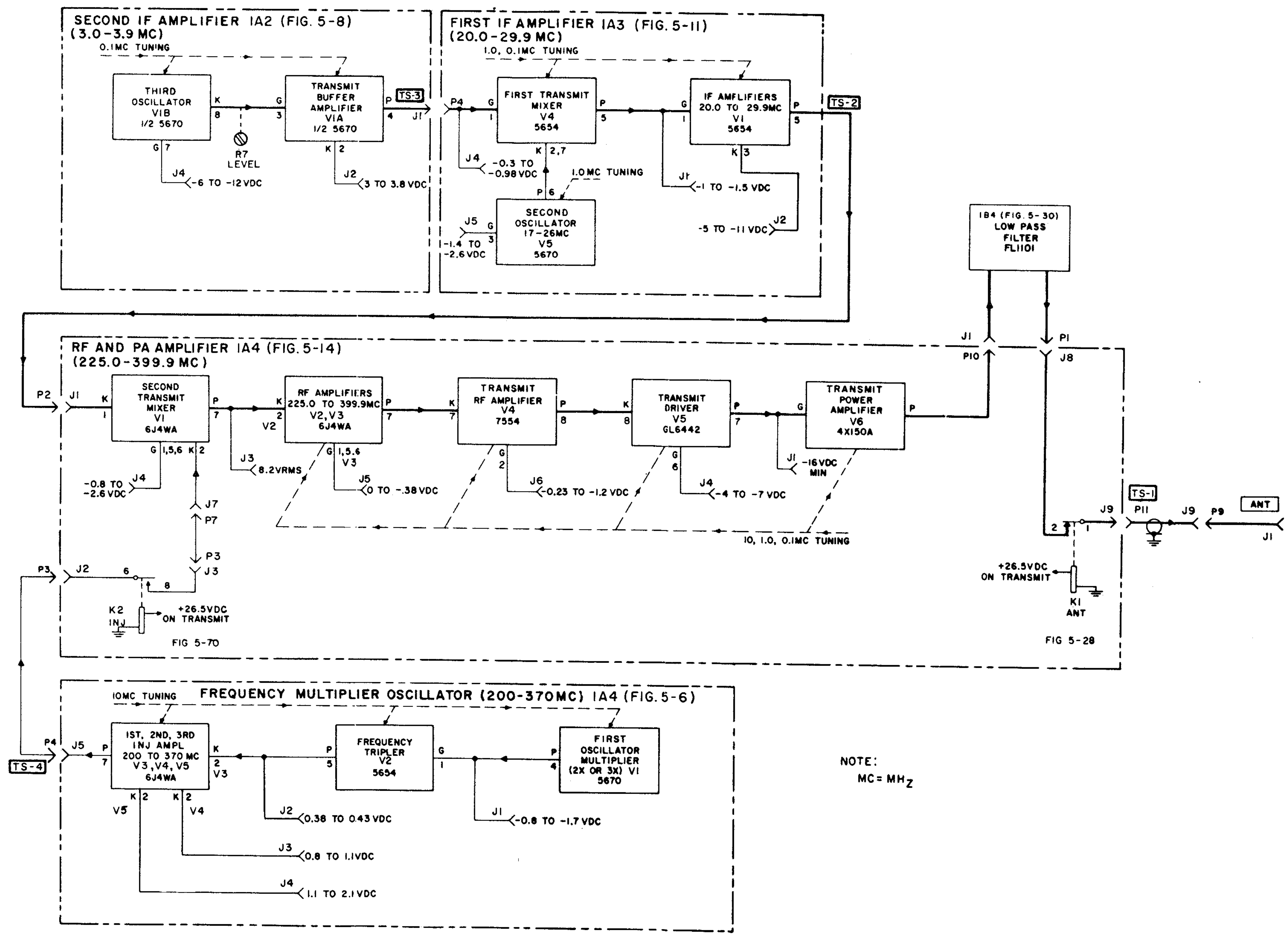

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Figure 1-8.—Functional signal flow diagram.

NOTE:

A. ALL RELAYS AND SWITCHES ARE SHOWN IN OPERATING POSITION.

PART LOCATION INDEX

Ref Des	Zone	Ref Des	Zone	Ref Des	Zone	Ref Des	Zone
DS1	7B	7DS3	2C	9K2-L2F	6C	9TB1-A6D	6B
DS2	7B	7DS4	3C	9K2-L2R	6C	9TB2-A7B	5B
DS3	7B	7DS5	3C	9K2-L3F	6C	9TB2-A8C	5B
1FL5	4A	7F1	2C	9K2-L3R	6C	9TB2-A8D	6B
1FL6	4A	7F2	3C	9K3-1F	3B	9TB2-A8E	5B
1T1	4A	7F3	3C	9K3-1R	3B	9XF1	2B
1TB2-A4H	4A	7T12	2C	9K3-2F	3B	9XF2	2B
3B1	3C	7TB10-15	2C	9K3-2R	3B	9XF3	2B
3FL42	4D	7TB10-16	2C	9K3-3F	4B	9XF4	6D
3FL43	4C	7TB10-17	2C	9K3-3R	4B	9XF5	6D
3FL44	4C	7TB10-18	2C	9K3-4F	4B	9XF6	6D
3TB3-A4C	4C	9CB1	7C	9K3-4R	4B	9XF10	4B
3TB3-A5C	4D	9F1	2B	9K4B-1B	2C	9XF11	3A
3TB3-A6C	4C	9F2	2B	9K4B-1T	2C	9A2T1	4A
3TB4-1	4D	9F3	2B	9K4C-2B	3C	9A2T2	3A
3TB4-2	4C	9F4	7C	9K4C-2T	3C	9A2TB3-4	4A
3TB4-3	4C	9F5	6C	9K4D-3B	3C	9A2TB3-4-1	4A
6T1	2A	9F6	6C	9K4D-3T	3C	9A2TB4-3	3A
6T2	2A	9F7	7B	9M1	3A	9A2TB4-4	3A
6T3	2A	9F8	7B	9S1A	3B	10B1	5D
6TB8-A78	5B	9F9	6B	9S1B	3B	10S1	6D
6TB15-A4A	2A	9F10	4B	9S2A	7D	10T1	5D
6TB15-A5A	2A	9F11	3A	9S3A	6D	10TB1-2	5D
6TB15-A6A	2A	9F12	5D	9T3	6B	10TB1-A7A	4D
6A5DS1	5B	9F13	5C	9T4	4B	10TB1-A8A	4D
6A5DS9	6B	9F14	5C	9T5	4B	10TB2-2	5D
6A5DS19	4D	9FL1	7C	9TB1-A4B	7D	10TB2-3	5D
6A5DS22	5B	9K1A-1F	2B	9TB1-A4C	5D	10A2F1	4D
6A5DS52	1C	9K1A-1R	2B	9TB1-A4D	7B	10A2T1	4D
6A5R1	5B	9K1B-2F	2B	9TB1-A5B	6D	10A2TB1-1	4D
6A5R9	5B	9K1B-2R	2B	9TB1-A5C	5C	10A2TB1-2	4D
6A5R19	4D	9K1C-3F	2B	9TB1-A5D	7B	14HR1	7A
6A5R22	5B	9K1C-3R	2B	9TB1-A5H	3A	14HR2	6A
6A5R52	1C	9K2-L1F	7C	9TB1-A6B	6D	14HR3	6A
7B2	3D	9K2-L1R	7C	9TB1-A6C	5C	14HR4	5A

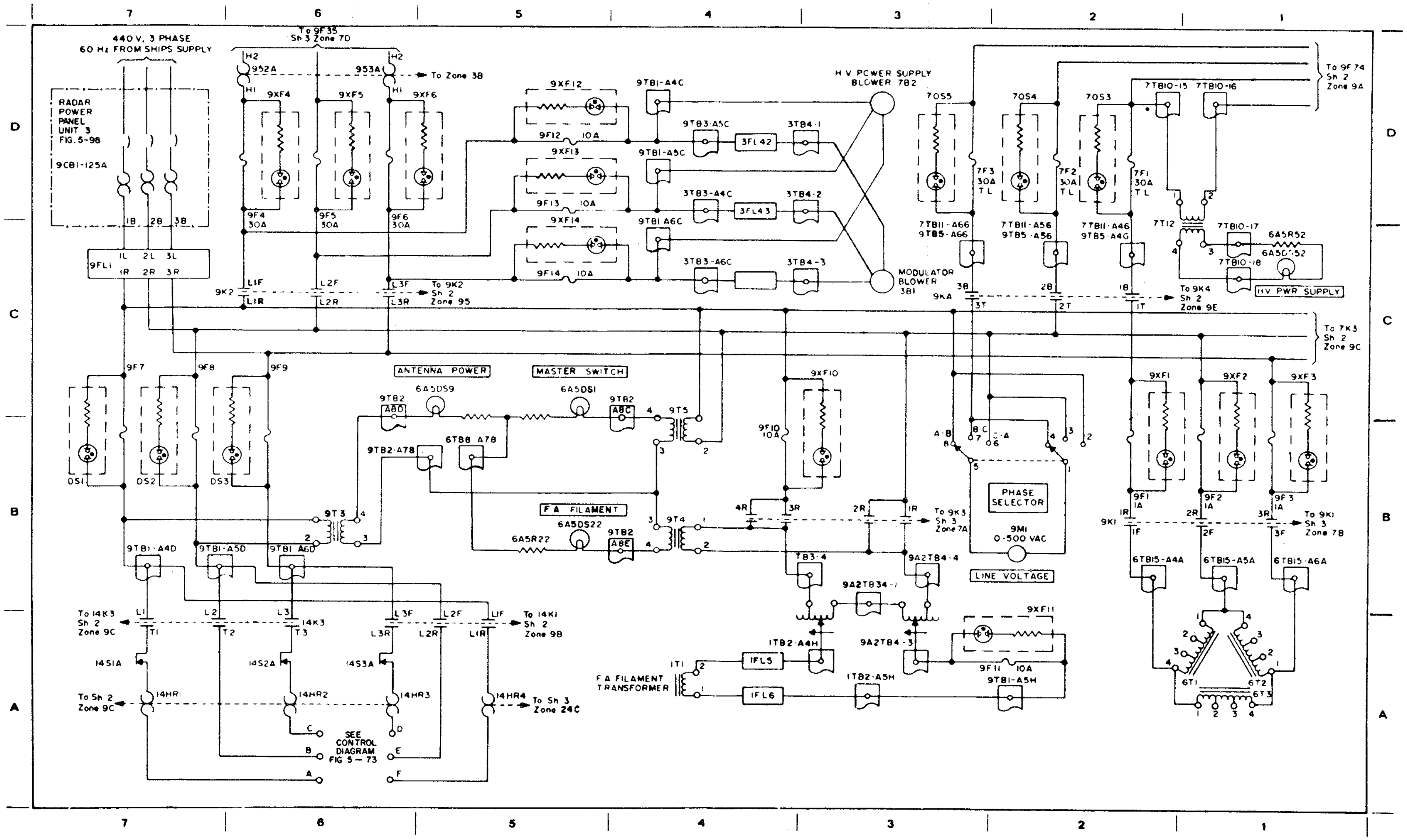

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Figure 1-10.—Power distribution diagram.

GENERAL NOTES

UNLESS OTHERWISE SPECIFIED:

A. ALL RESISTANCE VALUES ARE IN OHMS, 1/4W, ±5%.
B. ALL CAPACITANCE VALUES ARE IN MICROFARADS.
C. ALL DIODES ARE 1N916.
D. ALL TRANSISTORS ARE 2N718.
E. ◄◄— FEEDBACK

PART LOCATION INDEX

REF DES	ZONE	REF DES	ZONE	REF DES	ZONE	REF DES	ZONE
C1	6C	CR12	2C	R2	6C	R32	2B
C2	6C	CR13	2B	R3	6C	R33	2B
C3	6C	CR14	1C	R4	6C	R34	2B
C4	5C	CR15	1C	R5	6C	R35	3B
C5	5C	CR16	1C	R6	6C	R36	3B
C6	5C	CR17	2C	R7	6C	R37	6C
C7	4C	CR18	2C	R8	6C	R38	5B
C8	6A			R9	5C	R39	5B
C9	4C	DL1	2C	R10	5C	R40	5B
C10	4C			R11	5C	R41	5B
C11	3C	J102	6C	R12	5C	R42	5B
C12	3C			R13	5C	R43	4B
C13	3C	Q1	6C	R14	5B	R44	4B
C14	6A	Q2	5C	R15	4C	R45	2C
C15	2B	Q3	5C	R16	4C	R46	1C
C16	2B	Q4	4C	R17	6A	R47	6B
C17	3B	Q5	4C	R18	4C	R48	6B
C19	5B	Q6	3C	R19	4C	R49	5B
		Q7	2B	R20	4C	R50	5B
CR1	5C	Q8	2B	R21	4C	R51	6A
CR2	5C	Q9	3B	R22	4C		
CR3	4C	Q10	6B	R23	4C	T1	6C
CR4	3C	Q11	5B	R24	3C	T2	5C
CR5	3C	Q12	5B	R25	3C	T3	5C
CR6	3C	Q13	4B	R26	3C	T4	3C
CR7	3C	Q14	2C	R28	3C	T5	2C
CR8	3C	Q15	1C	R29	2B	T6	1C
CR9	2B			R30	2B		
CR11	4B	R1	6C	R31	2B	1AP1	1C

CAUTION

Use ohmmeter on highest usable scale to avoid damage to transistors.

VOLTAGE CHART

	E	B	C		E	B	C
Q_1	+2V	+1V	+10V	Q_{11}	+.5V	+.1V	+20V
Q_2	+3V	+2.8V	+17V	Q_{12}	+.6V	+.8V	+17V

SPECIFIC NOTES:

1. All voltage readings taken with equipment in STANDBY.

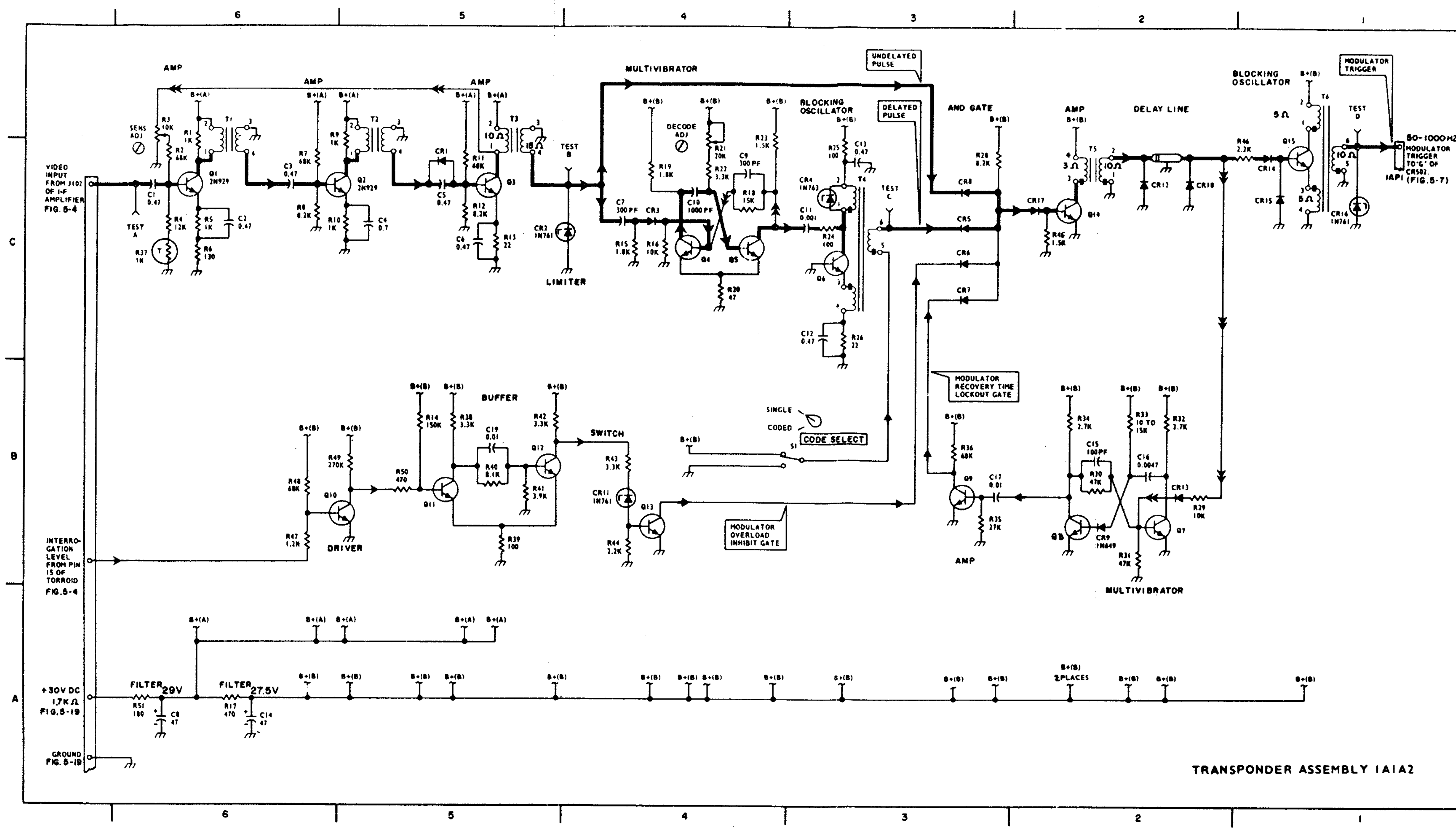

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Figure 1-11.—Maintenance schematic diagram.

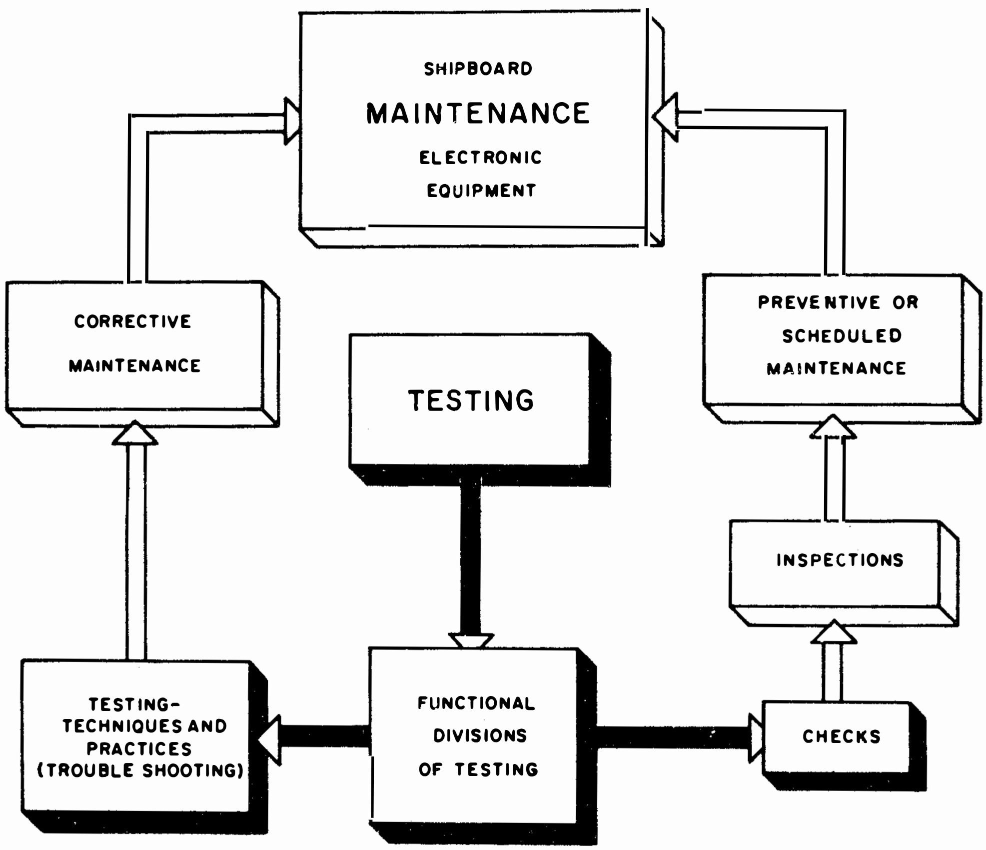
CHAPTER 2

USE OF TEST EQUIPMENT

As discussed in chapter 1 of this manual, all maintenance of Navy electronics equipment is divided into two main categories–preventive maintenance and corrective maintenance. As illustrated in figure 2-1, testing is the major function performed by the ET in carrying out maintenance.

Testing or test procedures may sometimes be referred to as tests, measurements, or checks. These terms are sometimes used interchangeably and overlap in meaning depending upon their use and the results obtained. For example, a power output MEASUREMENT and a frequency CHECK may constitute a TEST for the proper operation of a transmitter.

Basic testing procedures and some of the general purpose test equipment used by the ET are discussed in volumes 1 and 2 of *Basic*



162.112

Figure 2-1.—Electronic maintenance functional diagram.

Electronics, NAVPERS 10087-C, and the *Navy Electricity and Electronics Training Series (NEETS).* This chapter builds upon this information by presenting some of the safety precautions to be observed when using test equipment, and discussing additional test equipments and procedures.

TEST EQUIPMENT SAFETY PRECAUTIONS

The electrical measuring instruments included in portable test equipment are delicately constructed and require certain precautions when they are handled to avoid damaging them. In addition, there are precautions that must be observed while using portable test equipment to avoid injury to personnel.

Three precautions that apply to all electrical measuring instruments to avoid damage are as follows:

1. Avoid mechanical shock. Instruments contain permanent magnets, meters, etc., which are sensitive to shock. Heavy vibrations or shock can cause loss of calibration to the instruments.

2. Avoid exposure to strong magnetic fields. Strong magnetic fields may permanently impair the accuracy of an instrument by leaving residual magnetic effects in the magnet, iron parts, or in the magnetic materials used to shield the instruments. Locations subjected to strong magnetic fields include regions near the pole pieces of large motors and generators, degaussing coils, electrical propulsion cables, submarine main storage battery leads, and radar magnetrons.

3. Avoid excessive current flow. This includes various precautions, depending on the type of instrument. When in doubt, use the maximum scale range of the instrument. Connections should be made while the circuit is deenergized if possible and then all connections checked to ensure that the instrument will not be overloaded before energizing.

Precautions to be observed to avoid instrument damage include the following:

1. Keep in mind that the coils of wattmeters, frequency meters, and power meters may be carrying excessive current even when the meter pointer is on scale.
2. Secondaries of current transformers should never be short-circuited when the primary is energized.
3. Secondaries of potential transformers should never be short-circuited when the primary is energized.
4. Ensure that meters in motor circuits can handle the motor starting current which may be as high as 6 or 8 times normal running current.
5. Never leave an instrument connected with its pointer off-scale or deflected in the wrong direction.
6. Never attempt to measure the internal resistance of a meter movement with an ohmmeter, as the movement may be damaged by the current required to operate the ohmmeter.
7. Never advance the intensity control of an oscilloscope to a position which causes an excessively bright spot on the screen or permits a sharply focused spot to remain stationary for any length of time.
8. When checking electron tubes with a tube tester always perform the inter-element short test first. If the tube is shorted, no further tests should be made.
9. Before measuring resistance, always discharge capacitors in the circuit to be tested. Note and record any points not having bleeder resistors or discharge paths for capacitors.
10. Always disconnect voltmeters from field circuits or other highly inductive circuits before the circuit is opened.

Situations can arise during the use of portable test equipment that are extremely dangerous to personnel. For example, an oscilloscope may be plugged into one receptacle, an electronic voltmeter plugged into another, and a soldering iron in still another, using an extension cord, or many other combinations. Some of the hazards presented by situations such as these are coming into contact with live terminals or test leads, or accidentally throwing the equipment to the deck due to a sudden roll or pitch of the ship, which may possibly entangle personnel in the leads or cords and cause severe or fatal shocks. In addition, the situation may be such that a potential difference exists between the metal cases of two or more instruments sufficient to cause harmful shocks.

Wires attached to portable test equipment should extend from the back of the instruments away from the observer if possible. If this is not possible, they should be clamped to the bench or table near the instruments.

When used in places where vibration is present, the instruments should be placed on pads of folded cloth, felt, or similar material. Additional precautions are necessary when using portable test equipment during heavy seas.

Precautions to be observed to avoid injury to personnel include the following:

1. Ensure that the metal cases of all instruments are grounded.
2. Ensure that one side of the secondary of external instrument transformers is also grounded.
3. If equipment must be energized for testing after removal from its normal rack or mounting, ensure that all parts normally at ground potential are securely grounded.
4. Avoid testing voltages in excess of 300 volts when holding test probes in the bare hands.

BASIC MEASUREMENTS

Basic electrical and electronic measurements involve the fundamental electrical quantities (voltage and current) and the inherent circuit characteristics (resistance, capacitance, and inductance).

VOLTAGE AND CURRENT

Voltage measurements, when compared with voltage charts provided for a specific piece of equipment, are a valuable aid in locating trouble quickly and easily. However, if the sensitivity of the test voltmeter differs from that of the voltmeter used in preparing the chart, the voltage measurements must be evaluated before the true circuit conditions can be determined. It should be kept in mind that in certain cases a voltmeter, particularly one of low sensitivity used on a low range, may disturb some circuits to such a degree as to render them inoperative.

Since many troubles encountered in equipment and systems result from or cause abnormal voltages, voltage measurements are considered indispensable in locating trouble. Testing techniques that utilize voltage measurements have the advantage over other tests of not interrupting circuit operation. Point-to-point voltage measurement charts, which contain the normal operating voltages encountered in the various stages of the equipment, are available to the technician. These voltages are usually measured between the indicated points and ground, unless otherwise stated. When voltage measurements are taken, it is considered good practice to set the voltmeter on the highest range initially, so that any excessive voltages existing in a circuit will not cause overloading of the meter. To obtain increased accuracy, the voltmeter may then be set to the designated range for the proper comparison with the representative value given in the voltage charts. When checking voltages, it is important to remember that a voltage reading can be obtained across a resistance, even if that resistance is open. The resistance of the meter (and the multipliers) forms a circuit resistance when the meter prods are placed across the open resistance. Thus, the voltage across the part may appear to be approximately normal, as read on the meter, but may be abnormal when the meter is disconnected from the circuit. Therefore, to avoid unnecessary delay in troubleshooting, it is good practice to make a resistance check on a "cold" circuit (before applying power) to determine whether the resistance values are normal.

If the internal resistance of the voltmeter and multiplier is approximately comparable in value to the resistance of the circuit under test, it will indicate a considerably lower voltage than the actual voltage present when the meter is removed from the circuit. The sensitivity (in ohms per volt) of the voltmeter used to prepare the voltage charts is always given on those charts, therefore, if a meter of similar sensitivity is available, it should be used, so that the effects of loading will not have to be considered.

The following precautions are general safety measures, pertinent to the measurement of voltages, that you should follow when working with electronic equipment. You should constantly keep in mind that almost all voltages are dangerous and can possibly be fatal if contacted. When it is necessary to measure high voltages, the following precautions should be observed:

1. Connect the ground lead of the voltmeter first. While making measurements, place one hand in a pocket or behind the back.
2. If the voltage to be measured is less than 300 volts, place the end of the test probe on the point to be tested, which may be either positive or negative with respect to ground.

If the voltage to be measured is more than 300 volts, proceed as follows: shut off the circuit power, discharge any filter capacitors and pulse-forming networks several times, and temporarily ground the point to be measured; then connect (clip on) the proper test lead to the high potential point (remove the temporary ground), and move away from the voltmeter. Turn on the circuit power and read the voltmeter. Turn off the circuit power again and discharge any capacitors and pulse-forming networks several times before disconnecting the meter.

Current measurements, as a rule, are not often taken in the course of testing, unless the ammeter (or other current-measuring meter) is an integral part of the equipment being tested. Current measurements are infrequently used because in most cases the circuit must be opened (unsoldered) for the necessary series connection of the ammeter. Usually, a voltage measurement and a calculation by means of Ohm's law are sufficient to determine the circuit current. In a circuit of extremely high resistance, a current measurement is inadvisable because the current may be so low that it cannot be measured accurately with ordinary test equipment.

RESISTANCE

Resistance measurements are valuable in locating trouble, hence, many maintenance handbooks contain resistance charts which are referenced to accessible points (usually tube sockets) within the equipment. Without these charts, making resistance measurements in a complex circuit is a slow process, sometimes necessitating the unsoldering of one side of a particular resistor or group of resistors in order to prevent erroneous readings as a result of shunting circuits. It is important that the operation of ohmmeters and the calibration of their scales be understood, especially on the high ranges, since often it is impossible to attain reasonable accuracy when the meter is operated at its maximum range. For best results select a range that will indicate a near mid-scale reading on the meter.

For an ohmmeter to be used for troubleshooting, portability, convenience, and speed are considered of greater importance than extreme accuracy. Resistor tolerances vary so widely that approximate resistance readings are adequate for most jobs, with the exception of bridge circuits, voltage dividers, and balanced circuits. Two precautions to be observed when an ohmmeter is used are: (1) the circuit under test (including heaters of tubes) must be completely deenergized; and (2) any meters, tubes, or transistors which may be damaged by the ohmmeter current must be removed before any measurement is made. It is not practicable to measure very low values of resistance with an ohmmeter, because of the effect of lead and contact resistance and the possibility of damage to the electronic parts under test. For precision measurement of low values of resistance, a special type of bridge instrument must be used.

ELECTRICAL METERS

A thorough understanding of the construction, operation, and limitations of electrical measuring instruments, coupled with the theory of circuit operation, is most essential in servicing and maintaining electrical equipment. Remember that the best and most expensive measuring instrument is of NO use to the person who does not know what is being measured or what the readings indicate.

The three types of meters that will most frequently be encountered are the ammeter, ohmmeter, and voltmeter. It is well to pay special attention to each application in the following discussion.

The **AMMETER** is used to measure current. It must always be placed in series with the circuit to be measured. The ammeter consists of a basic meter movement and a combination of shunt resistors in parallel with it. A multiposition switch or a series of pin jacks is used to allow the use of various sizes of shunt resistors to give different current ranges. When using an ammeter, always have the meter on the highest range before connecting it to a circuit.

The **OHMMETER** is widely used by electronic technicians in making resistance measurements and continuity checks. Technicians will find wide use for this instrument in checking cables and locating malfunctioning components in electrical circuits. The ohmmeter consists of a basic meter movement connected as an ammeter, a voltage source, and one or more resistors used to adjust the current through the meter movement. The meter must be adjusted for "zero resistance" prior to making resistance measurements. Care must also be exercised not to use an ohmmeter on an energized circuit.

The **VOLTMETER** utilizes the basic meter movement by placing a high resistance in series with it. The value of this series resistance is determined by the current necessary for fullscale deflection of the meter and the voltage being measured. Because the current is directly proportional to the voltage applied, the scale can be calibrated directly in volts for a fixed series resistance.

The sensitivity of voltmeters is given in ohms per volt, and may be determined by dividing the resistance of the meter plus the series resistance by the full-scale reading in volts. This is the same as saying that the sensitivity is equal to the reciprocal of the current (in amperes). Thus, the sensitivity of a 100-microampere movement is the reciprocal of 0.0001 ampere or 10,000 ohms per volt. The sensitivity of the meter depends on the strength of the permanent magnetic field and the weight of the moving coil.

The sensitivity of a voltmeter is an identification of how accurately it measures voltages in a circuit. In many cases, a sensitivity of 1,000 ohms per volt is satisfactory; however, if the circuit in which the voltage is being measured has high resistance, a greater sensitivity is required for accuracy. The higher the sensitivity rating, the higher the resistance in the meter branch of the circuit, and the less the possibility of the meter shunting the circuit. If a meter of low ohms per volt is used to measure the voltage in a high resistance circuit, the meter will shunt the load being measured and result in an inaccurate reading. Thus, the higher the sensitivity, the more accurate is the reading.

Like the ammeter and ohmmeter, the voltmeter normally utilizes several resistors with a switching arrangement to permit multirange operation. The importance of setting the selector switch for maximum voltage range before connecting it to an energized circuit cannot be overemphasized.

In the selection of an a.c. voltmeter, the frequency and waveform of the voltage being measured must be taken into consideration. Although some a.c. voltmeters react to the peak value and others to the average (of one alternation) value, most a.c. voltmeters are calibrated to indicate effective (root-mean-square) values of voltage. (Rms is explained in *Basic Electricity,* NavPers 10086-B and the *Navy Electricity and Electronics Training Series (NEETS).)*

MULTIMETERS

Multimeters capable of measuring a.c. voltages utilize conventional d.c. meter movements and metallic oxide rectifiers to change the a.c. to d.c. Most multimeters have an accuracy of two to five percent at low frequencies. However, the shunt capacity of the metallic oxide rectifiers affects the accuracy of the multimeter as the frequency of the voltage being measured increases. When the frequency is above the audio range, the voltage reading is no longer accurate. Where accuracy at the higher frequencies is desired, an electronic multimeter or an a.c. vacuum tube voltmeter should be used.

MULTIMETER AN/PSM-4C

The multimeter AN/PSM-4C (fig. 2-2) is designed to permit the technician to make measurements of voltage, resistance, and current

Figure 2-2.—Multimeter AN/PSM-4C. **243.371**

with a completely self-contained portable instrument. It can measure either a.c. or d.c. voltage, d.c. resistance, or direct current in a wide range of values. This capability covers the basic requirements for a portable tester of this type. All leads and accessories are stored in a compartment built into the cover, which should remain with the instrument at all times. The cover forms a watertight seal when clamped over the face of the meter. While the instrument is in use, the cover clamps over the back of the meter keeping the accessory compartment convenient to the operator. Batteries used with the meter are: one BA-30 (1.5 volts) and one BA-261/U (22.5 volts).

In the accessory compartment there is a pair of standard test leads (one red and one black) which are used for most applications of the instrument. These leads have elbow probes on one end to connect the lead into the circuit jacks on the instrument. They have probe tips on the other end, which have threaded shoulders to accept the alligator clips which are screwed on. These parts are used to make all measurements, except d.c. voltage over 1,000 volts.

For measuring d.c. voltages over 1,000 volts, a special high-voltage probe is provided, and is used in conjunction with the standard black lead. One end of the lead has a threaded tip which screws on a post in the face of the meter (labeled 5,000 VDC MULTIPLIER). The other end of the lead has a high-voltage multiplier assembly made of red plastic with a clear plastic end and terminates in an alligator clip at the end of a short piece of flexible wire. The clear plastic end allows the operator to observe the glow of a neon lamp when there is high voltage present. This is a warning to the operator that there is high voltage present at the clip and the operator should not touch it. The neon lamp is in series with a 100-megohm resistor within the housing. When a high voltage is being measured, the current passes through the lamp making it glow, through the resistor, and through the armature of the meter.

There are three controls on the face of the meter. One is a 10-position rotary switch in the lower left-hand corner which is used as a function switch. Five of the positions on this switch are used to set up different resistance scales. Two of the positions are for selection of d.c. voltage measurement (direct and reverse). The normal position of the switch is in the DIRECT position. If a negative voltage is to be measured, the switch is moved to the REVERSE position. (NOTE: Never switch leads to read a reverse or negative voltage.) One position of the switch is marked ACV; in this position the meter may be used to read a.c. voltage. A rectifier in the instrument changes the a.c. voltage to an equivalent d.c. value which is applied to the meter. One position is marked OUTPUT; in this position the a.c. portion of mixed a.c. and d.c. voltage may be read. The last position of the switch is used when measuring direct current and is marked DC with three ranges (μA, MA, AMPS) indicated to the right of the letters DC. In the lower right-hand corner is an eight-position switch used to select current and voltage ranges. Near the center of the meter is a control marked ZERO OHMS. This control, which is a continuously variable adjustment, is used to zero the meter thus compensating for battery aging in the ohmmeter circuits. This control is adjusted until the meter indicates full-scale deflection (indicating zero ohms) when the function switch is set at one of the resistance range positions and the meter probes are shorted together. To prevent erroneous readings when switching to a different position, a check of the meter zero indication is always necessary.

The Multimeter AN/PSM-4C is designed to make the following electrical measurements:

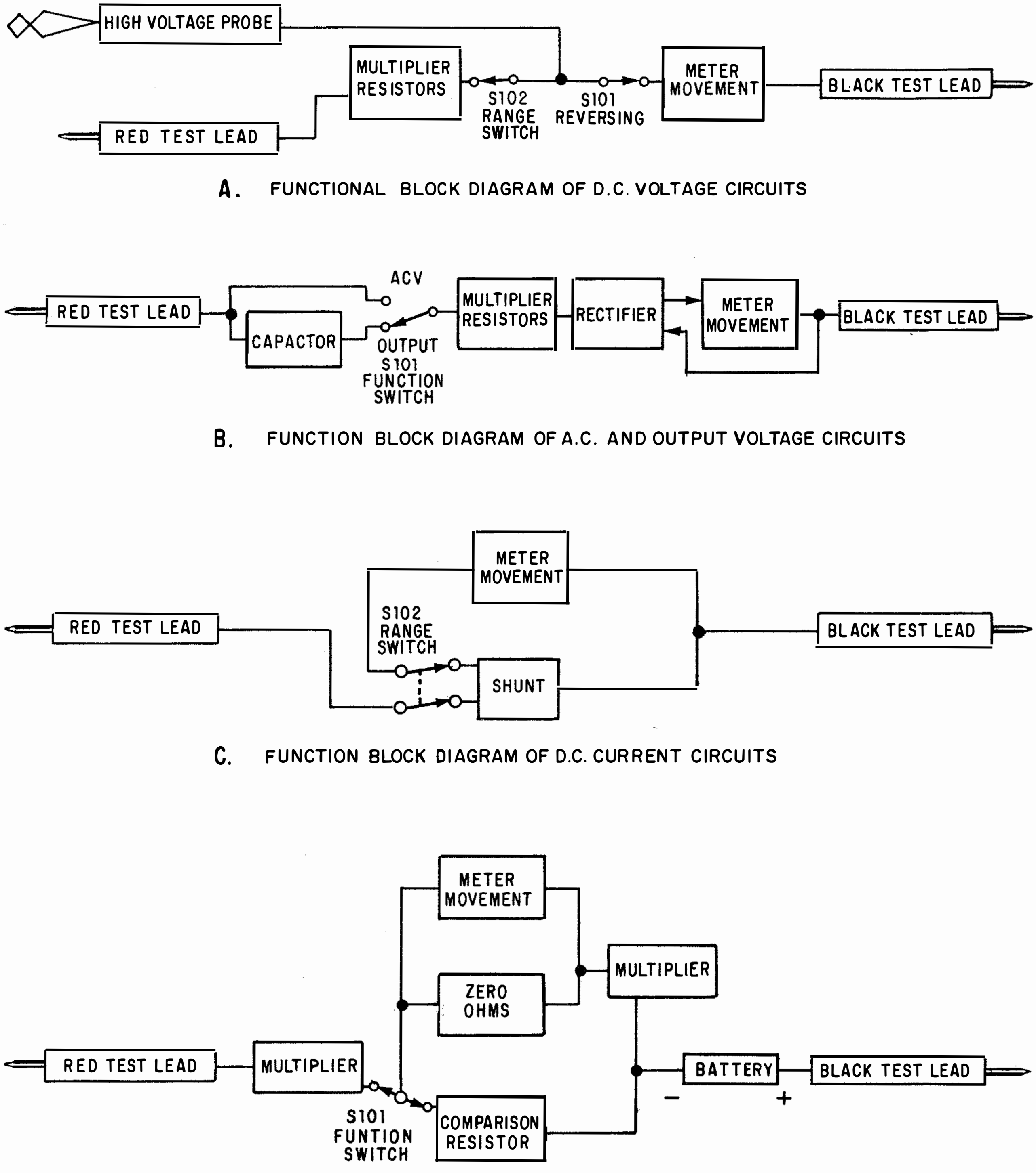
1. Measure direct current up to 10 amperes
2. Measure resistances up to 300 megohms
3. Measure d.c. voltages up to 5,000 volts
4. Measure a.c. voltages up to 1,000 volts
5. Measure output voltages up to 500 volts

Input impedance for measuring d.c. voltages is 20,000 ohms per volt and is accurate to within three percent of fullscale (four percent for the 5,000 VDC scale). When measuring a.c. voltages, the input impedance is 1,000 ohms per volt and is accurate to within five percent of full scale.

The following discussion and the associated block diagrams treat the general circuit within the instrument part of the multimeter as it is arranged when used to measure voltage, current, or resistance.

D.C. Voltmeter Circuits

The block diagram of the circuit in Multimeter AN/PSM-4C which is used for measuring d.c. voltages is shown in figure 2-3A. The circuit is selected with function switch S-101, in either its DIRECT or REVERSE DCV position. For voltages up through 500 volts, a range is selected with range switch S-102 (only one position shown in figure 2-3A). For the 1000 volt range, the red test lead connects into the special 1000 VDC jack, and the range switch is not in the circuit. For the 5000 volt range the high-voltage probe (not shown) connects the special 5000 VDC jack, and places its resistance in series with the meter movement. For any range, the total resistance in series with it will regulate the meter current to provide a proportional current to indicate the amount of voltage in the circuit.



A. FUNCTIONAL BLOCK DIAGRAM OF D.C. VOLTAGE CIRCUITS

B. FUNCTION BLOCK DIAGRAM OF A.C. AND OUTPUT VOLTAGE CIRCUITS

C. FUNCTION BLOCK DIAGRAM OF D.C. CURRENT CIRCUITS

D. FUNCTIONAL BLOCK DIAGRAM OF OHMMETER CIRCUITS

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Figure 2-3.—Functional block diagram of AN/PSM-4C.

A.C. and Output Voltage Circuits

The circuits which measure a.c. and output voltages (fig. 2-3B) are selected with the ACV and OUTPUT positions of function switch S-101. For voltages up through 500 volts, a range is selected with range switch S-102. For the 1000 volt range, the red test lead connects into the special 1000 VAC jack, and the range switch, S-102, is not in the circuit. The a.c. voltage impressed across the circuit between the red and black test lead sends current through the resistance of the circuit in both directions, but the rectifier allows only one direction of current flow through the meter movement. The meter is calibrated to indicate the rms value of the a.c. voltage applied to the instrument circuit.

D.C. Current Circuits

The circuit which measures d.c. currents (fig. 2-3C) is selected with the DC μA MA AMPS position of function switch S-101. For currents up to 1000 milliamperes, the range is selected with range switch S-102. For the 10-ampere range, the red test lead connects into the special ten AMPS jack, and range switch S-102 is not in the circuit. Each range provides a parallel shunt resistance for the meter movement, and the circuit current divides between these two parallel paths. The proportional part which passes through the meter movement indicates the total circuit current.

Ohmmeter Circuits

The ohmmeter circuit (fig. 2-3D) and its ranges are selected with function switch S-101. Its positions are Rx1, Rx10, Rx100, Rx1000, and Rx10000. An internal battery furnishes the power for all resistance measurements. For each range, the circuit is arranged so the meter will indicate zero ohms and full-scale deflection whenever the red test lead and the black test lead are shorted together. When a resistance is connected between the test leads, this resistance will be in series with the instrument circuit, and less current will flow through the meter movement. The amount of reduced meter deflection indicates how much resistance is between the test leads.

Application

Function switch S-101 (fig. 2-2), located in the lower left-hand corner of the front panel, selects the type of circuit for which the instrument is connected. There are two positions for d.c. volts: DIRECT AND REVERSE. The normal position is DIRECT. When using the meter to make a d.c. voltage measurement and a connection is made which causes the meter to read backwards (deflection of the pointer to the left), set switch S-101 to REVERSE and the pointer will be deflected up-scale. Set switch S-101 at ACV to read alternating current voltages. A rectifier within the instrument will change the a.c. voltage to an equivalent d.c. value and apply this to the meter. The instrument will indicate the rms value of the applied voltage. Set switch S-101 at OUTPUT to read the a.c. portion of mixed a.c. and d.c. voltages. Set switch S-101 at DC μA MA AMPS to read direct current. Set switch S-101 at Rx1, Rx10, Rx100, Rx1000, or Rx10000 to read resistance. Switch S-101 also serves as a range switch for resistance measurements.

Range Switch S-102

This eight-position range switch, located in the lower right corner of the front panel, permits the selection of voltage and current ranges. The full-scale value for each range switch position is marked on the front panel.

Zero Ohms Control

The ZERO OHMS control is located near the center of the front panel. Each time the function switch S-101 is placed in a position to read resistance, short the test leads together and rotate the ZERO OHMS control knob to make the pointer read full scale, or zero ohms. If it cannot bring the pointer to full scale, replace the battery in the rear of the case.

Under normal conditions, no routine service inspection is necessary beyond visual examination at established inspection periods. If the instrument is to be stored for periods of six months or longer, the batteries must be removed to prevent corrosion. The periodic inspection should include removal of the battery case cover to facilitate inspection of battery connections. If the instrument is used under extreme temperature conditions, a visual inspection of all parts should be made at least once a month. No periodic maintenance is required except for inspection, test, and replacement of batteries.

ELECTRONIC METERS

Electronic meters are used primarily for the same purposes as are the nonelectronic meters. Some characteristics of their operation, however, give them definite advantages. In the electronic multimeter, the current and resistance measuring circuits function in a manner identical to the corresponding nonelectronic measuring instruments. The measurement of voltage, however, involves the use of an amplifier, which in turn requires that the meter be calibrated prior to use.

Proper calibration and use of the instruments vary slightly according to the model. Details are included in the Operation Instruction Manual for each model.

The ordinary voltmeter has several disadvantages that make it practically useless for measuring voltages in high-impedance circuits. For example, suppose that the plate voltage of a pentode amplifier is to be measured. (See fig. 2-4.) When the meter is connected between the plate and cathode of the electron tube, the meter resistance, R_m, is placed in parallel with the effective plate resistance, R_{eff}, thereby lowering the effective plate resistance. The effective plate resistance is in series with the plate load resistor, R_L, and this series circuit appears across the supply voltage, E_{bb}, as a voltage divider. Since the overall resistance is lowered, it follows that current through R_L will increase, the voltage drop across R_L will also increase, and the voltage drop across R_{eff} will decrease. The result is an incorrect indication of plate voltage, and is called loading effect.

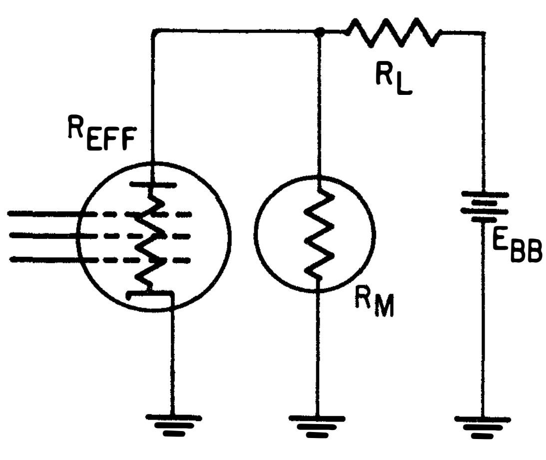

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Figure 2-4.—Loading effect created by meter resistance.

Calculation of Loading Effects

Before the voltmeter is connected, the plate current is determined by the effective resistance of the plate circuit, the plate load resistor, and the plate voltage. If the tube has an effective resistance of 100,000 ohms, a plate load resistance of 100,000 ohms, and the plate power supply is constant at 200 volts, then the plate current is

$$\frac{200 \text{ v}}{200{,}000\Omega}$$

or 0.001 ampere. The plate voltage (plate to cathode) is 0.001 x 100,000, or 100 volts.

Assume that the voltmeter used to measure the plate voltage of the tube has a sensitivity of 1,000 ohms per volt and that the selected meter range is from 0 to 250 volts. The meter will then have a resistance of 250,000 ohms. This resistance in parallel with the tube resistance of 100,000 ohms produces an effective resistance of 71,400 ohms in series with the plate load resistor. The total resistance across the plate voltage supply is therefore 171,400 ohms instead of the 200,000 ohms before the meter was applied, and the current through the plate load resistor is

$$\frac{200 \text{ v}}{171{,}400\Omega}$$

or 0.00117 ampere. Across the plate load resistor the voltage drop is 0.00117 x 100,000, or 117 volts, and the plate-to-cathode voltage on the tube is 200 - 117, or 83 volts when the meter is connected, thus causing an error of 17 volts. The lower the sensitivity of the meter, the greater the error will be; in this example, the error of 17 volts when the reading should be 100 volts is a 17-percent error.

A meter having a sensitivity of 20,000 ohms per volt and a 250-volt maximum scale reading would introduce an error of about one percent. However, in circuits where very high impedances are encountered, such as in grid circuits of electron tubes, even a meter of 20,000 ohms-per-volt sensitivity would impose too much of a load on the circuit.

VTVM Advantages

Another limitation of the alternating current, rectifier-type voltmeter is the shunting effect at high frequencies of the relatively large capacitance of the meter's rectifier. This shunting effect may be eliminated by replacing the usual metallic oxide rectifier with a diode electron tube; the output of the diode is applied to the grid of an amplifier in which the plate circuit contains the d.c. meter. Such a device is called an electron-tube voltmeter or a vacuum-tube voltmeter, usually abbreviated vtvm. Voltages at frequencies up to 500 megahertz, and sometimes even higher, can be measured accurately with this type of meter. The frequency limitation is determined by the model of vtvm.

The input impedance of a vtvm is large, and therefore the current drawn from the circuit whose voltage is being measured is small and in most cases negligible. The main reason for using a vacuum-tube voltmeter is to overcome the loading effect by taking advantage of the vtvm's extremely high input impedance. A vtvm that is used extensively for electronics maintenance is contained in the AN/USN-116 Multimeter.

Vacuum Tube Voltmeter AN/USM-116

Multimeter AN/USM-116 is a portable, combination electronic instrument used for general servicing of electronic equipment. It is designed for use where precise voltage, current, and resistance measurements are required. It provides a direct reading of values on a single indicating meter mounted on the control panel (fig. 2-5). A high-input impedance permits

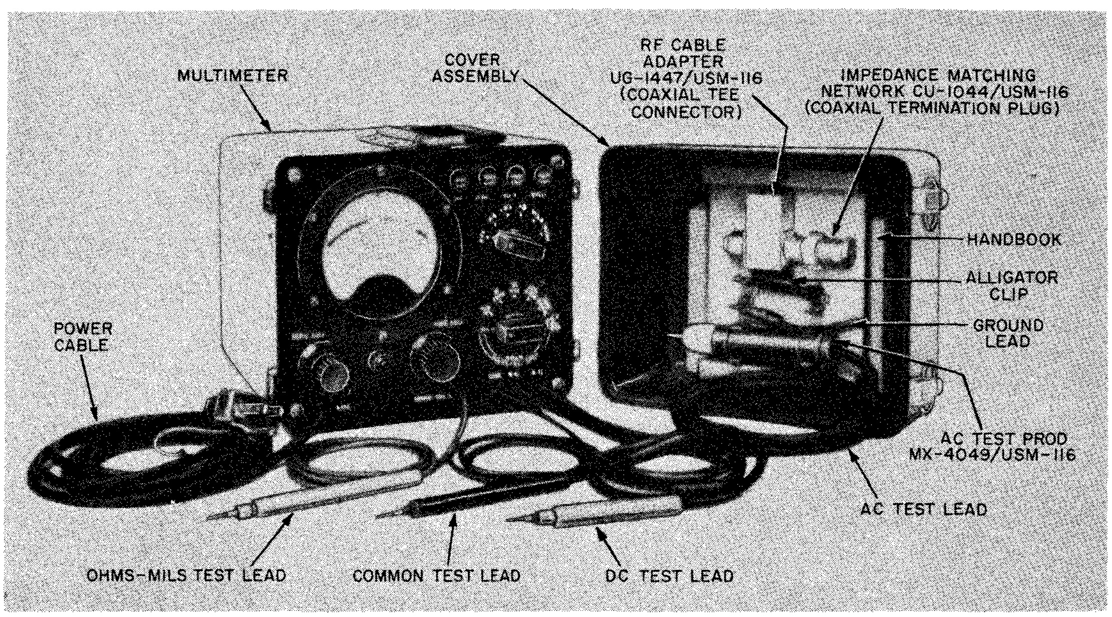

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Figure 2-5.—Electronic Multimeter AN/USM-116.

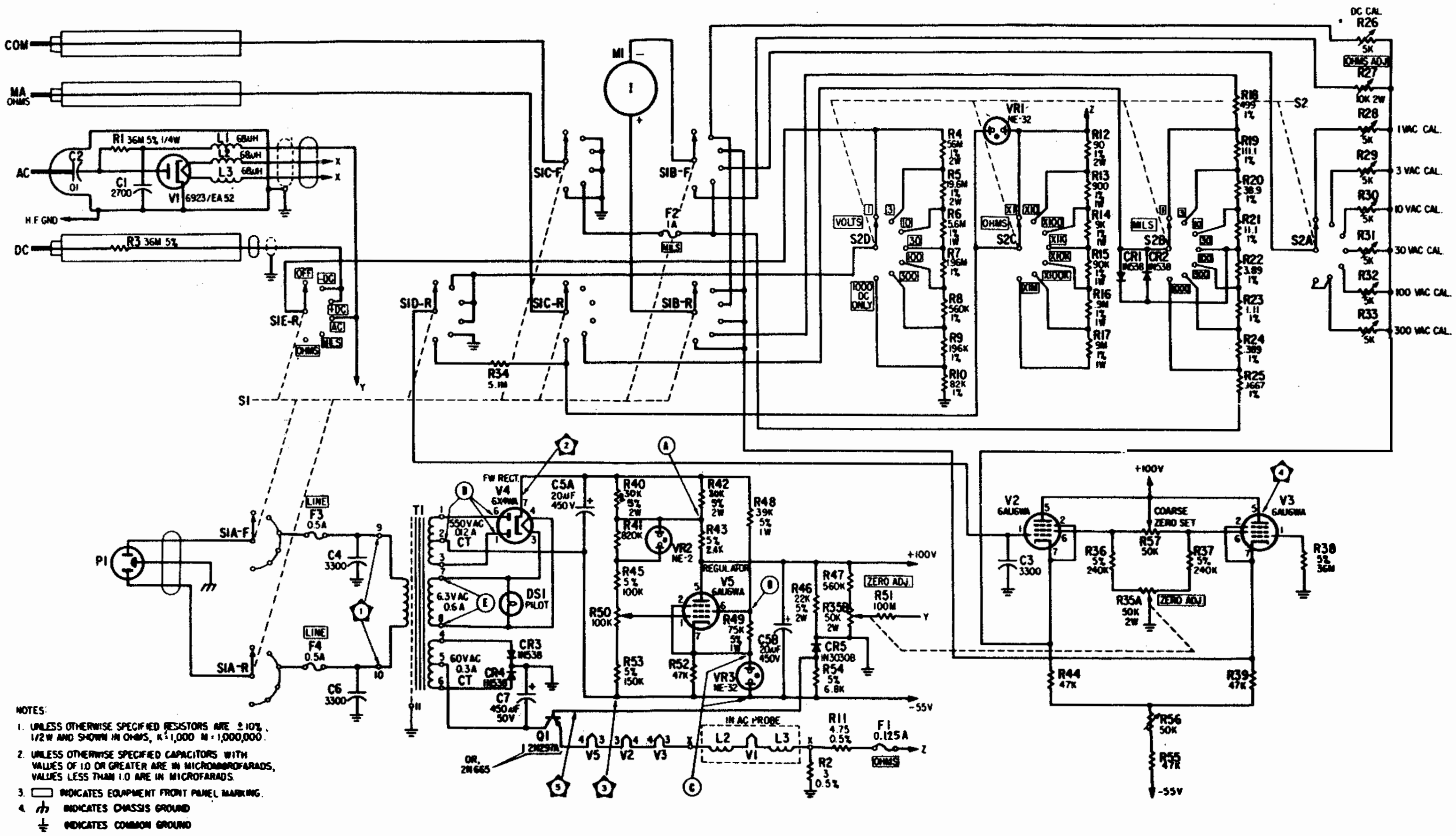

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Figure 2-6.—Electronic Multimeter AN/USM-116, schematic diagram.

voltage measurements to be made with only a small percentage of loading on the circuit under test. The multimeter can measure the following: alternating current voltages and radiofrequency voltages which are indicated in rms values (actual deflection is proportional to the rectified peak value), a.c. volts, d.c. current, and resistance. The specific ranges for each of these functions are as follows:

1. a.c. volts: 0.01 to 300 in rms values
2. d.c. volts: 0.02 to 1,000
3. d.c. current: 20 microamperes to 1,000 milliamperes
4. Resistance: 0.2 ohm to 1,000 megohms

To understand the principles upon which the operation of Multimeter AN/USM-116 is based, refer to figure 2-6 while reading the following explanation.

The multimeter can measure a.c. and d.c. voltages as well as resistance and current. When measuring a.c. voltages, the signal is first rectified by the diode in the probe. The signal must be rectified because the meter circuit is sensitive only to d.c. voltages. When d.c. voltages are measured, the a.c. probe containing the diode rectifier is not needed.

The d.c. or a.c. voltage to be measured is applied across a voltage-divider network so that the total input impedance of the multimeter remains constant when the position of range switch S2 is changed for various levels of input voltage.

The meter is connected across a balanced bridge network. With no input, the bridge circuit is balanced and the meter reads zero. When the bridge is unbalanced by an input voltage, the meter pointer is deflected up-scale. Switch S2 is used to connect the necessary resistance into the circuit for each range. The resistance across the voltage-divider networks reduces the input signal to a level suitable for application to the bridge. There are three voltage-divider networks, one for each function.

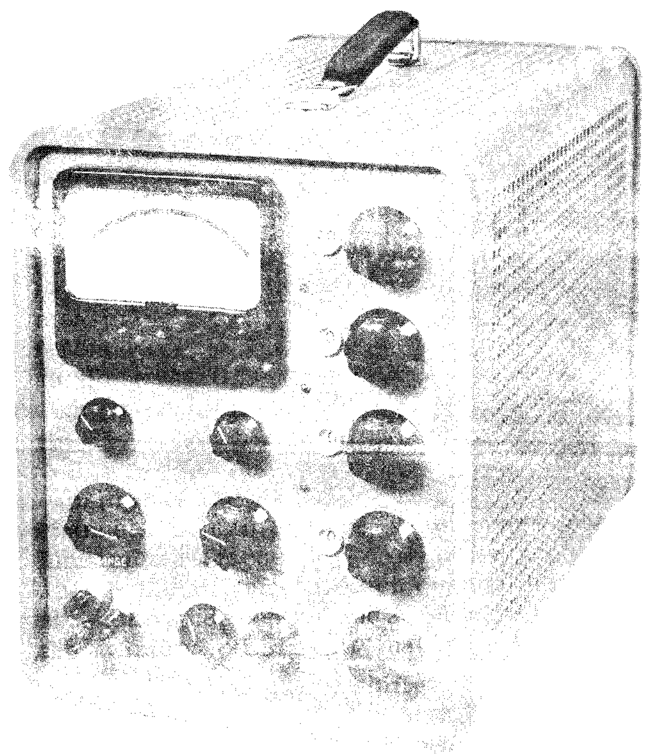
The ohmmeter section also utilizes the bridge circuit. When an unknown resistance is placed between the OHMS-MILS lead and the COM lead, the bias voltage on V2 decreases in proportion to the unknown resistance. The value of the unknown resistance determines the degree to which the bridge is unbalanced and hence the magnitude of the meter pointer deflection. No battery supply is required for the ohmmeter circuitry.

The milliammeter function does not make use of the bridge circuit. The range switch S2 connects various shunts across the meter to increase the range of current measurement.

A voltage regulator V5 tends to maintain the B+ supply voltage to tubes V2 and V3 at a constant value despite changes in line voltage.

Differential Voltmeter

The differential voltmeter is a reliable precision item of test equipment. Its general function is to compare an unknown voltage with an internal reference voltage, and to indicate the difference in their values. The differential voltmeter in most common use in Navy applications is the 803D/AG (fig. 2-7), manufactured by the John Fluke Co.



124.375
Figure 2-7.—Differential Voltmeter, Model 803D/AG.

The 803D/AG is usable as an electronic voltmeter, as a precision potentiometer, and as a megohmmeter. It can also be used to measure the excursions of a voltage about a reference value. Ease of operation, inherent protection from any accidental overload, and high reliability of readings are additional advantages of the instrument. It is accurate enough for precision work in calibration laboratories, yet rugged enough for general shop use.

The heart of the unit is a precision 500-volt d.c. reference power supply. This 500 volts can be precisely divided into increments as small as ten microvolts by means of five voltage dials. Unknown a.c. or d.c. voltages are matched against the precise internal voltage until no deflection occurs on the panel meter. The unknown voltage is then simply read from the voltage dials. In the highest null sensitivity range, a potential difference between unknown and reference voltage as small as 0.01 volt causes full-scale meter deflection.

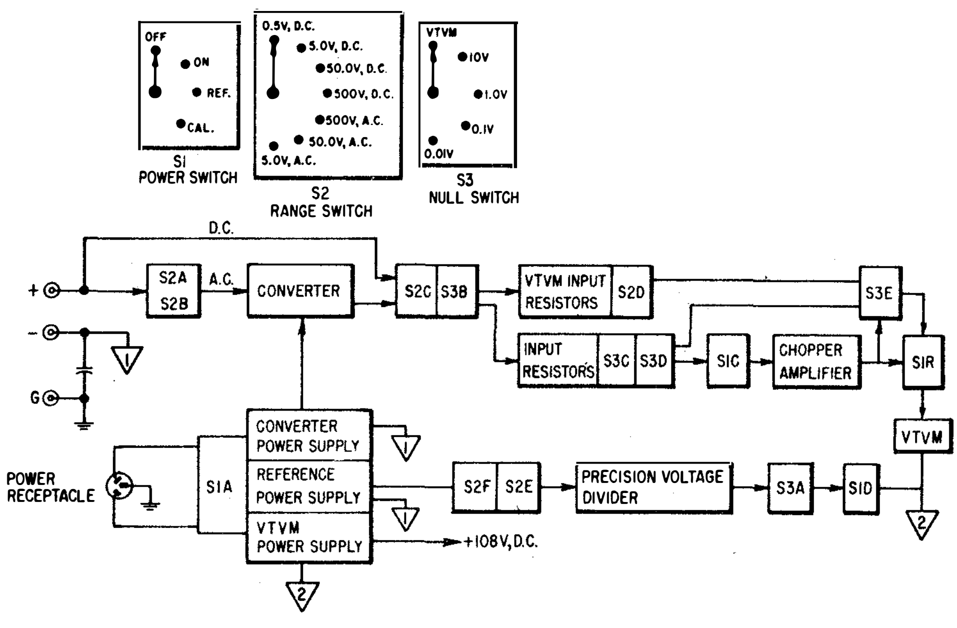
At null, the differential voltmeter presents an "infinite" input impedance to the voltage under measurement, almost completely eliminating circuit loading.

A functional block diagram of the differential voltmeter is shown in figure 2-8. The principal circuit divisions are as follows:

1. a 500-volt d.c. reference power supply
2. precision voltage divider network
3. vtvm
4. chopper-amplifier
5. converter and converter power supply

The system circuitry is designed with two separate common returns. One of these, the return for the converter power supply and reference power supply, provides a safety factor for personnel and a capability for measuring a potential difference between two voltages. The other, which is the common return of the vtvm power supply, is connected to the known reference voltage output from the precision voltage divider network. This arrangement provides a constant d.c. voltage of +108 volts across the differential amplifier regardless of the d.c. potential applied to the grid.

D.C. REFERENCE POWER SUPPLY.—A full wave rectifier with its associated filter



124.376

Figure 2-8.—Differential voltmeter, functional schematic diagram.

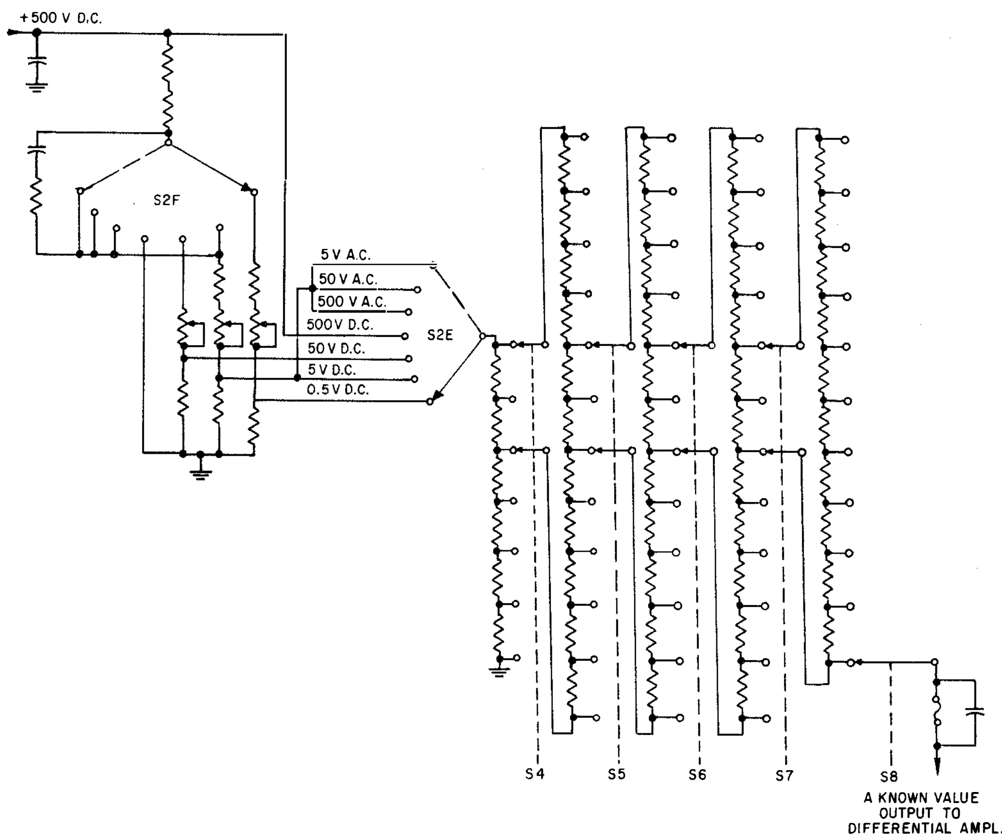
network supplies a d.c. voltage of approximately 1,000 volts to a conventional electron-controlled voltage regulator. The regulated output is maintained at 500 volts ± 0.01 percent.

In the 500 VDC position, the RANGE switch (S2E) passes this 500 volts directly to the precision voltage divider. In the 50 VDC, 5VDC, and 0.5 VDC positions, range resistors S2F divide the reference voltage to 50, 5, and 0.5 volts d.c., respectively. In all a.c. positions of the RANGE switch, only five volts of the reference supply are used, due to the fact that the maximum output of the a.c. to d.c. converter is five volts.

PRECISION VOLTAGE DIVIDER.—Each of the four precision voltages available from the reference supply must be made adjustable through a precision divider network so that unknown voltages may be nulled or matched exactly. The five decade resistor strings (fig. 2-9) accomplish this function.

Note that each string, with the exception of the first, parallels two resistors of the string that precedes it. Between the two wipers of S4, there is a total resistance of 40K and a total voltage of 100 volts d.c. with the RANGE switch in the 500 VDC position. Across the wipers of S5, S6, and S7, there are 10, 1, and 0.1 volts d.c., respectively. Switch S8 selects increments of 0.01 volt d.c. from the last decade. These voltages are reduced by a factor of ten for each successively lower voltage range.

All resistors of each decade are matched and all decades are matched for each instrument,



124.377

Figure 2-9.—Precision voltage divider.

providing an overall divider accuracy of 0.005 percent.

With the NULL switch in any null range, the output of the precision voltage divider appears at the grid of one-half of the vtvm differential amplifier. A 1/200-ampere (five-milliampere) fuse protects this output.

VACUUM-TUBE VOLTMETER.—When operating in the differential mode, the output voltage from the precision voltage divider appears on the grid of V4B, one-half of the differential amplifier. (See fig. 2-10.) The unknown voltage appears on the grid of V4A, the other half of the differential amplifier. Any difference between these potentials is indicated by the meter coupled between the cathodes of V4A and V4B. When the output voltage exactly matches the unknown, the meter reads zero and no current is drawn from the source being measured, because the same potential exists on both sides of the input resistances.

When used as a conventional vtvm, the grid of V4B is connected to the 0-volt bus, or negative binding post. With the range switch in the 0.5 VDC position, the unknown voltage appears directly on the grid of V4A and the meter indicates the approximate value of the unknown. Input divider resistors maintain the 0 to 0.5 grid voltage range for all instrument voltage ranges. The input resistance of the instrument in the vtvm position is ten megohms.

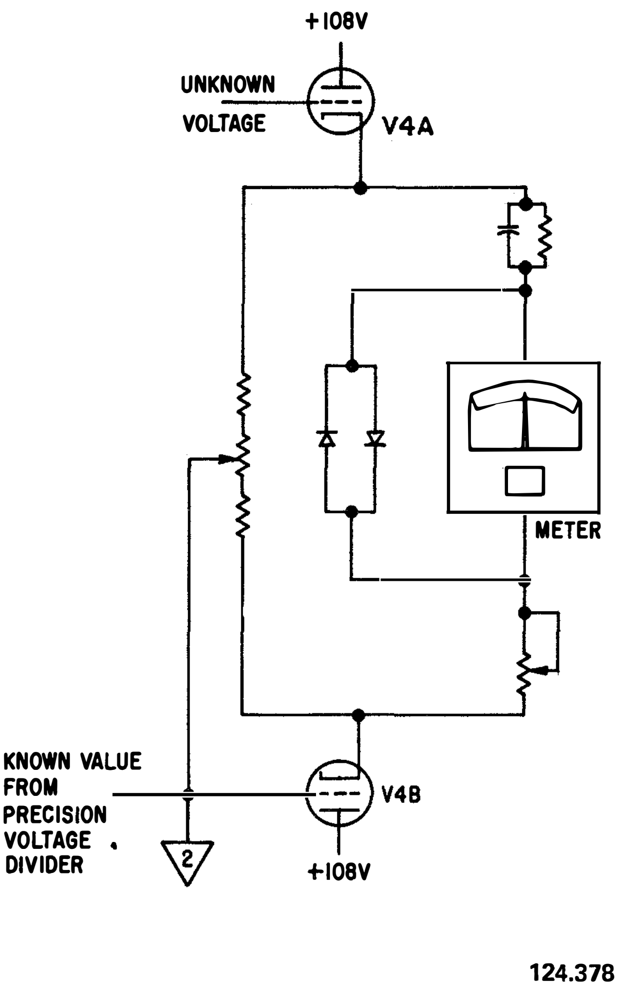


Figure 2-10.—Differential amplifier.

CONVERTER.—All a.c. measurements are made by first converting the a.c. input to a d.c. voltage. The converter provides a maximum d.c. output of five volts for a maximum a.c. input of five volts rms. In the five VAC position, range switch sections of S2A and S2B couple the converter amplifier input directly to the binding post. In the 50 VAC and 500 VAC positions, input attenuators reduce the unknown a.c. to provide a maximum of five volts a.c. input to the first converter amplifier.

The overall frequency response of the converter is essentially flat from 30 Hz to 10 kHz.

Capacitance

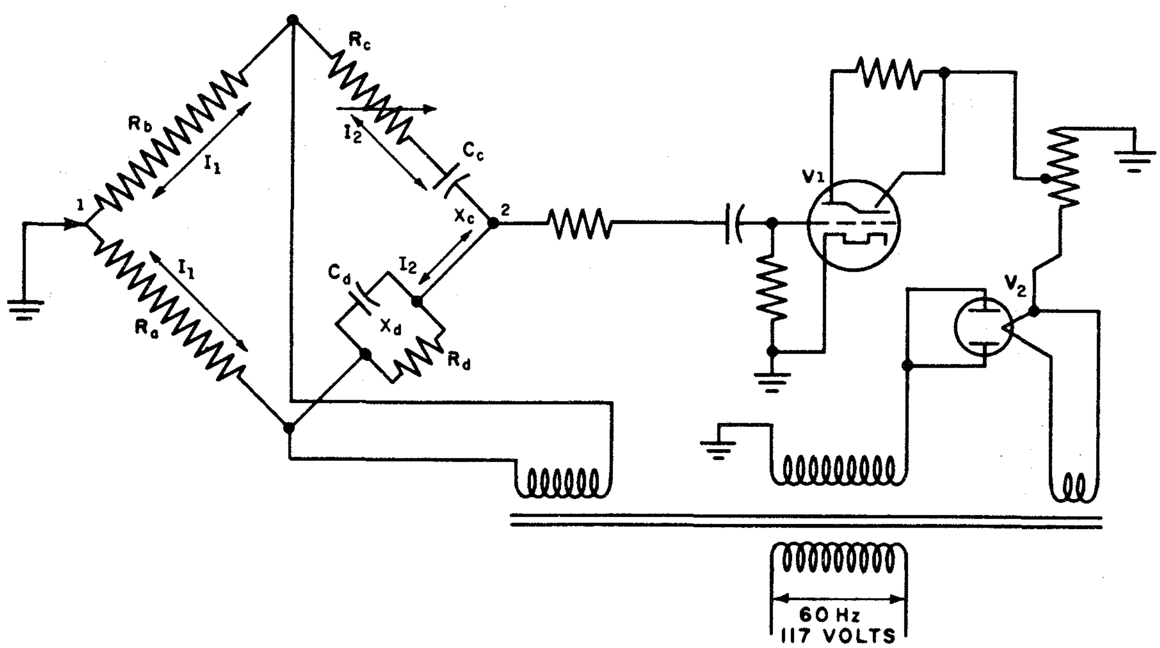
Capacitance measurements are usually accomplished by either a bridge-type or a reactance-type capacitance meter. For accuracy, the former equipment is comparable to the resistance bridge, and the latter instrument is comparable to the ohmmeter. Capacitance tolerances vary even more widely than resistance tolerances, being dependent upon the type of capacitor, the value of the capacitance, and the voltage rating. The results of capacitance tests must be evaluated to determine whether a particular capacitor will fulfill the requirements of the circuit in which it is used. The power factor of a capacitor is important because it is an indication of the various losses attributable to the dielectric, such as current leakage and dielectrical absorption. Current leakage is of considerable importance, especially in electrolytic capacitors. The measurement of capacitance is very simple; however, you must make the important decision of whether to reject or continue to use a certain capacitor after it has been tested.

Inductance

Inductance measurements are seldom required in the course of troubleshooting. However, in some cases inductance measurements are useful and instruments are available for making this test. Many capacitance test sets can be used to measure inductance. Most manufacturers of capacitance test sets furnish inductance conversion charts if the test equipment scale is not calibrated to read the value of inductance directly.

Capacitance-Inductance-Resistance Bridges

Capacitance, inductance, and resistance are measured for precise accuracy by alternating current bridges which are composed of capacitors, inductors, and resistors in a wide variety of combinations. These bridges operate on the principle of the Wheatstone bridge, in which an unknown resistance is balanced against known resistances. The unknown resistance is calculated in terms of the known resistance after the bridge has been balanced. One type of capacitance bridge circuit is shown in simplified form in figure 2-11. When the bridge is balanced by adjusting the variable resistor Rc, there is no a.c. voltage developed across the input of the indicator tube, V1, and the shadow angle is maximum. (V1 is an electron-ray tuning indicator tube.) Any slight unbalance produces an a.c. voltage, which, in turn, develops a grid-leak bias and lowers the plate current of V1,



20.344

Figure 2-11.—Simplified schematic of capacitance checker.

reducing the shadow angle. The following relations exist when the bridge is balanced:

$$\frac{C_d}{C_c} = \frac{R_b}{R_a} \cdot \frac{R_c}{R_d}$$

and

$$\omega 2 = \frac{1}{R_d R_c C_d C_c}$$

where R_a, R_b, R_c, and R_d are the resistances indicated in the figure; C_c is the standard capacitance; and C_d the unknown capacitance. $\omega = 2\pi f$, where f is the frequency of the voltage applied across the bridge. In the basic wheatstone bridge circuit, using d.c. voltages and simple resistances, the balance is obtained when the voltage drops across the ratio arms are equal. In the a.c. capacity bridge it is not sufficient to have equality of voltage drops in the ratio arms, but, in addition, the phase angle between current and voltage in the two arms containing the capacitors must be equal in order to obtain a balance. When a balance is obtained, the current in R_a is equal to that in R_b, and the current in C_c is equal to the current in the parallel circuit of C_d and R_d.

The capacitance-inductance-resistance bridge shown in figure 2-12 is used to measure C, L, and R values in addition to special tests, such as the turns ratio of transformers and capacitor quality tests. This instrument is self-contained except for a source of line power, and has its own source of 1000-Hz bridge current with a sensitive bridge balance indicator, and an adjustable source of direct current for electrolytic capacitor and resistance testing. The bridge also contains a meter with suitable ranges for leakage current tests on electrolytic capacitors.

Resistance Measurements

To make resistance measurements with the bridge tester (fig. 2-12), set the FUNCTION switch to the resistance (5000m or 10000m) position and connect the resistor to be measured to the R posts (second and fourth posts from the left, fig. 2-12). Select an appropriate range on the R scale of the RANGE switch; then turn the MULTIPLY BY dial until the indicator tube (a type 6E5 electron-ray tube) shows the maximum opening, indicating balance on the BALANCE INDICATOR.

If balance is indicated at either extreme of the MULTIPLY BY dial, change the setting of the RANGE switch and rebalance. Multiply the RANGE switch reading by the MULTIPLY BY dial reading to obtain the unknown resistance reading.

Capacitance Measurements

Connect the capacitor to be tested to the C posts (third and fourth from the left, fig. 2-12) and set the FUNCTION switch to position C. Select a suitable range on the C scale of the RANGE switch. Obtain a balance by turning the MULTIPLY BY dial and simultaneously adjusting the D dial. When balance is achieved, multiply the range setting by the MULTIPLY BY dial reading to obtain the unknown capacitance. The D dial reading indicates the loss factor of the capacitor. Multiply the D dial reading by 10 when using any range in the colored section of the RANGE Switch.

Inductance Measurements

Connect the inductor to be measured to the L posts (second and fourth posts from the left, fig. 2-12), and set the FUNCTION switch to the L(D) or L(Q) position, depending upon the probable loss of the coil to be tested. Usually coils used in the af ranges will fall within the loss range of L(D), while RF and IF coils will fall within the loss range of L(Q).

Select a probable range setting on the L scale of the RANGE switch and obtain a balance by turning the MULTIPLY BY dial simultaneously adjusting the Q or D dial. Read the range setting and multiply it by the MULTIPLY BY dial reading to obtain the unknown inductance. Read the Q or D dial to obtain the coil loss factor.

MEGGERS

A Megger is an instrument that applies a high voltage to the component under test and

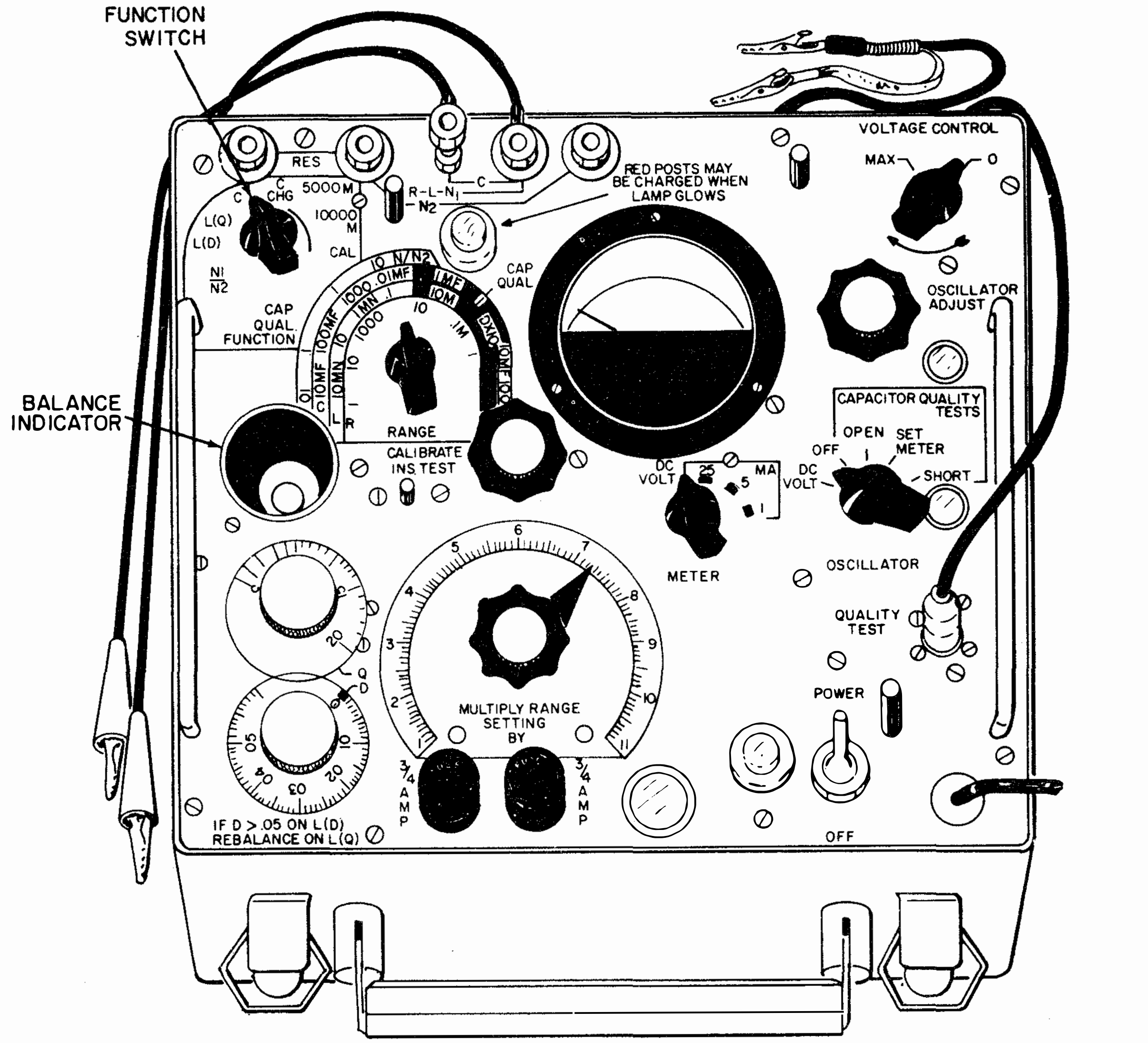
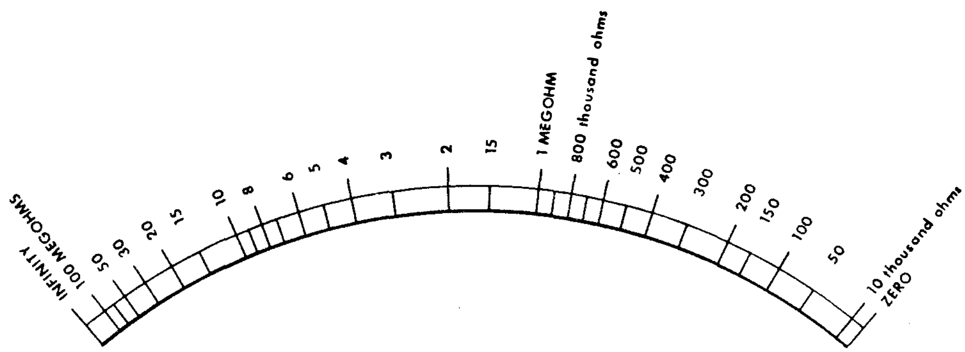


Figure 2-12.—Capacitance-Inductance-Resistance Bridge (ZM-11A/U).

measures the current leakage of the insulation. Thus a capacitor or insulated cable can be checked for leakage under much higher voltages than an ohmmeter is capable of supplying. It consists of a hand-driven, d.c. generator and an indicating meter. The name Megger is derived from the fact that it measures resistance of many megohms.

There are various resistance ratings of Meggers with full-scale values as low as five megohms, and as high as 10,000 megohms. Figure 2-13 shows the scale of a 100-megohms, 500-volt Megger. Notice that the upper limit is infinity and that the scale is crowded at the upper end. The first scale marking below infinity represents the highest value for which the instrument can be accurately used. Thus, if the pointer goes to infinity while making a test, it means only that the resistance is higher than the range of the set.



162.379

Figure 2-13.—Scale of 100-megohm, 500-volt megger.

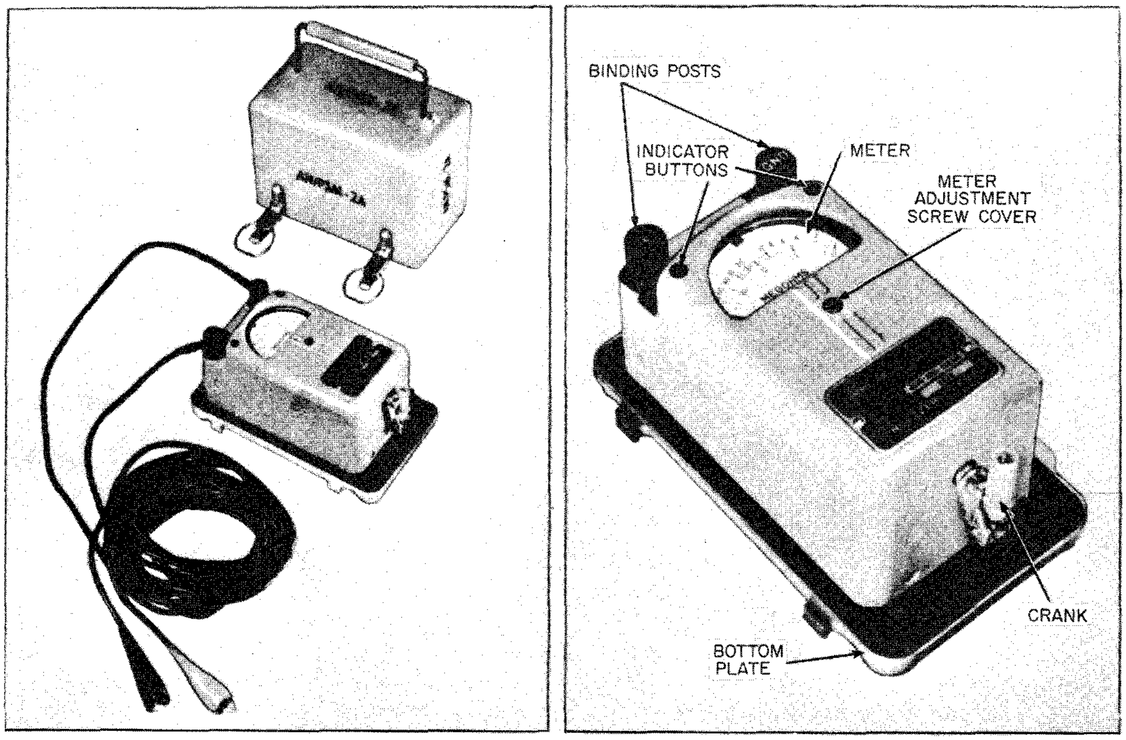
There are also various voltage ratings of Meggers (100, 500, 750, 1,000, 2,500, etc.). The most common type is the one with a 500-volt rating. This voltage rating refers to the maximum output voltage of the Megger. The output voltage is dependent upon the speed of turning of the crank and armature. When the Megger's armature rotation reaches a predetermined speed, a slip clutch will maintain the armature at a constant speed. The voltage rating is important, for the application of too high a voltage to even a good component will cause a breakdown. In other words, do not use a 500-volt Megger to test a capacitor rated at 100 volts.

Meggers are used to test the insulation resistance of conductors in which shorting or breaking down under high voltage is suspected. In some situations, Meggers are used in the prevention of unnecessary breakdowns by maintaining a record of insulation resistance of power and high-voltage cables, motor and generator windings, and transmission lines. These records will reflect fluctuations in resistance and aid in determining when the components should be replaced to prevent a breakdown.

Meggers are used for testing capacitors whose peak voltages are not below the output of the Megger. They are also used to test for high-resistance grounds or leakage on such devices as antennas and insulators.

A Megger employing an a.c. generator, a rectifier, and an ohmmeter circuit with a conventional d.c. milliammeter (Insulation Test Set AN/PSM-2A) is illustrated in figure 2-14. The operation of the insulation test set is relatively simple.

1. Be sure that the apparatus, line, or circuit to be tested is disconnected from its power supply in accordance with safety instructions. Ground the apparatus, line, or circuit to be tested to discharge any capacitors connected to it.
2. Connect the spade-type terminal lug of the black lead to the GND binding post of the test set.
3. Attach the alligator clip of the black test lead to the side of the circuit (under test) nearest ground potential.
4. Connect the spade-type terminal lug of the red lead to the L binding post of the test set.
5. Attach the alligator clip of the red test lead to the conductor to be tested.
6. Turn the crank in either direction at the minimum speed required to provide steady illumination of the indicator buttons.
7. Read the megohms of resistance offered by the material being tested. If the resistance is more than 1000 megohms at 500 volts d.c. the meter will remain at rest over the infinity mark (∞), indicating that the resistance of the insulation being tested is beyond the range of the meter.



1.55

Figure 2-14.—Insulation Test Set AN/PSM-2A.

Precautions to be followed in the use of the Megger are as follows:

1. When making a Megger test, the equipment must not be energized. It must be disconnected entirely from the system before it is tested.
2. Observe all rules for safety in preparing equipment for test and in testing, especially when testing installed high-voltage apparatus.
3. Use well-insulated test leads, especially when using high-range Meggers. After the leads are connected to the instrument and before connecting them to the component to be tested, operate the Megger and make sure there is no leak between the leads. The reading should be infinity. Make certain the leads are not disconnected or broken by touching the test ends of the leads together while turning the crank slowly. The reading should be approximately zero.
4. When using high-range Meggers, take proper precautions against electric shock. There is a sufficient amount of capacitance in most electrical equipment to "store up" sufficient energy from the Megger generator to give a very disagreeable and even dangerous electric shock. Owing to a high protective resistance in the Megger, its open-circuit voltage is not as dangerous, but care should be exercised.
5. Equipment having considerable capacitance should be discharged before and after making Megger tests in order to avoid the danger of receiving a shock. This can be accomplished by grounding or short-circuiting the terminals of the equipment under test.

TECHNIQUES FOR METER USE

Having considered the more common meters, now consider some of the techniques employed in their use. The techniques suggested here are not all-inclusive. As technical skill is developed, there are other variations and techniques that can be used. As an example, consider the techniques for measuring current in a circuit. This can be done by placing an ammeter in series. It can also be accomplished by measuring the voltage across a resistor of known value. Then, by application of Ohm's law, the current in the circuit can be calculated. This last technique has the advantage of eliminating the necessity of opening the circuit for placement of the ammeter.

Continuity Test

Open circuits are those in which the flow of current is interrupted by a broken wire, defective switch, or any means by which the current cannot flow. The test used to check for opens (or to see if the circuit is complete or continuous) is called CONTINUITY TESTING.

An ohmmeter (which contains its own batteries) is excellent for a continuity test. In an emergency a continuity test can readily be made using two sound-powered telephone handsets. Normally continuity tests are performed in circuits where the resistance is very low (such as the resistance of a copper conductor). An open is indicated in these circuits by a very high or infinite resistance.

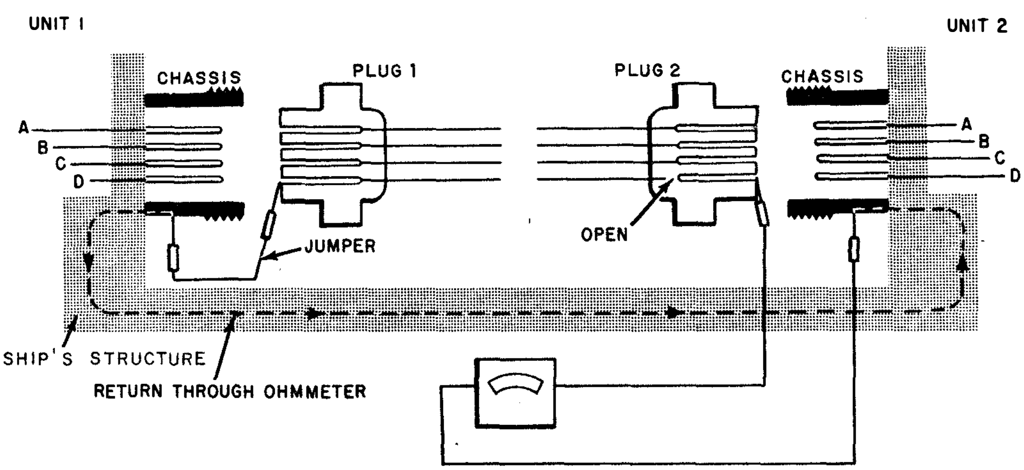
The diagram in figure 2-15 shows a continuity test of a cable. Notice that both connectors are disconnected and the ohmmeter is in series with the conductor under test. The power should be off. Checking conductors A, B, and C, the current from the ohmmeter will flow through plug No. 2, through the conductor, and plug No. 1. From this plug it will pass through the jumper to the chassis which is "grounded" to the ship's structure. The metal structure will serve as the return path to the chassis of unit 2 completing the circuit to the ohmmeter. The ohmmeter will indicate a low resistance.

Checking conductor D in figure 2-15 will reveal an open. The ohmmeter will indicate maximum resistance because current cannot flow. With an open circuit, the ohmmeter needle is all the way to the left since it is a series-type ohmmeter (reads right to left).

Where conditions are such that the ship's structure cannot be used as the return path, one of the other conductors may be used. For example (referring to fig. 2-15), to check D a jumper is connected from pin D to pin A of plug 1 and the ohmmeter leads are connected to pins D and A of plug 2. This technique will also reveal the open in the circuit.

Test for Grounds

Grounded circuits are caused by some conducting part of the circuit making contact



12.250

Figure 2-15.—Continuity test.

either directly or indirectly with the metallic structure of the ship. Grounds may have many causes. The two most common are the fraying of insulation from a wire allowing the bare wire to come in contact with the metal ground, and moisture-soaked insulation.

Grounds are usually indicated by blown fuses or tripped circuit breakers. Blown fuses or tripped circuit breakers, however, may also result from a short other than ground. A high-resistance ground may also occur where not enough current can flow to rupture the fuse or open the circuit breaker.

In testing for grounds, a Megger or an ohmmeter may be used. By measuring the resistance to ground of any point in a circuit, it is possible to determine if the point is grounded. By considering figure 2-15, one possible means of testing a cable for grounds can be seen. If the jumper is removed from pin D of plug No. 1, a test for grounds is made for each conductor of the cable. This is accomplished by connecting one meter lead to ground and the other to each of the pins of one of the plugs. A low resistance will indicate that a pin is grounded. Both plugs must be removed from their units; if only one plug is removed, a false indication is possible for a conductor may be grounded through the unit.

Test for Shorts

A short circuit, other than a grounded one, is one where two conductors accidentally touch each other directly or through another conducting element. Two conductors with frayed insulation may touch and cause a short. Too much solder on the pin of a connector may short to the adjacent pin. In a short circuit enough current may flow to blow a fuse or open a circuit breaker. However, it is entirely possible to have a short between two cables carrying signals; such a short will not be indicated by a blown fuse.

As when checking for continuity, the device used for checking for a short is the ohmmeter. By measuring the resistance between two conductors, a short between them may be detected by a low resistance reading. In figure 2-15 by removing the jumper and disconnecting both plugs, a short test may be made. This is performed by measuring the resistance between the two suspected conductors.

Shorts occur in many components, such as transformers, motor windings, capacitors, etc. The major test method for detecting such components is a resistance measurement, and then comparing the indicated resistance with the resistance given on schematics or in the equipment technical manual.

Voltage Test

The voltage test must be made with the power applied; therefore, the prescribed safety precautions MUST be followed to prevent injury to personnel and damage to the equipment. You will find in your maintenance work that the voltage test is of utmost importance. It is used not only in isolating casualties to major components but also in the maintenance of subassemblies, units, and circuits. Before checking a circuit voltage, a check on the voltage of the power source should be made to be sure that the normal voltage is being impressed across the circuit.

Obviously, the voltmeter is used for voltage tests. In using the voltmeter make certain that the meter used is designated for the type current (a.c. or d.c.) to be tested and has a scale of adequate range. Since defective parts in a circuit may cause higher than normal voltages to be present at the point of test, the highest voltmeter range available should be used at first. Once a reading has been obtained, determine if a lower scale can be employed without damaging the meter movement. If so, use the lower scale, so as to obtain a more accurate reading.

Another consideration in the circuit voltage test is the resistance and current in the circuit. A low resistance in a high-current circuit would result in considerable voltage drop, whereas the same resistance in a low-current circuit may be negligible. Abnormal resistance in part of a circuit can be checked with either an ohmmeter or a voltmeter. Where practical, an ohmmeter should be used, because the test is then carried out with the circuit "dead".

The majority of the electronics circuits encountered in equipment will be low-current circuits, and most voltage readings will be direct current. Also many of the schematics indicate the voltages at many test points. Thus if a certain stage is suspected and you desire to check the voltage, a voltmeter placed from the test point to ground should read the voltages as given on the schematic.

Some technical manuals also contain voltage charts where all the voltage measurements are tabulated. These charts usually indicate the sensitivity of the meter used to obtain the voltage readings for the chart. To obtain comparable results, the technician must use a voltmeter of the same sensitivity as that specified. Make certain that the voltmeter is not loading the circuit while taking a measurement. If the meter resistance is not considerably higher than the circuit resistance, the reading will be markedly lower than the true circuit voltage.

Resistance Test

Before checking the resistance of a circuit or of a part, make certain that the power has been turned off and that capacitors in an associated circuit are discharged. To check continuity, always employ the lower ohmmeter range. If a high range is used, the meter may indicate zero even though appreciable resistance is present in the circuit. Conversely, to check a high resistance, use the highest scale, since the low-range scale may indicate infinity though the resistance is less than a megohm.

In making resistance tests, take into account that other circuits that contain resistances and capacitance may be in parallel with the circuit to be measured, in which case an erroneous conclusion may be drawn from the reading obtained. Remember, a capacitor will block the d.c. flow from the ohmmeter. To obtain an accurate reading if other parts are connected across the suspected circuit, one end of the circuit to be measured should be disconnected from the equipment. For example, many of the resistors in major components and subassemblies are connected across transformer windings. To obtain a valid resistance measurement, the resistor to be measured must be isolated from the shunt resistances.

Resistance tests are also used for checking a part for grounds. In these tests, the parts should be disconnected from the rest of the circuit so that no normal circuit ground will exist. It is not necessary to dismount the part to be checked. The ohmmeter, which is set for a high resistance range, is then connected between ground and each electrically separate circuit of the part under test. Any resistance reading less than infinity indicates at least a partial ground. Capacitors suspected of being short-circuited can also be checked by a resistance measurement. To check a capacitor suspected of being open, temporarily shunt a known perfect capacitor across it, and recheck the performance of the circuit.

PRECAUTIONS IN USE OF METERS

The following are guides for the proper use of meters.

1. An ammeter is always connected in series—NEVER in parallel.
2. A voltmeter is connected in parallel.
3. An ohmmeter is NEVER connected to a live circuit.
4. Polarity must be observed in the use of a d.c. ammeter or a d.c. voltmeter.
5. Meters should be viewed directly from the front. When viewed from an angle off to the side, an incorrect reading will result because of optical parallax.
6. Always choose an instrument suitable for the measurement desired.
7. Select the highest range FIRST and then switch to the proper range.
8. In using a meter, choose a scale which will result in an indication as near midscale as possible.
9. Do not mount or use instruments in the presence of a strong magnetic field.
10. Remember, a low internal-resistance voltmeter (low sensitivity) may shunt the circuit being measured and result in incorrect readings.

POWER MEASUREMENTS

It is often necessary to check the power consumption and the input signal power levels of communication and electronic equipment. The determination of d.c. power is comparatively simple; the unit of power, the watt, is the product of the potential in volts and the current in amperes.

As discussed in *Basic Electricity,* NAVPERS 10086-B and the *Navy Electricity and Electronics Training Series (NEETS),* to make accurate a.c. power measurements, the phase angle of the voltage and current must be considered. The measurement of a.c. power is further complicated by the frequency limitations of various power meters. If there is no phase difference, a.c. power may be computed in the same manner as d.c. power, by determining the average value of the product of the voltage and current.

Electric power at a line frequency of approximately 60 Hz may be measured directly by a dynamometer-type wattmeter. This type of meter indicates the actual power, and, therefore, the phase angle of the voltage and current does not have to be determined. Normally, the exact power consumption of equipment is not necessary for maintenance, and a current measurement is sufficient to permit you to decide whether the power consumption is within reason.

In the audio-frequency range, power levels have to be determined in the course of routine checks and during corrective maintenance procedures. When working with audio-frequency amplifiers, it is ordinarily easier and more convenient to measure voltage, current, and impedance and then compute the power than it is to measure power directly. Power measurements for audio-frequency circuits are usually indicated in terms of decibels (dB), decibels referenced to one milliwatt (dBm), or volume units (vu). The power gain of an amplifier can be expressed in dB. The power level of a sinusoidal signal compared to a one-milliwatt reference is indicated in dBm. The power level of a complex signal, such as voice, music, or multiplexed information, compared to a reference level of one milliwatt, is indicated in vu. Many a.c. voltmeters have scales calibrated in decibels or volume units. Such meters are useful for making measurements where a direct indication in decibels is desired. However, it must be remembered that these are voltmeters, and that power measurements are not meaningful unless the circuit impedance is known.

At radio frequencies below the uhf range, power is usually determined by voltage, current, and impedance measurements. One common method, used to determine the output power of rf oscillators and radio transmitters, consists of connecting a known resistance to the equipment output terminals, measuring the current flow through the resistance, and then calculating the power as the product of I^2R. Since the power is proportional to the current squared, the meter scale can be calibrated to indicate power units directly. A thermocouple ammeter is usually used for this measurement of rf current. The resistor used to replace the normal load is usually specially designed to have low reactance, and has the ability to dissipate the required amount of power. Such resistors are commonly called dummy loads or dummy antennas.

In the uhf and shf portion of the radio-frequency spectrum, it is usually difficult to accurately measure the voltage, current, and impedance. These basic measurements may change greatly at slightly different points in a circuit, and are appreciably affected by small changes in the placement of parts in the vicinity of the tuned circuits. To measure the output of microwave radio or radar transmitters, test instruments which convert rf power to another form of energy, such as light or heat, can be used to indirectly measure the power. A method which measures the heating effect of a resistor load on a stream of passing air can be used. Accurate measurement of large-magnitude power can be achieved by measuring the temperature change of a water load. The most common type of power meter for use in this frequency range employs a bolometer. The bolometer is a loading device that undergoes changes of resistance as changes in the power dissipation occur. Resistance is measured before and after rf power is applied, and power can be determined by the change in resistance.

STANDING WAVE MEASUREMENTS

A transmission line which is not terminated in its characteristic impedance is subject to a condition known as "standing waves." Reflection of energy at the load end of a transmission line gives rise to a wave that travels toward the generator end. This reflected wave varies continuously in phase in much the same way that the incident wave varies in phase. At certain points, one-half wave-length apart, the two waves are exactly in phase, and the resultant voltage is maximum. At points a quarter wave-length from the maximums, the two waves are in continuous opposition, and voltage nodes are produced. The ratio of maximum to minimum voltage at such points is called the "standing wave ratio" (swr) or "voltage standing wave ratio" (vswr). The ratio of maximum to minimum current along a transmission line will have the same value as the vswr. A high swr indicates that the characteristic impedance of a transmission line differs greatly from the terminating impedance, and a low swr indicates that there is a good impedance match between a transmission line and the terminating impedance. If it is desired to terminate a transmission line in its characteristic impedance, an swr of 1.0 is optimum.

Transmission line swr measurements are often made during installation, tuning, and maintenance of communication equipment. Radio antenna transmission lines can be constructed to have the correct length and wire spacing to provide impedance matching for transmitter and receiver equipment. For maximum transfer of energy, the transmission line characteristic impedance should match the terminating impedance. However, unmatched (resonant) transmission lines are useful as impedance-matching devices. In many situations it is not necessary to determine the actual swr. As an example, loading devices, such as antennas, are often adjusted for the condition of minimum swr. Absorption wavemeters or neon-lamp indicators are capable of providing a rough check of the swr and the location of standing waves for an open-wire transmission line. Slotted coaxial lines or waveguides in conjunction with an indicator are used for standing-wave measurements in the vhf to shf range.

Standing-wave measurement for radar equipment is discussed in volume 2 of this manual.

RF WATTMETER

Wattmeter AN/URM-120 (fig. 2-16) is designed to measure incident and reflected rf power from 10 to 1000 watts with a frequency range of 2 to 1000 MHz. Three coupler-detectors, each rated to cover a portion of the frequency and power ranges, are provided with the wattmeter. Each coupler-detector has a knurled knob which projects through a hole in the top of the wattmeter case as shown in figure 2-16. A nameplate on the knurled knob indicates the power range. Centered on the nameplate is the power range knob, which can be rotated 360° to any desired power range. The coupler-detector rotates only 180° along the coaxial primary line inside the metal cases for forward or reverse power measurement. Also located inside the metal case are the indicating meter and cable for interconnecting the meter to the coupler-detector.

Two N-type connectors (one male and one female) are located on either side of the instrument case for connecting the wattmeter between the power source and the load. The upper and lower parts of the instrument are held together with quick action fasteners, which permit easy access to the coupler-detector, the coaxial primary line, and the indicating meter.

Power measurements are made by inserting the proper coupler-detector and connecting the wattmeter in the transmission line between the load and the rf power source. To determine incident power, the arrow on the coupler-detector knurled knob is rotated toward the load, and the power range knob is positioned for peak meter reading. To determine reflected power, the arrow is positioned toward the rf power source. In effect, rotation of the coupler-detector (which is a directional coupler) causes the coupler to respond only to a wave traveling in a particular direction while being unaffected by a wave traveling in the opposite direction. A diode rectifier in the coupler rectifies the energy picked up by the coupler, and this energy is measured across a known impedance to obtain the incident or reflected power.

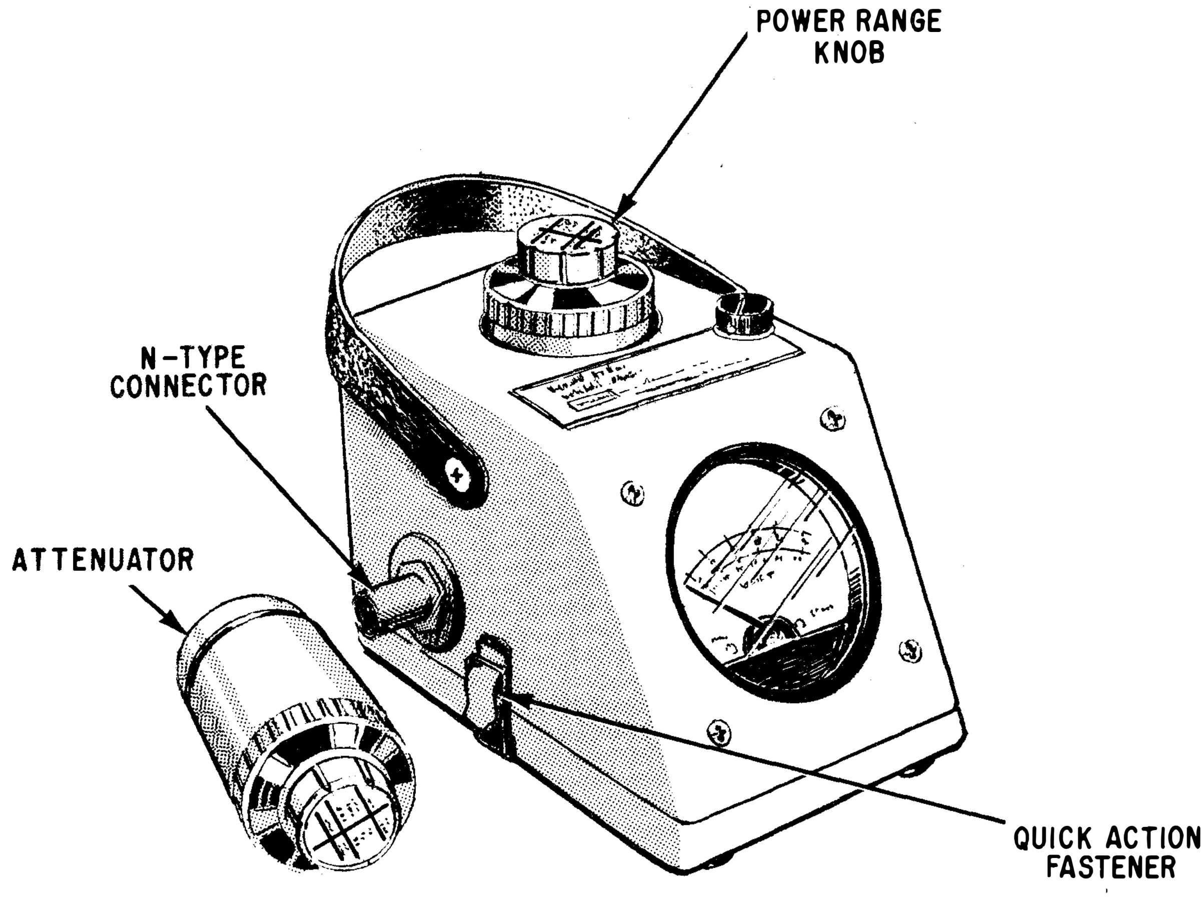


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Figure 2-16.—RF in-line wattmeter.

Operation

Insert the proper coupler-detector for the rf power being measured into the wattmeter case. Remove the wire shunt from the meter terminals. De-energize and tag the rf power source and connect the wattmeter in the transmission line, either at the load or the rf source. Ensure that all connections are tight.

Position the power range knob to a position higher than the rated power of the rf source. IF THE RATED POWER IS NOT KNOWN, PLACE THE POWER RANGE KNOB IN THE HIGHEST POWER POSITION BEFORE THE POWER SOURCE IS TURNED ON.

To measure incident power, rotate the coupler-detector so that the arrow indicating power flow points toward the load. Apply rf power to the transmission line under test. Rotate the power range knob to the proper range for measuring and observe the point at which the indicating meter peaks. This is the incident power.

Reflected power is measured in the same manner as described for incident power, except that the coupler-detector is rotated so that the arrow points toward the rf source. After power measurements have been completed, de-energize the rf source, disconnect the wattmeter from the transmission line, and place the wire shunt on the meter terminals.

Interpreting Power Measurements

The rf power measurements made by the wattmeter are used to determine the vswr of the load and the power absorbed by the load. The vswr may be determined from a chart provided in the wattmeter technical manual, or it may be calculated by the following formula:

$$\text{vswr} = \frac{\sqrt{Pi} + \sqrt{Pr}}{\sqrt{Pi} - \sqrt{Pr}}$$

where Pi is the incident power and Pr is the reflected power as measured by the wattmeter.

The rf power absorbed by the load may be determined by subtracting the reflected power reading from the incident power reading.

SIGNAL GENERATORS

In the maintenance of electronic equipment, it is often necessary to employ standard sources of a.c. energy, both audio frequency and radio frequency. These sources are called signal generators. They are used in testing and aligning radio transmitters, receivers, and amplifiers, they are also used when troubleshooting various electronic devices, and sometimes for measuring frequency.

The principal function of a signal generator is the production of an alternating voltage of the desired frequency and amplitude which has the necessary modulation for the test or measurement concerned. It is very important that the amplitude of the generated signal be correct. In many generators, output meters are included in the equipment so that the output may be adjusted and maintained at a standard level over a wide range of frequencies.

When using the generator, the output test signal is coupled into the circuit being tested, and its progress through the equipment is traced by the use of high-impedance indicating devices such as vacuum-tube voltmeters or oscilloscopes. In many signal generators, calibrated networks of resistors, called attenuators, are provided. These are used to regulate the voltage of the output signal and also provide correct impedance values for matching the input impedance of the circuit under test. Accurately calibrated attenuators are used, as the signal strength must be regulated to avoid overloading the circuit receiving the signal.

There are many types of signal generators. They may be classified roughly by frequency into audio generators, video-signal generators, radio-frequency generators, frequency-modulated rf generators, and special types which combine all of these frequency ranges.

AUDIO AND VIDEO SIGNAL GENERATORS

Audio signal generators produce stable audio-frequency signals used for testing audio equipment. Video signal generators produce signals which include the audio range and extend considerably further into the rf range. These generators are used in testing video amplifiers and other wideband circuits. In both audio and video generators (fig. 2-17), the major components include a power supply, an oscillator (or oscillators), one or more amplifiers, and an output control. Voltage regulation circuits are necessary to insure stability of the oscillator in generators which derive power from 115-volt, a.c. sources. In portable generators, battery power supplies are usually used, and these require no voltage regulation.

In the audio and video generators of the beat-frequency type the output frequency is produced by mixing the signals of two radio-frequency oscillators, one of which is fixed in frequency and the other variable. The

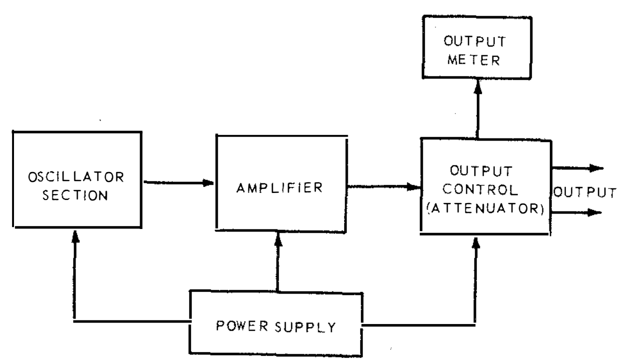

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Figure 2-17.—Block diagram of audio or video signal generator.

difference in frequency of the two is equal to the desired audio or video frequency.

Audio signal generators often include RC oscillators in which the audio-frequency is directly produced. In these, a resistance-capacitance circuit is the frequency determining part of the oscillator. The frequency varies when either the resistance or the capacitance is changed in value. In commercial generators, however, the capacitance alone is often chosen as the variable element. The change in frequency which can be produced by this method is limited, and it is usually necessary to cover the entire range of the generator in steps. This is accomplished by providing several RC circuits, each corresponding to a portion of the entire range of frequency values. The circuits in the oscillator are switched one at a time to give the desired portion of the audio range.

The amplifier section of the block diagram (fig. 2-17) usually consists of a voltage amplifier and one or two power amplifiers. These are coupled by means of RC networks, and the output of the final power amplifier is often coupled to the attenuator, or output control, by means of an output transformer.

The output control section provides a means of matching the output signal to the input of the equipment under test and regulating the amplitude of the signal.

RADIO-FREQUENCY SIGNAL GENERATORS

A typical radio-frequency signal generator contains, in addition to the necessary power supply, three main sections: an oscillator circuit, a modulator, and an output control circuit. The internal modulator modulates the radio-frequency signal of the oscillator. In addition, most rf generators are provided with connections through which an external source of modulation of any desired waveform may be applied to the generated signal. Metal shielding surrounds the unit to prevent the entrance of signals from the oscillator into the circuit under test by means other than through the output circuit of the generator.

A block diagram of a representative rf signal generator is shown in figure 2-18. The function of the oscillator stage is to produce a signal which can be accurately set in frequency at any point in the range of the generator. The type of oscillator circuit used depends on the range of frequencies for which the generator is designed. In low-frequency signal generators, the resonating circuit consists of one of a group of coils combined with a variable capacitor. One of the coils is selected with a range selector switch which attaches it to the capacitor to provide an LC circuit which has the correct range of resonant frequencies.

The function of the modulating circuit is the production of an audio (or video) voltage which

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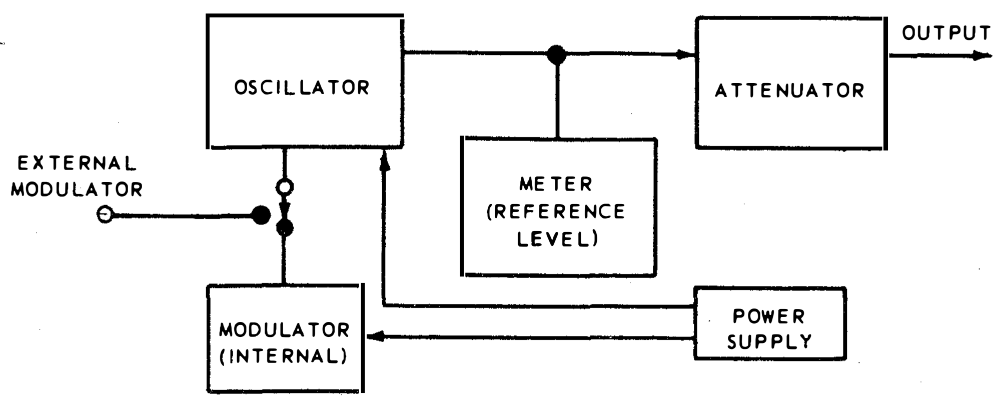

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Figure 2-18.—Block diagram of rf signal generator.

can be superimposed on the rf signal produced by the oscillator. The modulating signal may be provided by an audio oscillator within the generator (internal modulation), or it may be derived from an external source. In some signal generators, either of these methods of modulation may be employed. In addition, a means of disabling the modulator section is used whereby the pure unmodulated signal from the oscillator can be used when it is desired.

The type of modulation used depends on the application of the particular signal generator. The modulating voltage may be either a sine wave, a square wave, or pulses of varying duration. In some specialized generators, provision is made for pulse modulation in which the rf signal can be pulsed over a wide range of repetition rates and at various pulse widths.

Usually the output circuit of the generator contains a calibrated attenuator and often an output level meter. The output level meter gives an indication of, and permits control of, the output voltage of the generator by indicating arbitrary values of output read in tenths through the value of one. The attenuator selects the amount of this output. The attenuator, a group of resistors forming a voltage-dropping circuit, is controlled by a knob which is calibrated in microvolts. When the control element is adjusted so that the output meter reads unity (1.0), the reading on the attenuator knob gives the exact value (no multiplication factor) of the output in microvolts. If output voltage is desired at a lower value, the control is varied until the meter indicates some decimal value less than one, and this decimal is multiplied by the attenuator reading to give the output in microvolts.

Frequency-modulated rf signal generators are widely used for testing frequency-modulated (FM) receivers and for visual alignment (using an oscilloscope) of amplitude-modulated receivers. A frequency-modulated signal is an alternating voltage in which the frequency varies above and below a given center frequency value. The overall frequency change is called the frequency swing.

There are several methods by which the frequency of the oscillator in the signal generator may be frequency modulated. In one type of FM generator, use is made of a vibrating plate which forms one of the elements of the tuning capacitor of the oscillator to be modulated. The plate is driven by a device similar to a magnetic loudspeaker. The audio-modulating voltage is applied to the driving coil which moves in the field of a permanent magnet and vibrates the plate of the capacitor at the applied audio frequency. Movement of the plate causes variation of the capacitance in the oscillator tuning circuit with the result that the frequency of the oscillator is periodically raised or lowered.

Another method of producing frequency modulation is based on the action of a reactance tube which is connected in parallel with the tuning circuit of the oscillator to be modulated.

In signal generators of microwave frequencies, frequency modulation is accomplished in the oscillator by applying the modulating voltage to the repeller plate of the reflex Klystron tube, which is usually employed in these generators.

FREQUENCY MEASUREMENTS

Frequency measurements are an essential part of preventive and corrective maintenance for electronics equipment. Frequency measurements for radio equipment are made during tuning, preventive maintenance, and corrective maintenance procedures. The type of test equipment selected depends on the frequency to be measured and the required accuracy. Signal frequencies of radio transmitters which operate in the low-frequency to the very-high-frequency range are normally measured by absorption-type wavemeters, reaction-type wavemeters, heterodyne-type frequency meters, or calibrated radio receivers. Where accuracy is not of prime importance, in making preliminary adjustments, or for general experimental work, rapid frequency checks may be made by the absorption-type wavemeter. Since the wavemeter is relatively insensitive, it is very useful in determining the fundamental frequency in a circuit generating multiple harmonics.

The signal frequencies of radio and radar equipment which operate in the ultra-high-frequency and super-high-frequency range can be measured by resonant-cavity-type wavemeters, resonant-coaxial-line-type wavemeters, or Lecher-wire devices. When properly calibrated, resonant-cavity and resonant-coaxial-line wavemeters are more accurate and have better stability than wavemeters used for measurements in the low-frequency to very-high-frequency range. These frequency-measuring instruments are often furnished as part of communication and electronic equipment, but are also available as general-purpose test sets.

Frequency-measuring equipment and devices, particularly those used to determine radio frequencies, constitute a distinct class of test equipment because of the important and critical nature of such measurements. The requirement of precise calibration is extremely important in all frequency-measuring work. In order to provide accurate measurements, every type of frequency meter must be calibrated against some frequency standard.

Frequency standards are divided into two general categories: primary and secondary standards. The primary frequency standard is determined and maintained by the U.S. Bureau of Standards. It has long-term stability and accuracy that are determined by comparison with a standard interval of time. A secondary frequency standard is a highly stable and accurate standard that has been calibrated against the primary standard.

The accuracy of a secondary frequency standard is maintained only when periodic calibration checks are made against a primary standard, or against standard frequency transmissions of radio stations WWV or WWVH. These transmissions are broadcast continuously, and are monitored for agreement with the National Primary Frequency Standard, which is maintained by the Bureau of Standards, Time and Frequency Division, Boulder, Colorado.

Frequency Standard

Frequency Standard AN/URQ-10 (fig. 2-19) is a compact, multipurpose, secondary frequency standard designed for continuous duty operation aboard ship or at shore facilities. The standard operates from a 115-volt, 50- to 400-Hz single-phase a.c. source, and provides three highly stable output frequencies (100 kHz, 1 MHz, and 5 MHz). Frequency Distribution Amplifier AM-2123 (not shown) provides for distributing these frequencies to remote locations aboard ship. A battery is provided in the frequency standard which automatically supplies the power for operation in the event the external power source fails.

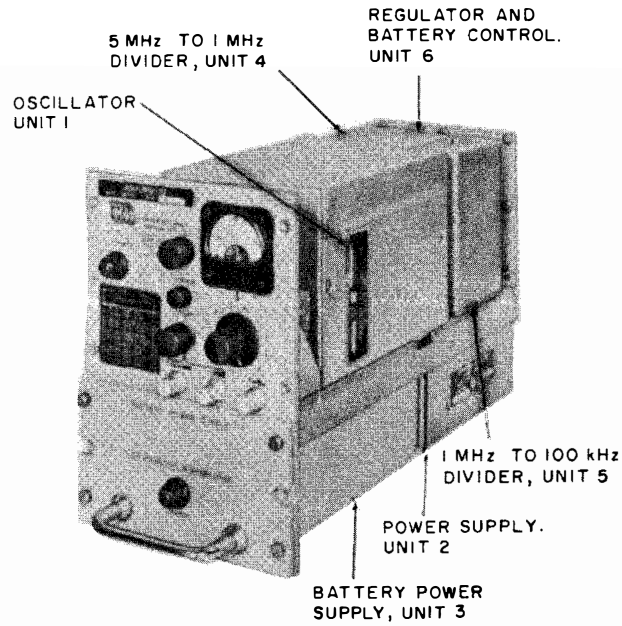

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Figure 2-19.—Frequency Standard (AN/URO-10) cover removed.

Functional Description

The functional block diagram of the AN/URQ-10 is shown in figure 2-20. The standard consists of two basic sections, the section which actually produces the frequency outputs, and the power supply section with its control circuits.

The section which actually produces the frequency outputs consists of the oscillator module, unit A1; the 5-MHz to 1-MHz frequency divider module, unit A4; and the 1-MHz to 100-kHz frequency divider module, unit A5. The power supply section consists of the power supply module, unit A2; the battery power supply, unit A3; and the regulator and battery control module, unit A6.

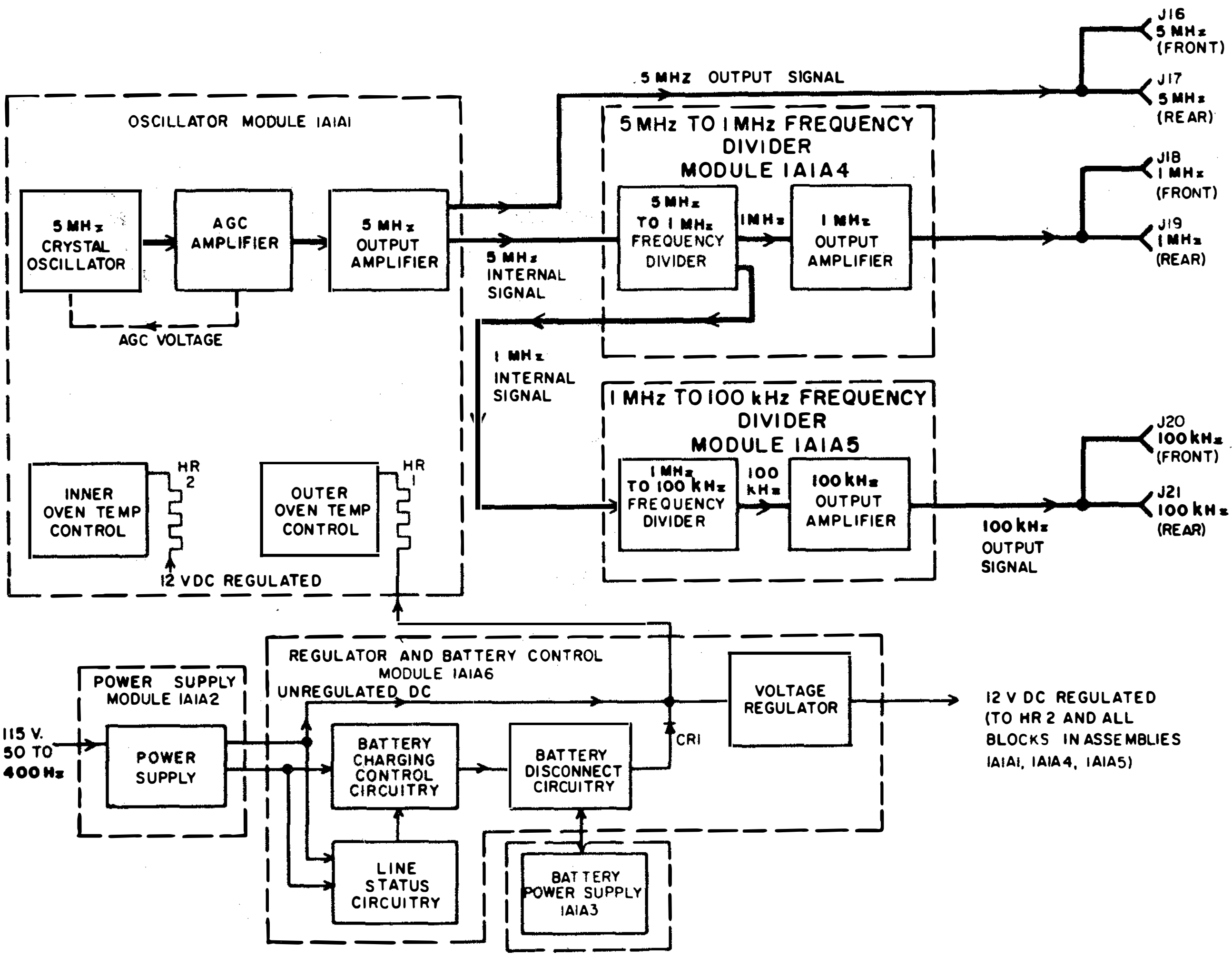

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Figure 2-20.—Frequency Standard (AN/URO-10) block diagram.

The basic 5-MHz signal, from which all other frequencies are derived, is generated in the oscillator module by the 5-MHz crystal oscillator (fig. 2-20). The signal from the oscillator is amplified by the agc amplifier and then by the output amplifier. The output amplifier increases the signal to the level necessary for the 5-MHz output signal and also provides the 5-MHz internal signal which is utilized by the 5-MHz to 1-MHz frequency divider module. An inner oven and an outer oven, located within the oscillator module, maintain constant temperature control for the 5-MHz crystal oscillator and the agc amplifier. The oven temperature circuits, the crystal oscillator, and the agc amplifier are a single potted assembly which is contained in the oscillator module along with the 5-MHz output amplifier. The 5-MHz to 1-MHz frequency divider consists of the frequency divider proper and the 1-MHz output amplifier. The 5-MHz to 1-MHz frequency divider circuit utilizes the internal 5-MHz signal to produce two separate 1-MHz outputs. One output is applied to the 1-MHz amplifier, and the other is applied to the 1-MHz to 100-kHz frequency divider module. The output amplifier increases the signal level to provide the 1-MHz output signal. The 1-MHz to 100-kHz frequency divider module, which consists of a frequency divider and a 100-kHz output amplifier, accepts the 1-MHz internal signal to provide the 100-kHz signal. The signal is then increased to the required level for the final 100-kHz output signal.

The power supply module uses the primary a.c. power to provide unregulated d.c. for recharging the battery and for the operation of the other circuits in the frequency standard.

The battery charging current passes through the battery charging control circuitry and the battery disconnect circuitry (located in the regulator and battery control module) before reaching the battery power supply. The battery charging control circuitry maintains a full charge for the battery power supply as long as primary a.c. power is present. The battery disconnect circuitry removes the battery from the load before its terminal voltage drops to a potential at which the battery could be damaged. The other unregulated d.c. supply line provides power for the outer oven heater in the oscillator module and for the regulator which supplies all regulated operating power for the frequency generation circuits. The line status circuitry detects a loss of primary a.c. power.

Operation

The front panel controls and indicators for the frequency standard are shown in figure 2-21. Some of these controls (as shown by table 2-1) are not operator controls but are used only by laboratory technicians for calibration purposes. DO NOT OPERATE ANY CONTROLS UNNECESSARILY. UNNECESSARY CONTROL MANIPULATION CAN DISRUPT THE OUTPUT FREQUENCIES OF THE UNIT REQUIRING LABORATORY CALIBRATION.

When normal a.c. power is supplied to the standard, it automatically reverts to a.c. operation and continues to operate automatically as long as the power is available. If the a.c. power fails, operation will be maintained by the standby battery for a minimum of eight hours, provided the battery is fully charged.

DO NOT ALLOW THE FREQUENCY STANDARD TO BE SHUT OFF EXCEPT IN AN EMERGENCY OR UNLESS IT REQUIRES MAJOR REPAIR. COOLING OF THE CRYSTAL WILL ALTER ITS FREQUENCY CHARACTERISTICS, MAKING LABORATORY CALIBRATION NECESSARY. DO NOT REMOVE THE BATTERY POWER SUPPLY FROM THE SET UNLESS THE STANDARD IS PLUGGED INTO THE NORMAL A.C. SOURCE.

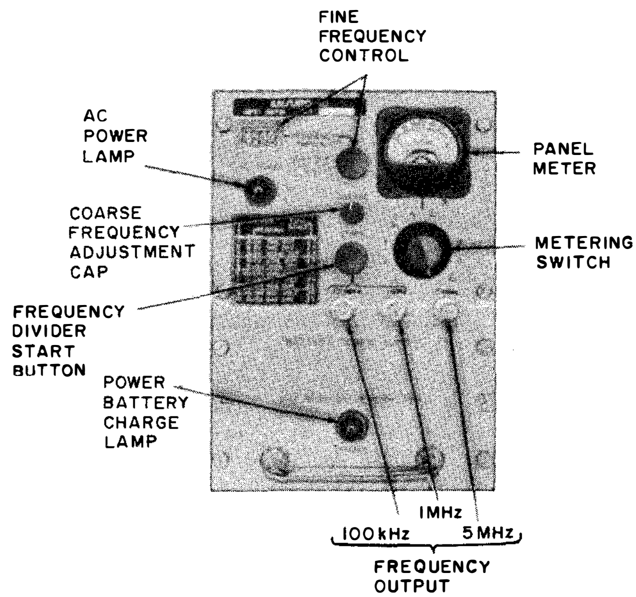

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Figure 2-21.—Front panel controls and indicators.

When the standard is operating from battery (emergency operation), both indicator lamps on the front panel (fig. 2-21) are off. No special precautions are necessary during emergency operation. If the normal a.c. supply is not restored, however, the set must be connected to an alternate supply source or shut down before the battery becomes discharged. If it becomes necessary to shut down the standard, it must be disconnected from the a.c. source and the battery removed.

Normal operation for the standard is determined by the use of the panel meter and metering switch. Normal meter readings for the various switch positions are listed in the equipment technical manual.

FREQUENCY COUNTER

The AN/USM-207 is a portable, solid-state electronic counter for precisely measuring and

Table 2-1.—Controls and indicators

Control or Indicator	Function	Normal Status
OPERATOR CONTROLS AND INDICATORS		
AC POWER lamp (figure 4-9).	Lights when ac input is supplied to the frequency standard. Extinguishes when ac input is interrupted.	Remains lighted during normal operation.
Battery CHARGE lamp	Indicates that battery is being charged in the manual mode of operation or in the higher (not trickle) automatic charge mode.	Lamp remains extinguished during normal operation, except after interruption of ac input.
Battery charge switch (Not shown)	Selects either manual or automatic battery charging mode. MANUAL CHARGE position causes constant, higher rate charging. AUTO CHARGE position causes higher rate charging only when required to restore battery to full charge, automatically decreasing to trickle charge to maintain battery in full charge position.	Switch remains in AUTO position except at initial start or when battery power supply is replaced.
Frequency output connectors	Provides 5-MHz, 1-MHz, and 100-kHz frequencies.	Frequencies are available at connectors whenever frequency standard is operating.
Panel meter	Indicates circuit conditions of circuit selected by metering switch.	Indicates zero when metering switch is set at normal unmarked position.
Metering switch	Selects circuit to be checked on panel meter.	Remains in unmarked, lower position.
CALIBRATION LABORATORY CONTROLS AND INDICATORS		
COARSE frequency adjustment cap	Provides access to coarse frequency control. Coarse frequency control provides coarse adjustment of oscillator output. This must be adjusted with special insulated tool. Tool is stored in clips mounted directly above battery power supply.	Screwed into panel to prevent adjustment of coarse control.
Fine frequency adjustment indicator	Indicates in parts per 10^{10} the amount of adjustment provided by the operation of the fine frequency control.	Varies for each unit.
Fine frequency control	Provides a fine frequency control, changing frequency of oscillator output by the amount, in parts per 10^{10} indicated on fine frequency adjustment indicator.	Screwed in to lock control and associated indicator.
Frequency divider START button	Starts operation of frequency dividers at initial operation or after shutdown.	Remains in undepressed position.

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displaying on an 8-digit numerical readout the frequency and period of a cyclic electrical signal, the frequency ratio of two signals, the time interval between two points on the same or different signals, or the total number of electrical impulses (totalizing). The counter also provides the following types of output signals:

1. Standard signals from 0.1 Hz to 10 MHz in decade steps derived from an internal 1-MHz frequency standard, frequency dividers, and a frequency multiplier.
2. Input signals divided in frequency by factors from 10 to 10^8 by a frequency divider.
3. Digital data of the measurement in four-line, binary-coded-decimal form with decimal point and control signals for operation of printers, data recorders, or control devices.
4. A 1-MHz output from an internal frequency standard.

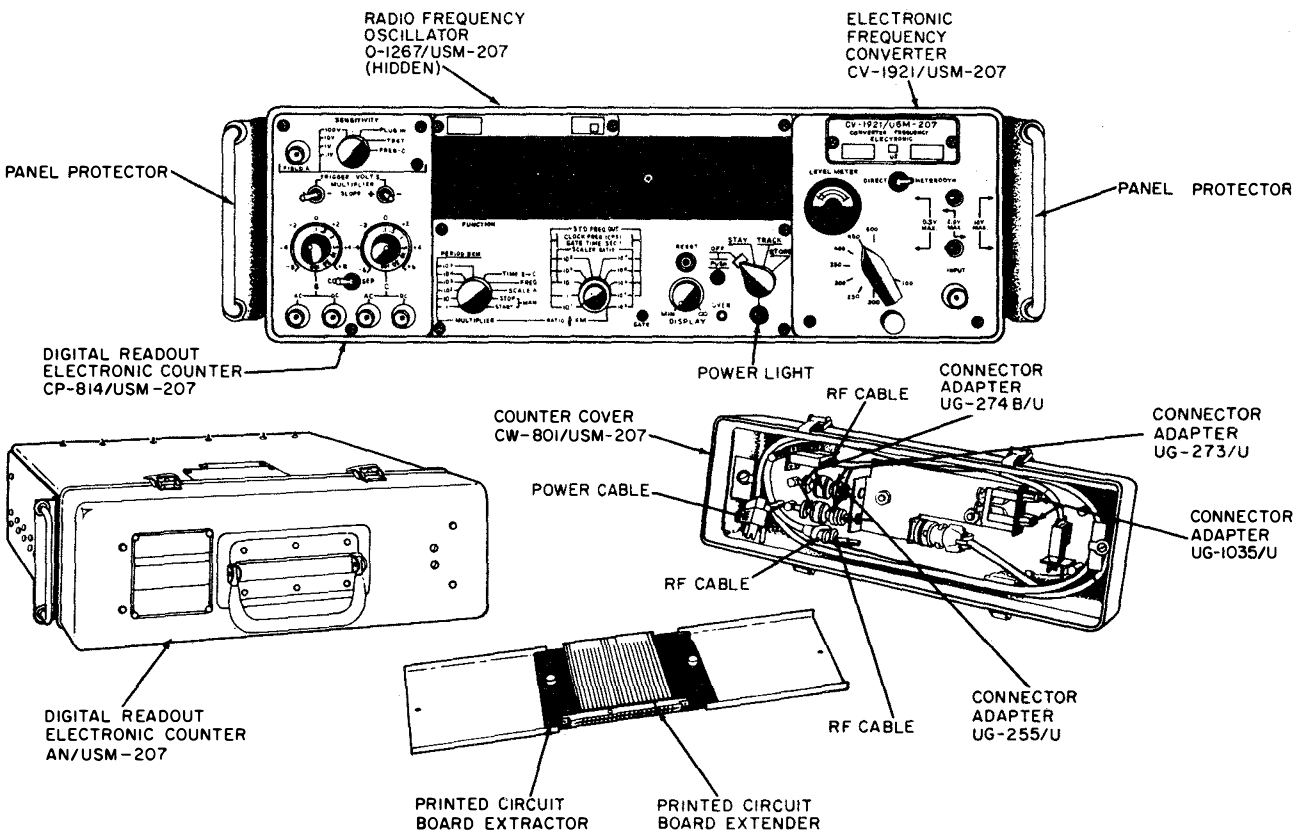

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Figure 2-22.—Digital Readout Electronic Counter (AN/USM-207).

General Description

The AN/USM-207 (fig. 2-22) consists of a major counter assembly, two plug-in assemblies installed in recesses on the front and rear panel, and a group of accessory cables and connectors stored in the detachable front cover.

The major assembly Digital Readout Electronic Counter CP-814/USM-207 contains the input amplifiers, gate control, display, reset and transfer control, frequency multipliers, time base dividers, decade and readout boards, numerical display tubes, decimal point and units indicators, power supply and regulator, and controls associated with these circuits.

The Radio Frequency Oscillator 0-1267/USM-207 plug-in assembly develops a 1-MHz signal and includes its own power supply. The oscillator includes the 1-MHz output receptacle which may be used as a source of that frequency when the oscillator is connected to a.c. power through the basic counter or when connected to the power line independently of the counter. The oscillator plugs into the right rear of the counter. The counter may be operated without the oscillator in totalizing, scaling the input signal, time interval with external clock, and frequency ratio measurements. For other measurements the counter does not require the oscillator when a separate external 100-kHz or 1-MHz signal is connected. In either of these two situations, the oscillator may be left in the counter or removed.

The Electronic Frequency Converter CV-1921/USM-207 plug-in assembly permits measurement of frequencies up to 500 MHz, using the heterodyne principle. The unit consists of the broadband amplifier, mixer, multiplier, and controls and indicators associated with these circuits. When measurements other than heterodyne frequency measurements are made, the converter is not required, but need not be removed. The converter also permits the measurement of signals from 35 MHz to 100 MHz, with a greater sensitivity than available with the basic counter. The converter plugs into the right front of the counter.

Functional Description

Figure 2-23 is the overall functional block diagram of the counter. To make a measurement requires two types of information: a count signal and a gate control signal. These two signals may be generated within the instrument, or they may be supplied from outside sources. The type of measurement the counter will make depends upon the relationship of these two signals. In any function the instrument counts the count signal for a period of time determined by the gate control signal. Routing of these signals within the instrument is accomplished by logic circuits. These logic circuits are controlled by means of the front-panel controls.

The Radio Frequency Oscillator O-1267/USM-207 generates a signal of precise frequency for use throughout the counter or to provide a precise 1-MHz signal for use outside the equipment.

The Electronic Frequency Converter, CV-1921/USM-207, accepts radio frequencies between 100 MHz and 500 MHz and converts them to radio frequencies between 5 MHz and 100 MHz for measurement by the basic counter.

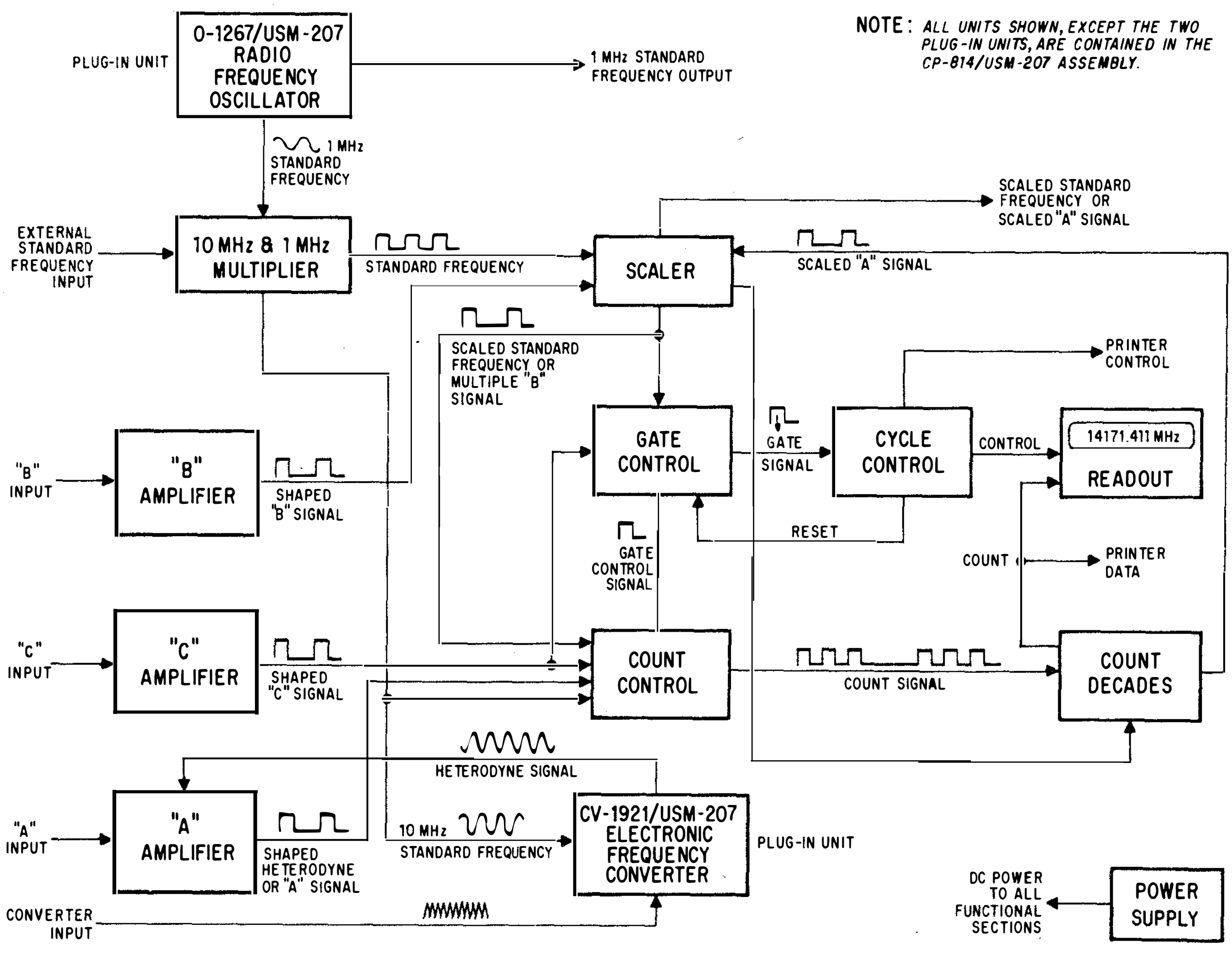

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Figure 2-23.—Digital readout electronic counter overall block diagram.

The "A", "B", and "C" amplifiers amplify and shape the respective input signals for use throughout the counter.

The 10-MHz and 1-MHz multiplier multiplies the frequency and shapes the signal generated by the radio frequency oscillator. It also provides precise timing signals to the various functional sections of the basic counter and to the frequency converter.

The scaler consists of a series of decade dividers and gating systems which provide divided standard frequencies and control signals depending on the type of measurement the instrument is making.

The gate control generates the gate control signal. This signal determines the length of time that the count decades will count the count signal.

The count control provides the proper count signal to the count decades, as selected by the setting of the front-panel switches.

The cycle control produces all signals necessary to display the measurement results on the readout and to recycle the counter.

The count decades count the count signal when permitted to do so by the gate control.

The result of their counting becomes the final reading displayed by the readout at the end of each measurement.

The readout receives binary-coded-decimal (BCD) data from the count decades, decodes this data into decimal form, and drives the readout indicator tubes. The readout also contains memory circuits which function when the counter is operated in the "Store" mode.

The power supply supplies all d.c. power required by the basic instrument and the converters, and consists of seven d.c. supplies. Five of these supplies (+18 volt, +12 volt, +6 volt, -6 volt, and -12 volt) are regulated, and two (+180 volt and +45 volt) are unregulated.

OSCILLOSCOPES

The basic principles of operation and a general description of operation of an oscilloscope have been covered previously in *Basic Electronics, Volume 1,* NAVPERS 10087-C and the *Navy Electricity and Electronics Training Series (NEETS).*

The AN/USM-281 oscilloscope operates on the same principle as the ones described in *Basic Electronics* and *NEETS*. The only difference is that the AN/USM-281, a later model, has complete solid-state design except for the crt. This oscilloscope is a dual-trace oscilloscope that will operate from d.c. to 50 MHz and has the capability of measuring up to 600 volts. With a weight approximately 30 pounds it is portable and can be used just about anywhere.

Functional Description

The AN/USM-281 oscilloscope (fig. 2-24) is a direct-coupled, wideband oscilloscope that provides a visual display of simple and complex waveforms. In addition to displaying waveforms, the oscilloscope provides the user with the capability of accurately measuring the rise time of any portion of a waveform, the waveform magnitude, and the time difference between any two points on a displayed waveform. It also provides an accurate comparison of two separate waveforms.

Oscilloscope Assembly

The oscilloscope assembly provides the circuitry (low-voltage and high-voltage supplies) for projecting a beam onto the crt screen and the controls to adjust the intensity, focus (sharpness), and horizontal position of the beam on the crt. This unit also contains a horizontal amplifier (with front-panel controls for accepting an internal or external signal) to amplify the selected time base signal and provide a linear deflection voltage to the horizontal plates of the crt. The oscilloscope assembly also contains the power switch, scale illumination control, and two calibrator output jacks.

Time Base and Delay Generator

The time base and delay generator plug-in assembly receives operating power from the oscilloscope low-voltage power supply through a connector on the rear of the plug-in unit. This assembly generates the accurate main time base and delay time base voltages used for horizontal deflection during normal (internal) operation. Front-panel controls provide a choice of four

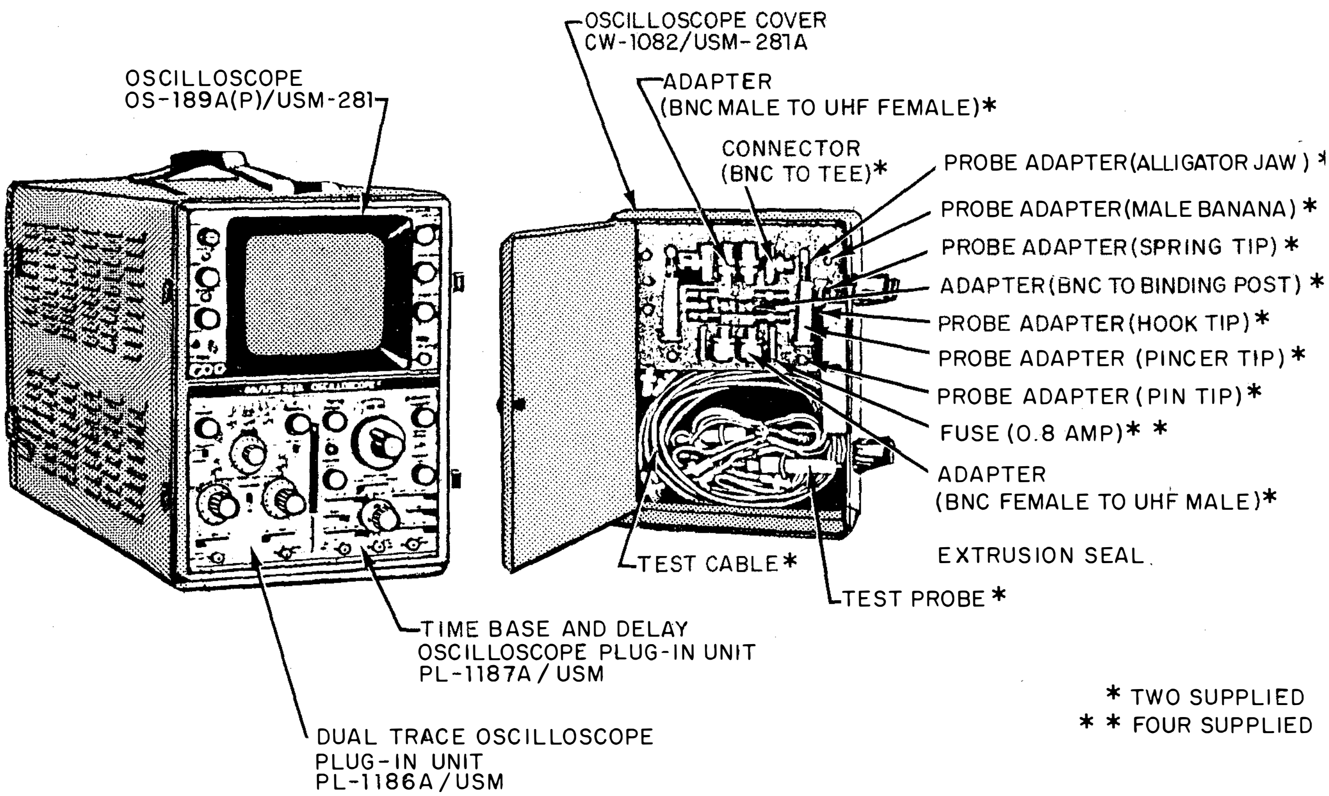

Figure 2-24.—Oscilloscope AN/USM-281A.

modes of operation: main sweep only, mixed sweep, delayed sweep, and single sweep. With the sweep mode selected, a front-panel control provides a choice of 23 sweep speeds for the main sweep, and 18 sweep speeds for the delayed sweep. The time base assembly also provides controls for selecting automatic (free-running or triggered by a signal above 50 Hz) or triggered time base, trigger source, polarity, level, and frequency range, and a calibrated ten-turn control for precise measurement of the delay time to the start of the delayed sweep.

Dual-Channel Vertical Amplifier

The dual-channel vertical amplifier plug-in assembly receives operating power from the oscilloscope low-voltage power supply through a connector on the time base and delay generator plug-in assembly. The dual-channel vertical amplifier contains two separate frequency-compensated d.c. amplifiers capable of displaying from d.c. to 50 MHz with 3% accuracy. Front-panel controls provide three types of operation: a single trace using either channel, a single trace algebraically combining the inputs of two separate channels, and three modes of dual-trace operation. The dual-trace modes available are: a dual trace displayed on alternate sweeps and triggered by the composite input signal, a dual trace displayed on alternate sweeps and triggered by the B channel input signal only, and a dual trace displayed on a chopped sweep that switches at a 400-kHz rate and is triggered by the B channel input signal. Front-panel polarity switches provide for inverting the waveform on either channel when displayed separately or alternately and allow the operator to choose the algebraic combination (A + B, -A + B, -A - B, +A - B) of the two waveforms displayed on a single trace. Controls are also provided for: vertically positioning each trace; d.c. balance of each channel separately and d.c. balance of the combined channels; calibrated input attenuation of each channel; and X5 magnification and input coupling selection (a.c. or d.c.).

Front Cover

The front cover of the oscilloscope is used to protect the controls of the oscilloscope when not in use and provides storage space for the test probes, test cables, adapters, spare fuses, and the Operators Manual.

TESTING ELECTRON TUBES

Electron tube failures are responsible for a large percent of troubles that occur in electronic equipments or systems. However, if a particular system uses a great number of tubes, it is obviously impracticable, as well as poor policy, for you to attempt to locate faults by general tube checking. Only when the fault has been traced to a particular stage should any tubes be tested, and then only those associated with the improperly functioning circuits.

The condition of a tube can be determined by substituting a tube known to be good for the questionable one. However, indiscriminate substitution of tubes is to be avoided, as detuning of circuits may result. In addition, a tube may not operate properly in a high-frequency circuit, although it performs well in a low-frequency circuit. Therefore, if you are to service electronic equipment, a knowledge of tube-testing devices and their limitations, as well as correct interpretation of the test results obtained, is indispensable for accurate and rapid job performance.

TYPES OF TESTS

In order to determine the condition of an electron tube, some method of testing is necessary. Because the operating capabilities (and design features) of a tube are shown by its electrical characteristics, a tube is tested by measuring its characteristics and comparing them with representative values established as standard for that type of tube. Tubes which read abnormally high or low with respect to the standard are subject to suspicion. Practical considerations, which take into account the limitations of the tube test in predicting actual tube performance in a particular circuit, make it unnecessary to employ complex and costly test equipment having laboratory accuracy. For most applications the testing of a single tube characteristic suffices to determine whether a tube is performing satisfactorily.

Testing the emission characteristic of the cathode or filament is perhaps the simplest method of determining the condition of a tube. Since emission normally decreases as the tube ages, low emission is indicative of the end of tube serviceability. This test, however, is subject to limitations, because it tests the tube under static conditions and does not consider the actual circuit operation of the tube. Furthermore, coated cathodes or filaments may develop highly emissive spots, so that the relatively small grid area adjacent to these spots cannot control the electron stream. Under these conditions, testing the total emission may indicate the tube to be satisfactory, while in reality it is defective.

The transconductance (Gm) of a tube used in an amplifier stage is normally a more useful characteristic to measure than the emission. Transconductance is the change of plate current which results from a change in grid voltage; this characteristic, therefore, indicates the ability of the tube to amplify a.c. signals. The most common military tube testers provide dynamic transconductance measurements, although some of the testers are limited to static measurements of this characteristic.

It should be kept in mind that a tube-testing device compares only the characteristic of a given tube with a standard for that particular type of tube. Since the operating conditions imposed upon a tube may vary over wide limits, it is not possible for the tube tester to evaluate a tube in terms of performance capability for all applications. Therefore, the tube tester is not considered the final authority in deciding

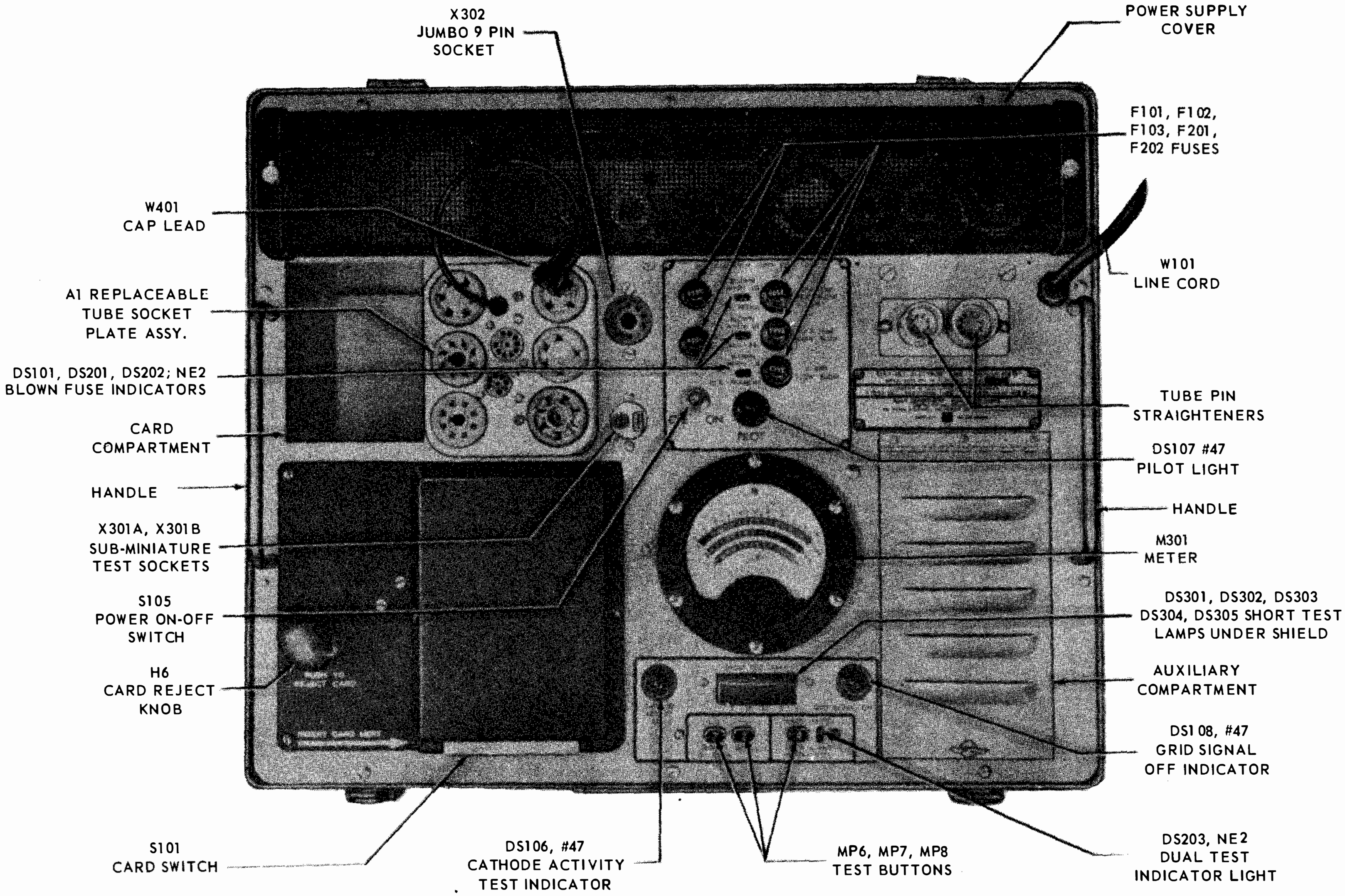

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Figure 2-25.—Tube Tester (AN/USM-118B).

whether or not a tube is always satisfactory. Substituting a good tube in the equipment, provides the most reliable evidence concerning the condition of the tube in question. Substitution is also the only method by which you may test many high-power tubes used for transmitter applications. Never-the-less, the tube tester plays a very important function, since in most cases it provides a quick and satisfactory check on tube serviceability.

TUBE TESTER

A representative field-type electron tube tester designed to test all common low-power tubes is shown in figure 2-25. The tube test conditions (which are as close as possible to the actual tube operating conditions) are programmed on a prepunched card. The card switch (S101, fig. 2-25) automatically programs the tube test conditions when it is actuated by a card. A card compartment on the front panel of the tester provides storage for the most frequently used cards. The cover of the tester (not shown) contains operating instructions, brackets for storing the technical manual, the power cord, a calibration cell for checking the meter and short tests, calibration cards, blank cards, and a steel hand punch.

Front Panel

When a prepunched card is fully inserted into the card switch (S101), a microswitch is actuated which energizes a solenoid, causing the card switch contacts to complete the circuit. The card switch has 187 single-pole, single-throw switches arranged in 17 rows with 11 switches in each row. The card is used to push the switches closed; thus, the absence of a hole in the card is required to actuate a switch.

The meter (M301, fig. 2-25) contains four scales. The upper scale is graduated from 0 to 100 for direct numerical readings. The three lower scales, numbered 1, 2, and 3, are read for LEAKAGE, QUALITY, and GAS, respectively. Each numbered scale includes green and red areas marked GOOD and REPLACE. Inside a shield directly in front of the meter, are five neon lamps (DS301 through DS305), which indicate shorts between tube elements.

The pushbutton marked 2 (MP6) is used for transconductance, emission, and other quality tests described later. The pushbutton marked 3 (MP7) is used to test for the presence of gas in the tube envelope. The pushbutton marked 4 (MP8) is used for tests on dual tubes. A neon lamp (DS203) lights when pushbutton number 4 is to be used. Eleven tube test sockets are located on the panel plus tube pin straighteners for the 7- and 9-pin miniature tubes.

The power ON-OFF spring return toggle switch (S105) turns the tester on by energizing a line relay. The pilot light (DS107) lights when this relay closes. Above the power ON-OFF switch are five fuses. Fuses F101, F201, and F202 protect circuits in the tester not protected by other means and have neon lamps to indicate when they have blown. Fuses F102 and F103 protect both sides of the power line.

Auxiliary Compartment

A group of auxiliary controls covered by a hinged panel are used for special tests and for calibration of the tester. Two of these controls labeled SIGNAL CAL (R152 and R155, fig. 2-26) are used with special test cards for adjusting the regulation and amplitude of the signal voltage. A pushbutton labeled CATH ACT (S302D) is used for making cathode activity tests. When this button is pressed, DS106 on the front panel (fig. 2-25) lights, and the filament voltage of the tube under test is reduced by ten percent. Results of the test are read as a change in reading on the numerical meter scale.

Pushbutton S302E and potentiometers R401 and R405 (fig. 2-26) are used for balancing the Gm bridge circuit under actual tube operating current. Pressing S302E removes the grid signal and allows a zero balance to be made with one potentiometer or the other, depending upon whether the tube under test is passing high or low plate current. Lamp DS108 on the front panel lights when S302E is pressed. Pushbutton S302C is used for checking grid-to-cathode shorts at a sensitivity much higher than the normal tests. Results of this test are indicated by the short test lamps on the front panel.

Certain special tests require the use of a continuously adjustable auxiliary power supply.

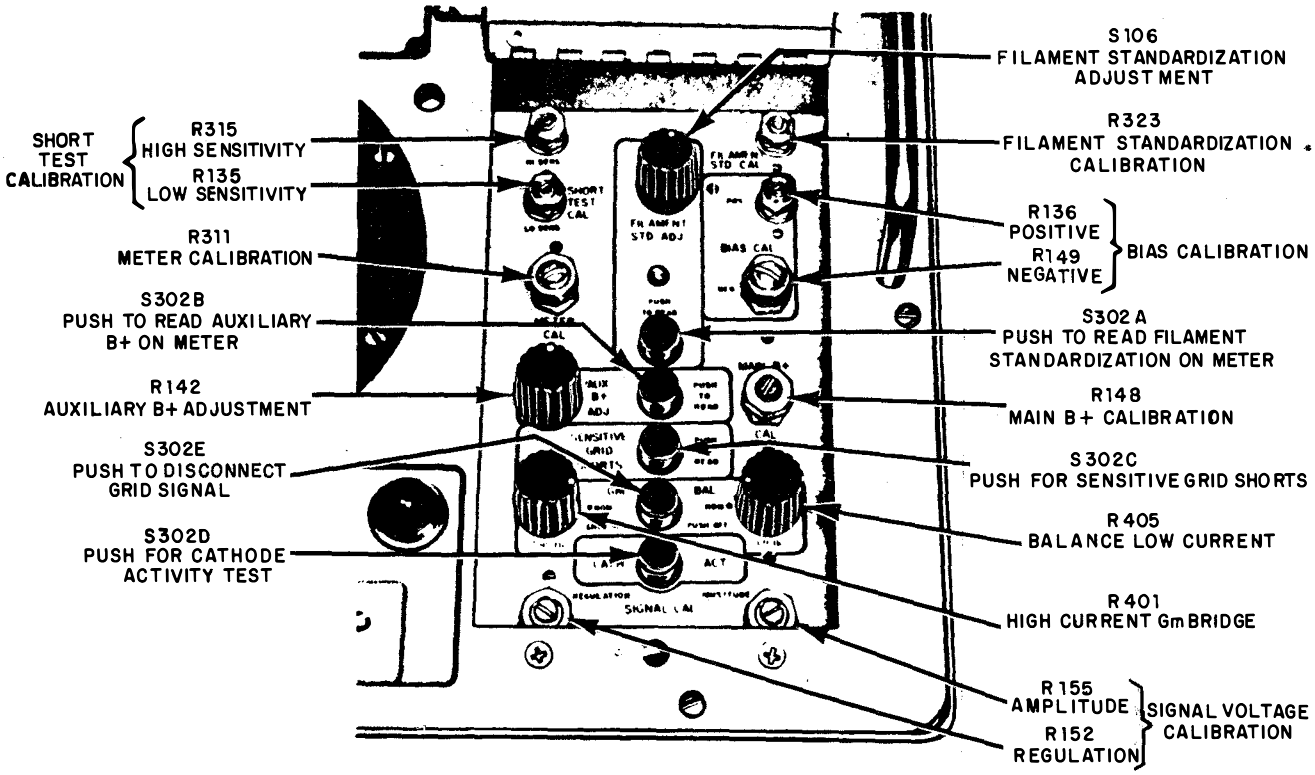

Figure 2-26.—Auxiliary compartment.

By pressing pushbutton S302B, meter M301 may be used to read the voltage of the auxiliary power supply. This voltage may be adjusted by the use of potentiometer R142. The rest of the potentiometer controls are calibration controls and are adjusted by the use of special calibration cards and a calibration test cell.

All circuits in the tester except the filament supply are electronically regulated to compensate for line voltage fluctuations. The filament supply voltage is adjusted by pressing pushbutton S302A and rotating the filament standardization adjustment switch S106 until meter M301 reads midscale.

Program Cards

As stated previously, the circuits to be used in testing are selected by a prepunched card. These cards are made of a tough vinyl plastic material. The tube numbers are printed in color on the tabs of the cards and also at the edge of the card for convenience in filing. A special card is provided to use as a marker when a card is removed for use.

Operation

Before operating for the first time, and periodically thereafter, the tester should be calibrated using the calibration test cards as described in the equipment technical manual.

NORMAL TEST.—The tester is equipped with a three-conductor power cord, one wire of which is chassis ground. It should be plugged into a grounded (105 to 125-volt, 50- to 400-Hz) outlet.

Before operating the tester, open the auxiliary compartment and ensure that the FILAMENT STD ADJ and the Gm BAL knobs are in the NOM position. The GRID SIG and

CATH ACT buttons (S302E and S302D) should be up and lamps DS108 and DS106 on the front panel should be out.

Turn on the tester and allow it to warm up for five to ten minutes, then press the PUSH TO REJECT CARD knob down until it locks. If a nontest card is installed in the card switch, remove it. This card is used to keep the switch pins in place during shipment and should be inserted before transporting the tester.

Plug the tube to be tested into its proper socket. (Use the pin straighteners before plugging in 7- and 9-pin miniature tubes.) Select the proper card or cards for the tube to be tested. Insert the card selected into the slot in the card switch until the PUSH TO REJECT knob pops up. The card will operate the tester only if it is fully inserted, and the printing is up and toward the operator. DO NOT put paper or objects other than program cards into the card switch as they will jam the switch contacts. If the overload shuts off the tester when the card is inserted in the switch, check to see that the proper card is being used for the tube under test, and if the tube under test has a direct interelectrode short.

As soon as the card switch is actuated, the tube under test is automatically subjected to an interelement short test and a heater-to-cathode leakage test. If the short test lamps remain dark, no interelement shorts exist within the tube. A blinking or steady glow of any of the short test lamps is an indication of an interelement short. If a short exists between two or more elements, the short test lamp or lamps connected between these elements will remain dark, and the remaining lamps will light. (This is caused by an imbalance of a balanced circuit). The abbreviations for the tube elements are located on the front panel just below the short test shield so that the neon lamps are between them. This enables the operator to tell which elements are shorted. Heater-to-cathode shorts are indicated as leakage currents on the #1 meter scale. If the meter reads above the green area, the tube should be replaced. A direct heater-to-cathode short will cause the meter to read full scale.

To make the QUALITY test, push the number 2 button (fig. 2-25) and read the number 2 scale on meter M301 to determine if the tube is good. (This test may be one of various types, such as transconductance, emission, plate current, or voltage drop, depending upon the type of tube under test.)

To test the tube for GAS, press the MP7 button and read the number 3 meter scale. The MP6 button also goes down when MP7 is pressed. If a dual tube having two identical sections is being tested, the neon lamp (DS203) will light, indicating that both sections of the tube may be tested with one card. To do this, check the tube for shorts, leakage, quality, and gas as described previously, then hold down button MP3 and repeat these tests to test the second section of the tube. Dual tubes with sections that are not identical require two cards for testing. A second card is also provided to make special tests on certain tubes.

AUXILIARY TESTS.–As mentioned previously, two special tests (cathode activity and sensitive grid shorts) may be made by use of controls located in the auxiliary compartment (fig. 2-26). The cathode activity test (CATH ACT) is used as an indication of the amount of useful life remaining in the tube. By reducing the filament voltage by ten percent and allowing the cathode to cool off slightly, the ability of the cathode as an emitter of electrons can be estimated. This test is made in conjunction with the normal quality test.

To make the CATH ACT test, allow the tube under test to warm up, press button MP6 (fig. 2-25) and note the reading of scale number 2 on meter M301. Note also the numerical scale reading on M301. Next, lock down the CATH ACT button (fig. 2-26), wait for about 1.5 minutes, then press button MP6 (fig. 2-25) again and note the numerical and number 2 scale readings on meter M301. The tube should be replaced if the numerical reading on M301 differs from the first reading by more than ten percent, or if the reading is in the red area on the number 2 scale.

It is sometimes desirable to check certain tubes for shorts at a sensitivity greater than normal. To make the SENSITIVE GRID SHORTS test, push S302C (fig. 2-26) and note if any short test lamps (fig. 2-25) light.

TESTING SEMICONDUCTOR DEVICES

Because of the reliability of semiconductor devices, servicing techniques developed for transistorized equipment differ from those normally used for electron-tube circuits. Electron tubes are usually considered to be the circuit component most susceptible to failure, and are, therefore, normally the first components to be tested. Transistors, however, are capable of operating in excess of 30,000 hours at maximum rating without failure and are often soldered in the line circuit in much the same manner as resistors and capacitors.

Substitution of a semiconductor diode or transistor known to be in good condition is a simple method of determining the quality of a questionable semiconductor device. This technique should be used only after you have made voltage and resistance measurements to make certain that there is no circuit defect that might damage the substitute semiconductor device. If more than one defective semiconductor is present in the equipment section where trouble has been localized, this method becomes cumbersome, since several semiconductors may have to be replaced before the trouble is corrected. To determine which stages failed and which semiconductors are not defective, all of the removed semiconductors must be tested. This can be accomplished by observing whether the equipment operates correctly as each of the removed semiconductor devices is reinserted into the equipment.

TESTING DIODES

Semiconductor diodes, such as general purpose germanium and silicon diodes, power silicon diodes, and microwave silicon diodes may be tested most effectively only under actual operating conditions. However, crystal rectifier testers are available to determine direct-current characteristics which provide an indication of crystal-diode quality.

A common type of crystal diode test set is a combination ohmmeter-ammeter. Measurements of forward resistance, back resistance, and reverse current may be made with this equipment. The condition of the diode under test can then be determined by comparison with typical values obtained from test information furnished with the test set or from the manufacturer's data sheets. A check which provides a rough indication of the rectifying property of a diode is the comparison of the diode's back and forward resistance at a specified voltage. A typical back-to-forward-resistance ratio is on the order of 10:1, and a forward-resistance value of 50 to 80 ohms is common.

Testing with Ohmmeter

A convenient test for a semiconductor diode requires only an ohmmeter. The forward and back resistance can be measured at a voltage determined by the battery potential of the ohmmeter and the resistance range at which the meter is set. When the test leads of the ohmmeter are connected to the diode, a resistance will be measured which is different from the resistance indicated if the leads are reversed. The smaller value is called the forward resistance, and the larger value is called the back resistance. If the ratio of back-to-forward resistance is greater than 10:1, the diode should be capable of functioning as a rectifier. However, you should keep in mind that this is a very limited test that does not take into account the action of the diode at voltages of different magnitudes and frequencies.

Testing with an Oscilloscope

An oscilloscope can be used to graphically display the forward and back resistance characteristics of a crystal diode. A circuit used in conjunction with an oscilloscope to make this test is shown in figure 2-27. This circuit uses the oscilloscope line test voltage as the test signal. A series circuit (composed of resistor R1 and the internal resistance in the line test circuit) decreases the three-volt, open-circuit test voltage to a value of approximately two volts, peak to peak. The test signal applied to the crystal diode is also connected to the horizontal input of the oscilloscope. The horizontal sweep will then represent the voltage applied to the diode under test. The voltage developed across

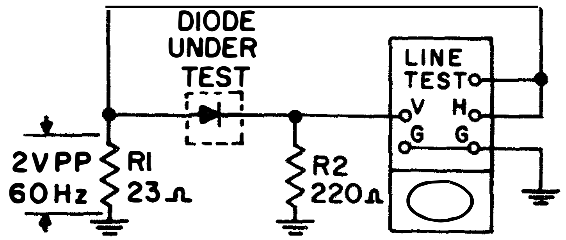

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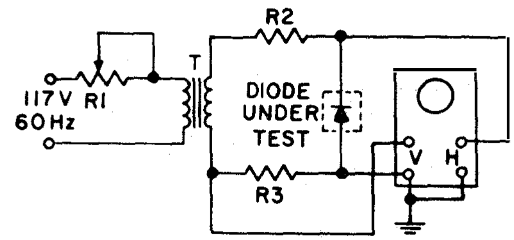
Figure 2-27.—Testing semiconductor diode with oscilloscope.



162.119
Figure 2-29.—Testing Zener diode.

current-measuring resistor R2 is applied to the vertical input of the oscilloscope. Since this voltage is proportional to the current through the diode under test, the vertical deflection will indicate crystal current. The resulting oscilloscope trace for a normal diode will be similar to the curve shown in figure 2-28.

To test zener diodes, a higher voltage than the oscilloscope line test signal must be used. This test can be made with a diode test set or with the circuit shown in figure 2-29. In this circuit, rheostat R1 is used to adjust the input voltage to a suitable value for the zener diode being tested, and resistor R2 limits the current through the diode. The signal voltage applied to the diode is also connected to the horizontal input of the oscilloscope. The voltage developed across current-measuring resistor R3 is applied to the vertical input of the oscilloscope. Therefore, the horizontal sweep will represent the applied voltage, and the vertical deflection will indicate the current through the diode under test. Figure 2-30 shows the characteristic pattern of a zener diode; note the sharp increase in current at the zener voltage (avalanche) point. For the zener diode to be acceptable, this voltage must be within the limits specified by the manufacturer.

Instructions for constructing a simple incircuit semiconductor diode and transistor tester (used in conjunction with an oscilloscope) are contained in EIB 815 of 15 November 1971.

TESTING TRANSISTORS

When trouble occurs in transistorized equipment, power supply voltage measurements, waveform checks, and signal substitution or signal tracing methods are normally the first tests made. If a faulty stage is isolated by one of these test methods, voltage, resistance, and

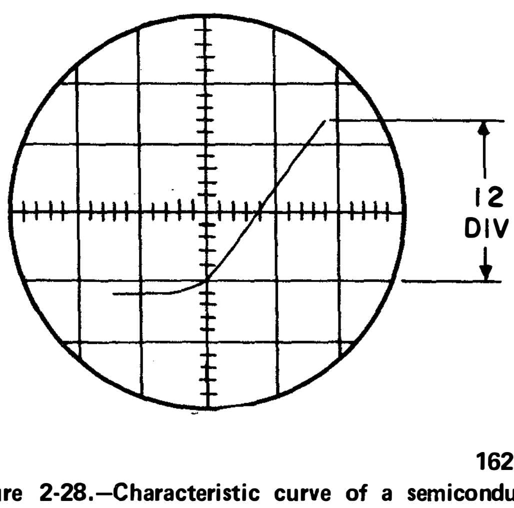


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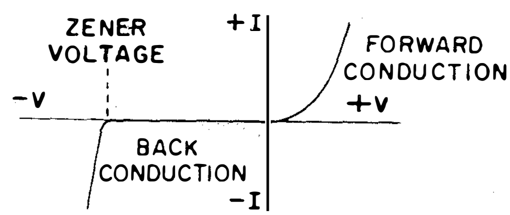
Figure 2-28.—Characteristic curve of a semiconductor diode.



162.120
Figure 2-30.—Zener diode characteristic curve.

current measurements can be made to locate defective parts. When making these measurements, you must make certain that the voltmeter resistance is high enough to have no appreciable effect upon the voltage being measured, and that current from the ohmmeter will not damage the transistor. If the transistors are not soldered into the equipment, it is usually advisable to remove the transistors from their sockets during a resistance test. Transistors should be removed from or reinserted into their sockets only after power has been removed from the stage, since damage by surge currents may otherwise result.

Transistor circuits other than pulse and power amplifier stages are usually biased so that the emitter current is from 0.5 to 3 milliamperes, and the collector voltage is from 3 to 15 volts. The emitter current can be measured by opening the emitter connector and inserting a milliammeter. When making this measurement, you should expect some change in bias due to the meter resistance. The collector current can often be determined by measuring the voltage drop across a resistor in the collector circuit and calculating the current. If the transistor itself is suspected, it can be tested with an ohmmeter or transistor tester as described in the following paragraphs.

Resistance Test

An ohmmeter can be used to test transistors by measuring the emitter-collector, base-emitter, and base-collector forward and back resistances. A back-to-forward resistance ratio on the order of 500:1 should be obtained for the collector-to-base and emitter-to-base measurements. The forward and back resistances between the emitter and collector should be nearly equal. All three measurements should be made for each transistor tested, since experience has shown that transistors can develop shorts between the collector and emitter and still have good forward and reverse resistances for the other two measurements.

Because of shunting resistances in transistor circuits, it will normally be necessary to disconnect at least two transistor leads from the associated circuit for this test. Caution must be exercised during this test to make certain that current during the forward resistance tests does not exceed the rating of the transistor. Ohmmeter ranges which require a current of more than one milliampere should not be used for testing transistors. Many ohmmeters are designed so that on the RX1 range 100 milliamperes or more can flow through the electronic part under test.

Transistor Tester

Laboratory transistor test sets are used in experimental work to test all characteristics of transistors. For maintenance and repair, however, it is not necessary to check all of the transistor parameters. A check of two or three performance characteristics is usually sufficient to determine whether a transistor needs to be replaced. Two of the most important parameters used for transistor testing are the transistor current gain (Beta) and the collector leakage or reverse current (Ico). These are discussed in *Basic Electronics, volume 1,* NAVPERS 10087-C and the *Navy Electricity and Electronics Training Series (NEETS).*

Semiconductor test set AN/USM-206-A (fig. 2-31) is a rugged field-type tester designed to test transistors and semiconductor diodes. The set will measure the Beta of a transistor, the resistance appearing at the electrodes and the reverse current of a transistor or semiconductor diode, a shorted or open condition of a diode, the forward transconductance of a field-effect transistor, and the condition of its own batteries.

In order to assure that accurate and useful information is gained from the transistor tester, the following preliminary checks of the tester should be made prior to testing any transistors:

With the POLARITY switch (fig. 2-31) in the OFF position the meter pointer should indicate exactly zero. (When required, rotate the meter adjust screw on the front of the meter to fulfill this requirement.) The POLARITY switch must always be left in the OFF position, when measurements are not actually being made, to prevent battery drain.

Always check the condition of the test set batteries by disconnecting the test set power cord, placing the POLARITY switch in the PNP

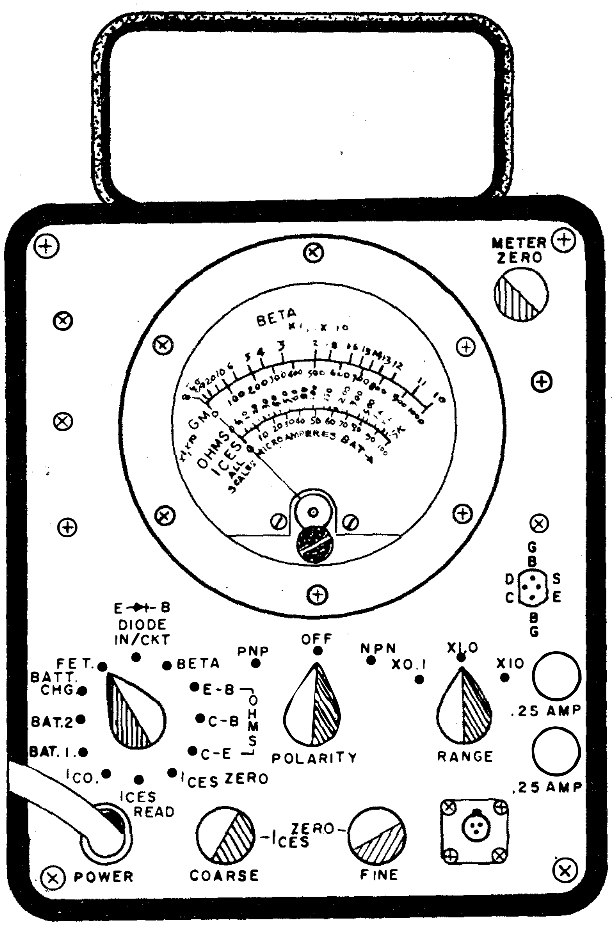


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Figure 2-31.–Semiconductor Test Set (AN/USM-206A).

position, and placing the FUNCTION switch first to BAT (1) then to BAT (2). In both BAT positions the meter pointer should move so as to indicate within the red BAT box.

BETA MEASUREMENTS.–If the transistor is to be tested out of the circuit, plug it into the test jack located on the right-hand side below the meter (shown in fig. 2-31). If the transistor is to be tested in the circuit, it is imperative that at least 300 OHMS exists between E-B, C-B, and C-E for accurate measurement. Initial setting of the test set controls is:

1. Function Switch to BETA
2. Polarity Switch to PNP or NPN (dependent on type of transistor under test) .
3. Range Switch to X10
4. Adjust meter zero for zero meter indication (transistor disconnected)

NOTE: The polarity switch should remain OFF while the transistor is connected to or disconnected from the test set. If it is determined that the Beta reading is less than ten, reset the range switch to X1 and reset the meter to zero.

After connecting the yellow test lead to the emitter, the green test lead to the base, and the blue test lead to the collector, plug the test probe (not shown) into the jack located at the lower right-hand corner of the test set.

When testing grounded equipment, unplug the 115 VAC line cord and use battery operation. A Beta reading is attained by multiplying the meter reading times the range switch setting. Refer to the Transistor Characteristics book provided with the tester to determine if the reading is normal for the type of transistor under test.

ELECTRODE RESISTANCE MEASUREMENTS.–Connect the in-circuit probe test leads to the transistor with the yellow lead to the emitter, the green lead to the base, and the blue lead to the collector. Set the function switch to the OHMS E-B position and read the resistance between the emitter and base electrode on the center scale of the meter.

To read the resistance between the collector and base and the collector and emitter, set the function switch to OHMS C-B and OHMS C-E. These in-circuit electrode resistance measurements are used to correctly interpret the in-circuit Beta measurements. The accuracy of the BETA X1, X10 range is ± 15 percent only when the emitter-to-base load is equal to or greater than 300 ohms.

ICO MEASUREMENTS.–Adjust the meter zero control for a zero meter indication. Plug the transistor to be tested into the jack or connect test leads to the device under test. Set the PNP/NPN switch to correspond with the transistor under test. Set the function switch to

ICO, and the range switch to X0.1, X1, or X10, as specified by the transistor data book for allowable leakage. Read leakage on the bottom scale, and multiply by the range setting figure as required.

DIODE MEASUREMENTS.—Diode qualitative in-circuit measurements are attained by connecting the green test lead to the cathode and the yellow test lead to the anode. Set the function switch to Diode IN/CKT and the range switch to X1. (Insure that the meter has been properly zeroed on this scale.) If the meter reads down-scale, reverse the polarity switch. If the meter reads less than midscale the diode under test is either open or shorted. The related circuit impedance of this test is less than 25 ohms.

PRECAUTIONS.—Transistors, although generally more rugged mechanically than electron tubes, are susceptible to damage by excessive heat and electrical overload. The following precautions should be taken in servicing transistorized equipment:

1. Test equipment and soldering irons must be checked to make certain that there is no leakage current from the power source. If leakage current is detected, isolation transformers must be used.
2. Ohmmeter ranges which require a current of more than one milliampere in the test circuit should not be used for testing transistors.
3. Battery eliminators should not be used to furnish power for transistor equipment because they have poor voltage regulation and, possibly, high ripple voltage.
4. The heat applied to a transistor, when soldered connections are required, should be kept to a minimum by using a low-wattage soldering iron and heat shunts, such as long-nose pliers, on the transistor leads.
5. All circuits should be checked for defects before a transistor is replaced.
6. The power should be removed from the equipment before replacing a transistor or other circuit part.
7. When working on equipment with closely spaced parts, conventional test probes are often the cause of accidental short circuits between adjacent terminals. Momentary short circuits, which rarely cause damage to an electron tube, may ruin a transistor. To avoid accidental shorts, the test probes can be covered with insulation for all but a very short length of the tips.

TEST EQUIPMENT ACCESSORIES

If test equipment only had to be used for one specific function, it would require a very simple design. However, the equipment that a technician maintains is very complicated and requires more test equipment that would take more room than there is available aboard ship. Therefore, it is not uncommon to find test equipment designed for many functions; such as, the multimeter, signal generator, power meter, etc.

To allow test equipment to be multi-functional, accessories for various purposes are normally supplied with the individual piece of test equipment. Examples of these accessories are: high voltage probes for meters, 10:1 attenuator probes for oscilloscopes, impedance matching networks for signal generators, etc.

When a piece of test equipment is used, these accessories must be used to insure that the measurement and information obtained from that reading are correct. If these accessories are not used, most information obtained would be useless in determining the operating status of the equipment under test.

It is imperative that whenever a piece of test equipment is used, all accessories should be checked to insure that they are operating properly. If it is found that one or more of these accessories are missing or inoperative, action should be taken immediately to correct this situation, either by procuring a new one through the supply system or repairing the broken item. Also, when the job is completed insure that all accessories are replaced in the test equipment and that the test equipment is returned to its original location.

REPAIR AND CALIBRATION OF TEST EQUIPMENT

Sophisticated electrical and electronic systems can be maintained at the required state of readiness only if sufficient precision test equipment is carried on board each ship. Because test equipments are complex, sensitive instruments, they must be repaired and calibrated periodically to ensure their acceptability as tools to support equipment repair actions.

Periodic repair and calibration of all portable and installed electrical and electronic test and measuring equipment used as shipboard standards, or in support of shipboard maintenance and repair, is mandatory and will be performed at the lowest level of activity authorized to affect required calibration or field calibration action.

All test equipment known to need repair should be investigated and troubleshooting procedures followed in an attempt to determine the cause of failure. Obvious problems such as open power cords, failed tubes, burned components, broken meters, and missing hardware should be repaired or replaced prior to referring inoperative test equipment to an Intermediate Maintenance Activity (IMA). Obviously, additional problems and damage to sealed units and precision assemblies must be avoided, but local replacement of known failed components will result in faster turn-around time and service from the IMA. The troubleshooting procedures for a piece of test equipments are usually found in the technical manual for that piece of test equipment and should be followed to expedite repairs.

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