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ELECTRONICS TECHNICIAN 3

Prepared by

BUREAU OF NAVAL PERSONNEL

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NAVY TRAINING COURSES

NAVPERS 10188-A

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E-2 or 8 mos. total service.	6 mos. as E-3 or 14 mos. total service.	12 mos. as E-4.	12 mos. as E-5; total service at least 36 mos.	36 mos. as E-6.
SCHOOL	Recruit Training.		Class A for PR3, PR53.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)			Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.			
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center.		BuPers	
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

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or

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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.

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PREFACE

This training course is written for men of the U. S. Navy and Naval Reserve who are interested in qualifying for advancement to Electronics Technician, Third Class. Combined with the necessary practical experience, this training course will aid the Electronics Technician striker in preparing for the advancement-in-rating examination.

The qualifications for Electronics Technicians are included in appendix II. This training course contains information on each examination subject; and, insofar as it is practicable in a training course, information is also included on each practical factor. Because examinations for advancement in rating are based on these qualifications, interested personnel should refer to them for guidance. The LATEST qualifications for advancement in rating should always be consulted.

The ET 3 training course was prepared by the U. S. Navy Training Publications Center, which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by the Bureau of Naval Personnel, the Bureau of Ships, and other Navy activities cognizant of electronic equipment and the duties of Electronics Technicians.

ELECTRONICS TECHNICIAN 3

READING LIST

NAVY TRAINING COURSES

Electronics Technician, 3, NavPers 10188-A
Basic Electricity, NavPers 10086
Basic Electronics, NavPers 10087
Basic Hand Tool Skills, NavPers 10085
Blueprint Reading and Sketching, NavPers 10077-A

OTHER PUBLICATIONS

U.S. Navy Safety Precautions, chapter 18, OPNav 34P1

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your information and Education Officer.* The following courses are recommended:

B150 *Review Arithmetic*
B151 *General Mathematics I*
B152 *General Mathematics II*
C164 *Beginning Algebra I*
C165 *Beginning Algebra II*
C166 *Advanced Algebra*
C290 *Physics I*
C291 *Physics II*
B781 *Fundamentals of Electricity*
B885 *Fundamentals of Radio*
B890 *Radio Servicing and Repair I*

* "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified on the active duty orders."

CHAPTER

1

PREPARING TO BE AN ET 3

THE ET'S PLACE IN THE NAVY

Upon deciding to strike for the rating of Electronics Technician, you selected one of the most interesting and challenging occupations available to men in the Navy. The field of electronics has advanced so far in the last few years that the Navy (as well as the country as a whole) is almost completely dependent on it. This makes the ET a key man in the Navy.

Because of the complexity of electronic equipment, the Electronics Technician must have a good working knowledge of the basic principles of electricity and electronics as well as a working knowledge of practical mathematics if he is to be effective in his maintenance work. Sources of information on these subjects are listed later in this chapter.

Other than the routine duties required of petty officers, your duty will be largely that of maintaining electronic equipment in top working order; this is a PROFESSIONAL duty. Of course, certain bookkeeping chores are involved; but these chores are a part of your overall duty of maintaining electronic equipment.

A knowledge of the content of *Military Requirements for PO 3 and 2*, NavPers 10056 is essential to understanding your MILITARY duties. This publication (as

well as the *Manual of Qualifications for Advancement in Rating*, NavPers 18068) lists the military requirements for advancement to all pay grades.

PURPOSE AND SCOPE OF THE ET 3 TRAINING COURSE

Like other Navy training courses, this course is designed to train a man for a particular job. It is designed to help the ET striker advance to ET 3. However, it can only help the ET striker toward this goal; the initiative and the effort must be supplied by the striker himself.

This course is written to cover the EXAMINATION SUBJECTS and, in so far as practicable, the PRACTICAL FACTORS of change No. 8 in the Electronics Ratings (group III) of the *Manual of Qualifications for Advancement in Rating*, NavPers 18068. These "quals" are included in appendix II of this training course.

OCCASIONALLY, THERE ARE CHANGES IN THE QUALS, AND IT IS THEREFORE NECESSARY FOR THE ET TO CHECK NAV PERS 18068 TO BE SURE THAT HE HAS THE LATEST QUALS.

It is, of course, impossible for an ET to gain complete familiarity with a piece of equipment simply by reading about the equipment. The same is true of certain military duties. A certain amount of practical experience is also needed. Therefore, a form is provided by the Bureau of Naval Personnel on which the supervising officer can date and initial each practical factor (professional and military) of the ET quals as they are completed by the candidate for the next higher rate. This form is called the Record of Practical Factors, NavPers-760 (ET).

IT IS VERY IMPORTANT TO USE THE RECORD OF PRACTICAL FACTORS CORRESPONDING TO THE LATEST QUALS.

A very important booklet published annually by the Bureau of Naval Personnel is *Training Courses and Publications for General Service Ratings*, NavPers

10052-E. The LATEST edition of this publication lists current Navy training courses and other publications that have been prepared for the use of all naval personnel concerned with advancement in rating examinations. Its use by examining authorities in preparing the professional and military examinations for advancement in rating, and its use by personnel preparing to take these examinations are directed by BuPers Instruction 1430.7C.

Because of the great importance of training in the field of electronics, certain information about training facilities is given in this chapter. Other information is contained in NavPers 10056. Also included are useful reference material and a description of the most commonly used forms and reports. However, the bulk of chapter 1 is taken up with brief descriptions of the various types of electronic equipment with which the ET will be working.

Chapter 2 deals with safety precautions that are necessary in working on electronic equipment. The measures that must be taken to reduce hazards cannot be overemphasized. Electricity is no respecter of persons (except, of course, the careful ones), and the life you save may very likely be your own.

Chapter 3 gives a brief treatment of equipment and component nomenclature and designations. It is a great help to the ET to be able to understand, at least to some extent, equipment indicator letters and what they mean. Stock numbers also will be used quite often, and some insight into this system is extremely helpful.

The use of hand tools in electronics is treated in chapter 4. Additional information on the use of hand tools is included in *Basic Hand Tool Skills*, NavPers 10085.

An introduction to electronic installations methods and procedures is given in chapter 5. The ET 3 will find that his job is much simplified if he has a general knowledge of the types and use of cabling, stuffing tubes and

kickpipes, insulating and waterproofing materials, shock-resistant mounts, filters, transmission lines, power systems, and so on.

Chapter 6 is an introduction to general maintenance procedures. Maintenance may be classified as preventive or corrective. Preventive maintenance is keeping the equipment in such shape that it will give maximum trouble-free service; corrective maintenance is getting the equipment to operate again after it breaks down. Some general procedures for repairing the various types of electronic equipment are also given.

The practical application of test equipment is given in chapters 7 and 8. It is, of course, impossible to describe all of the Navy's electronic test equipment in two chapters of reasonable length. An attempt is made, however, to describe typical instruments in each general classification, and the methods of using them in making measurements. Additional valuable information may be found in the latest edition of *Handbook of Test Methods and Practices*, NavShips 91828A.

Naturally, a facility in the use of test equipment comes with practice; and the candidate for ET 3 will do well to use every opportunity to become familiar with the use of all types of electronic test equipment.

You, as an ET striker, will find that Chapter 9 (Switches, Switchboards, and Switching Systems) will have wide application in shipboard electronic systems. In some instances, the switching systems used with electronic equipment are more difficult to understand than the operation of the equipment itself. The simplified approach in this chapter should afford an opportunity for the striker to become better acquainted with switches and switching systems.

Chapter 10 introduces the ET striker to sonar. In general, the treatment is similar to Chapter 14 (Introduction to Radar) of *Basic Electronics*, NavPers 10087. Some of the latest sonar equipments are classified and

cannot be described in this training course, but enough basic information is given so that the student can gain some insight into the operation of sonar gear.

Chapter 11 introduces the ET striker to radiac. He is given a general idea of why radiac instruments are needed in the Navy and how they operate. Much more training is needed, however, before the ET is qualified to repair or calibrate the instruments.

In Chapter 12, Common Operating Adjustments of Electronic Equipments, the importance of knowing how to make operating adjustments on shipboard electronic equipments is emphasized. Operating controls include starting and stopping the equipment, tuning it, selecting the operating frequency, gain control, intensity control, and so forth.

Examples are given for typical equipments in radio communications, radar, and sonar.

TRAINING FACILITIES FOR ADVANCEMENT

Training facilities for advancement are adequately covered in NavPers 10056. In any case, your Educational Officer can assist you in the matter of determining what is available in electronics training.

In general, good ET's are not in abundant supply and if you have the ability and the willingness to learn, there will be few obstacles to block your advancement in this field.

It should be emphasized, to begin with, that however interesting and challenging the field of electronics may be, it is not the easiest field of endeavor that one may choose. Nevertheless, the very fact that the subject is interesting and challenging tends to spur the interested technician on to overcome the difficulties.

Actually, the best way to increase your knowledge of electronics is to sharpen your curiosity first—ask yourself (and others) questions and then relentlessly ferret

out the answers. A great deal of reading is necessary in the field of electronics. Answers to your questions will eventually be found if you read diligently and with comprehension.

Very early in your career in the field of electronics it is extremely important to stick with the basic principles until they become a part of your thinking. If the basic principles are not mastered they will rise up later to block the mental processes when you try to understand electronic circuit operation, or, better, why it does not operate.

DO NOT SKIP OVER THE FUNDAMENTALS: LEARN YOUR WAY THROUGH THEM.

There are many definitions of training but the one used by the Navy is difficult to improve upon, especially because it involves directly ET strikers, like yourself. The Navy's definition of enlisted training is:

"The fastest (most reasonable and economical) methods of making civilians into Navy men and Navy men into expert seamen and technicians. The methods are as broad and varied as the operations and activities they support.

"The methods include precept and example, schools and courses, books and training aids, drills and on-the-job instruction. As these are used to intelligently supplement each other, and as they are taken all together and applied to the training problems of each ship and each man, they spell a 'total training' approach to the necessities of teaching so many men, so many things—quickly."

USEFUL REFERENCE MATERIAL

Electronics is one field in which there seems to be no lack of general reference material. The main problem is that of selecting the type of material suited to the needs of the student or suited to the needs of a particular job.

Reference material includes texts, handbooks, bulletins, instruction books, and technical maintenance publications. Of course, the most useful reference materials are those that contain the desired information in the most readily usable (and understandable) form.

Texts

There are several texts that you as a prospective ET 3 will find helpful. Certain basic Navy training courses are necessary. They include *Basic Electricity*, NavPers 10086; *Basic Electronics*, NavPers 10087; *Basic Hand Tool Skills*, NavPers 10085; *Mathematics*, vol 1, NavPers 10069-A (10069-B, when available); and *Mathematics*, vol 2, NavPers 10070-A (10070-B, when available).

There is a tendency sometimes for a person to hurry through the basic courses in order to get to the more advanced courses. As an ET, you will find that unless the basic principles are mastered first, certain blind spots will develop that prevent a complete understanding of circuit operation. As an example, if the technician is not thoroughly familiar with parallel circuits (parallel resistors, capacitors, or inductors, or parallel combinations of these elements), he will not be able to visualize the effect on a circuit of the failure of one of these elements. The same is true of series circuits. It is therefore necessary for the ET to build his knowledge of electronics on a firm base that includes an understanding of basic principles.

A great deal of effort is being made to tailor the basic training courses and the ET courses to the specific needs of the people who will study them. As new developments are made and new equipments become available, these training courses will be revised and brought up to date.

In addition to the Navy training courses that have been mentioned, there are many good commercial texts that may be used for reference material.

Handbooks

Handbooks serve a very useful purpose in that they present information about a particular field of work, or about a particular type of equipment, in a practical form that can be used by the technician in his everyday work. One such publication is the *Handbook of Test Methods and Practices*, NavShips 91828A (or the latest revision); others are the *Handbook of Naval Shore Station Electronics Criteria*, NavShips 92675, and the *Electronic Test Equipment Handbook*, NavShips 900,155.

Bulletins

One bulletin of great importance to the ET is the *Electronics Information Bulletin* (EIB), NavShips 900,022A, published biweekly for naval electronics activities. Of course, a complete file of these bulletins should be maintained.

This bulletin lists field changes and changes that must be made in instruction books and other publications that are used in the maintenance of electronic equipment. It also lists electronics publications that become available and gives valuable suggestions for servicing electronic equipment.

Although not called a bulletin as such, the *Electronics Maintenance Book* (EMB), NavShips 900,000, includes essentially the same information that was formerly contained in three maintenance bulletins: RMB, CEMB, and SB. For convenience, the EMB is comprised of several volumes, covering general information of an electronics nature in each major electronics field.

Instruction Books

Instruction books will very likely be the type that will become most familiar to you as an ET 3, and to other ET rates as well. Two copies of the instruction book are normally supplied with each new equipment.

Instruction books are divided into several sections (or, in a few instances, into several volumes). First, there

is a general description of the equipment, its purpose, capabilities, and the necessary auxiliary equipment. Generally, the next section treats the theory of operation. This section is extremely important and should not be skimmed over lightly. If the ET has acquired the proper background in electricity and electronics, the theory section of the instruction book should not cause him much trouble.

Other sections of the instruction book include installation, operation, preventive maintenance, corrective maintenance, and parts list. Some instruction books include Stock Number Identification Tables (SNITS), a very useful part of the book.

Installation and Maintenance Manuals

A very valuable source of information is the *Electronic Installation Practices Manual* (EIPM), NavShips 900,171. Composed of many separately bound chapters, this manual provides information on desired or standard methods of making electronic installations.

Another valuable source of information is *Shipboard Antenna Details*, NavShips 900,121(A). This publication is likewise composed of several separately bound chapters, and is intended to serve as a source of information for those concerned with installing and maintaining ship antennas.

Of course, one of the most important and useful manuals available to the ET is the *Bureau of Ships Manual*. Two of the chapters that are of primary interest to the ET are chapters 6 (Inspections, Records, Reports, and Tests) and 67 (Electronics).

RECORDS AND REPORTS

Material History

The *Bureau of Ships Manual* (chapters 6 and 67) states that each activity engaged in the operation of electronic equipment shall maintain suitable cards for

recording the results of inspections of equipments as well as any tests and field changes made. The manual states further that the material history, composed of cards filed in loose-leaf binders, supersedes the machinery history and hull repair books formerly required aboard ship. Such cards as the Machinery History Card (NavShips 527), Material History Card-Electrical (Nav Ships 527A), Electronic Equipment History Card (Nav Ships 536), and Hull History Card (NavShips 539) form the basis of the ship's material history. (ET's are responsible for NavShips 536 only.) The purpose of these cards, when properly used, is to provide a comprehensive record of the items concerned. They are kept up to date and available for inspection at all times and are integrated into preventive maintenance programs such as the Current Ships Maintenance Project (CSMP).

The maintenance history cards that the ET 3 should be especially familiar with are described in the following paragraphs.

ELECTRONIC EQUIPMENT HISTORY CARD (NAVSHIPS 536).—Because this card is the basic maintenance history card for electronic equipment, it is discussed in detail. It provides for recording failures and other information pertaining to electronic equipments. A separate card is filled in for each equipment and major unit on board. If additional cards are required for an equipment they are added behind the original card in the binder. All cards for a particular equipment are transferred with the equipment when it is removed from the ship.

The heading of the card should be typed, but entries on the body of the card may be either typed or written in ink or indelible pencil. The following instructions should be followed closely in filling in the form, a sample of which is shown in figure 1-1.

Equipment Model Designation: All letters and num-

RDZ-1	1204	RECEIVER	CNA-46275	1
Equipment Model Designation	Equip. Ser. No.	Name of Unit and Type No.	Contract No.	Date Acquired
National Company, Inc.			NXSP-15624	5 July 1945
Location	Room No. and Location	Installing Activity		
Radio Room	C-201-2	WNSY		
Brand	Part No. and Location	Part Name	Part No.	Part Location
Part	Part	Part	Part	Part
12/4/45	NO SIGNALS	OPEN FILAMENT REPLACED	TUBE	1201
12/4/45	F.C. & X			
	ADJUSTMENT TO			
	IMPROVE STABILITY			
	OF C.F. AMPLIFIER			

Figure 1-1.—Electronic Equipment History Card (NavShips 536).

bers should be included to indicate the specific model. For instance, AN/ARC-1 should not be entered as AN/ARC or ARC-1.

Equipment Serial Number: This number is taken from the equipment nameplate. If an over-all equipment number is not available, the serial number of the major unit is listed for the entire equipment. When it is definitely established that an item does not bear a serial number, an asterisk (*) is entered in this space. Cards are made up for each unit of an electronic equipment and placed together in the folder. For example, on the AN/SPA-8A the Azimuth-Range Indicator is listed as IP-97B/SPA-8, the Power Transformer as TF-129/SP, and the Power Supply as PP-560A/SP.

Card Number: The number in this space is "1" for each card in the original file. As additional cards for a specific equipment are filed, they are numbered consecutively.

Contract Number: The complete contract number includes all letters and numbers as given on the equipment or unit nameplate.

Date Installed: This space refers to the date the equipment or unit was installed. If the installation required several days, the date of completion is the date entered.

Installing Activity: This space is for the name of the activity that actually installed the equipment.

Box Number and Location: On ships with integrated parts system this space may be left blank, unless for some reason the equipment is not included in the system. Otherwise, the appropriate box number (and location) is entered in this space.

Instruction Book on Board: Check this space only when the final instruction book is received. If only the preliminary book is on board, this space should not be checked. EIB carries notices of the availability of final instruction books.

Date: Enter here the date of failure, field change, or other work involving maintenance or repair.

Nature of Trouble: External evidence of the equipment trouble is entered in this column and should be described in detail. Whenever a field change is made, the field change number and title are also shown in this column in addition to the entry required on the Record of Field Changes (NavShips 537).

Cause of Failure: This column is most important. Describe how the trouble was traced and what corrective measures were taken. Give detailed information. Note peculiarities and weaknesses. The clearer the information in this column, the more valuable it is to the ship, the Bureau of Ships, and the manufacturer. The information in this column, and that reported on the Defense Department Electronics Failure Report, DD787, assists in the production of better and more reliable equipment.

Some activities may wish to record in this column such information as the name and rate of the person actually doing or supervising the work, the man-hours

consumed, and the signature of the Division Officer. Such entries are optional.

Name of Part: List here the names of the parts involved in the failure.

Circuit Symbol: Record here the symbol designations of the parts that failed, as shown in the instruction book.

Navy Stock Number: This space is for the standard Navy stock number (FSN, if available), including all prefix and suffix letters, exactly as given in the instruction book, or preferably the SNITS list.

Life Hours: Enter here the estimated life of the part. To obtain this figure, use the machinery history cards, readings of elapsed time meters that total the operating time of the part, or any other available data.

Date DD787 Mailed: (This column was formerly headed "Date NavShips 383 Mailed.") Record the date the DD787 was mailed to the Bureau of Ships.

RESISTANCE TEST RECORD (NAVSHIPS 531).—This card, shown in figure 1-2, provides for recording the insulation resistance of a unit or circuit. It is inserted in

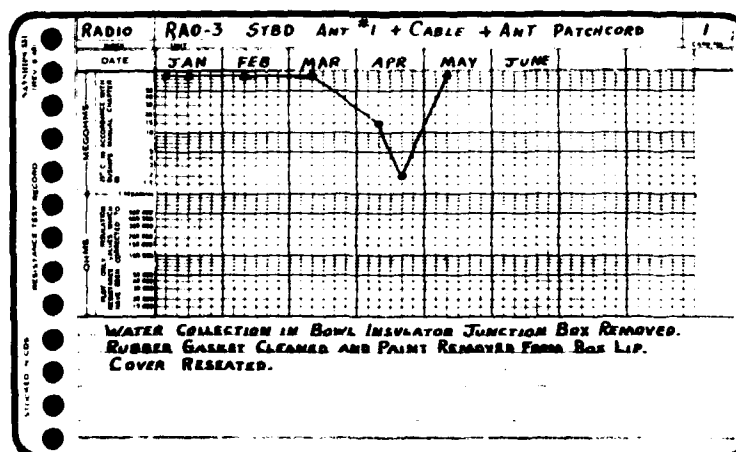


Figure 1-2.—Resistance Test Record (NavShips 531).

the material history binder adjacent to the applicable equipment history card. The lower part of the card may be used to indicate under what conditions the readings are to be taken—what is to be disconnected, how much of transmission line is included, etc. Also, it is sometimes convenient to multiply the scale by 10 for antennas because their reading should be 200 megohms and the card goes only to 100 megohms. If this is done it should be so noted. Keep in mind that some antennas are short circuited as far as d-c is concerned.

ELECTRON TUBE PERFORMANCE RECORD (NAVSHIPS 538).—The performance of service-life-guaranteed tubes is recorded on this card. In general, such tubes are not used aboard ship. The cards, however, may be used at the ship's discretion for any large or expensive tubes for which it may be desirable to maintain separate records. When used, the cards are inserted in the binder adjacent to the equipment history card for the equipment in which the tube is installed. If the tube is transferred the card is transferred with it. Upon failure of the tube the card may be destroyed after the DD787 (described later) has been completed and forwarded to the Bureau of Ships.

RECORD OF FIELD CHANGES (NAVSHIPS 537).—Field changes made to any portion of an electronic equipment are recorded on this card, which is filed in the binder adjacent to the history card for the equipment to which the change is applicable. Completion of field change information is also entered on NavShips 536.

This record is of paramount importance. Without modifications, an equipment may be dangerously out of date and subject to numerous serious difficulties. Without a record of field changes it is difficult to determine what modifications, if any, have been made. The information recorded on these cards is essential for routine maintenance, for troubleshooting, and for ordering

maintenance parts that belong to the improved equipment.

Figure 1-3 shows the Record of Field Changes (NavShips 537). The spaces for equipment model designation, serial number, date installed, and card number are filled in by typing or writing with ink or indelible pencil. The official name or Navy type number (or other official identification) of each component affected by a field change is shown parenthetically after the title of a change.

FDZ-1		1004		5 July 1948		1	
No.	Title of Field Change	Authority for Change	Serial Number	Date Installed	Card Number		
1	REMOVAL OF C-147 CAPACITORS (NOT APPLICABLE)	BUSSHIPS					
2	ADJUSTMENT OF TUNING INDUCTANCE (NOT APPLICABLE)	BUSSHIPS					
3	BONDING FOR AUTO TUNE UNIT	BUSSHIPS				5/8/48	
4	MODIFICATION TO IMPROVE STABILITY OF I-F AMPLIFIER	BUSSHIPS				2/2/48	

Figure 1-3.—Record of Field Changes (NavShips 537).

The columns headed "No.," "Title of Field Change," and "Authority for Change" are completed in numerical order for all changes affecting a specific equipment. Field changes affecting given equipments are listed in the *Electronics Maintenance Book* (EMB). Space is provided on the record to indicate these changes by using numbers corresponding to the numbers shown in this book. The *Electronics Information Bulletin* (EIB) also lists field changes and is also the authority for making the changes.

RECORD CARD-PLAIN (NAVSHIPS 532).—The purpose of this card is to provide for recording any desired supplementary information. It is inserted in the binder adjacent to the card that it supplements.

Current Ship's Maintenance Project

The purpose of the CURRENT SHIP'S MAINTENANCE PROJECT (CSMP) is to provide a current record of maintenance, modifications, and repairs to be accomplished by ship's personnel or during availabilities. The CSMP is composed essentially of the following three cards: Repair Record (NavShips 529), which is blue; Alteration Record (NavShips 530), which is pink; and Record of Field Changes (NavShips 537), which is white. As a repair is required, or an alteration or field change authorized, the applicable card is filled in and filed in the material history binder adjacent to the appropriate history card. Being of distinctive colors, the cards readily indicate outstanding work as the binder is examined.

With the exception of the Record of Field Changes, when work is completed, notations to this effect are entered on the material history card, and the applicable CSMP cards are removed from the binder and placed in a "completed work" file. Completion of field changes are entered on the history card, NavShips 536.

Repair Record Cards and Alteration Record Cards are retained for a period of 2 years after the work noted thereon is completed and entries made in the material history. After the 2-year period, these cards may be destroyed at the discretion of the Commanding Officer. When ships are decommissioned or placed out of service during this period, the cards are retained on board.

Electronic Equipment History Cards and Records of Field Changes remain with the equipments referred to on the cards. If the equipment is transferred, these cards are transferred with it.

This report also is important to the Bureau of Ships because it furnishes first-hand information on equipments under actual operating conditions. It is not re-

Figure 1-4.—Electronics Performance and Operational Report (NavShips 3878).

quired on all electronic equipments. The EMB lists the equipments for which this report is required and gives detailed information on the correct method for completing NavShips 3878.

Figure 1-4 shows an Electronics Performance and Operational Report. The space under general remarks should be filled in with care. In this space should be indicated any information not included elsewhere on the form, such as detailed information on any unusual trouble encountered in operation; exceptional maintenance required; and suggestions for improvement in design, tests, and new applications. The forwarding of suggested improvements is not to be construed, however, as authority to modify the equipment in any way; nor does the forwarding of this report eliminate the requirement for forwarding the Electronics Failure Report (DD787) for each failure of electronic equipment regardless of whether or not an operational report is submitted. Detailed instructions for filling out this report is given in Chapter 1, Section 3, of the EMB (change 9, January 1956).

Electronics Failure Report (DD787)

Because it is extremely important that the Bureau of Ships be informed promptly of all failures of and deficiencies in electronic equipments, systems, components, parts, and tubes, one of the reports most frequently required of the ET is the Electronics Failure Report.

This report serves several excellent purposes. It (1) provides the Bureau with a comprehensive presentation of the over-all performance of electronic gear, (2) points out the weakest parts of any particular equipment, and (3) forms the basis on which to procure maintenance parts. Because new models (or modifications of old models) are usually in some stage of development, prompt receipt of failure reports enables the Bureau to initiate immediate corrective action to eliminate similar or related deficiencies in subsequent production.

Reported failures are tabulated on IBM cards, and regular summaries are made to show at a glance the number and types of failures of any part of any equipment.

The importance of reporting failures and their causes cannot be too highly stressed, particularly if failures occur under actual operating conditions. The reports are to be filled in completely and in conformity with the instructions accompanying the card. Many reports received by the Bureau are valueless because they do not give the essential information required by the form or because the information given is incomplete. When indicating the model or type of equipment, include all significant nomenclature, letters, and digits. A separate DD787 is required for each failure. It is important that accuracy of the entry describing the reason(s) for the failure be verified.

This failure report is shown in figure 1-5. Every necessary detail must be supplied to give a clear picture of the failure—description, cause, corrective measures, and approximate life. This is the way all failure reports should be made if they are to be of value to the Bureau. Instructions are included in Chapter 1, Section 3 of the EMB.

Normally, duplicates of failure reports are not required except in the case of certain electron tubes and crystals. Another exception includes shore stations from which the cognizant maintenance yard requires a copy.

Failure reports on electron tubes must be filled in with the same care given any other failure report to ensure accuracy and completeness. Failure report forms are to be submitted for all tubes that fail in storage, handling, installation, or operation, including tubes used in BuAer and BuOrd electronic equipments. In case of other reported electronic failures, tube failure reports are used by the Bureau of Ships to compile the causes and rates of failures, both of which influence the design

of tubes and equipment and the number of replacement tubes allowed. Failures due to own gunfire should be so designated.

The form (DD787) carries no security classification. Classified military information, including, in some cases, the operating frequency, is therefore not to be included on this form.

All electron tubes received by a ship, station, or other using activity should be examined immediately upon receipt for obvious breakage, defective packing, or signs of rough handling; and electrical tests should be conducted if feasible. All large or expensive tubes should be checked for filament continuity, shorted elements, and loss of vacuum. When possible, tubes should be checked by operation in an equipment socket under rated operating conditions. Failure reports are then completed and forwarded to the Bureau for all tubes received in defective condition.

Equipment Stock Card and Custody Record

Tools and portable test equipment are equipment for which custody signatures are required. They are listed on Equipment Stock Card and Custody Records (NAV. S. and A. form 306), which are signed by the Operations Officer when he receives them from the Supply Officer. The Electronics Material Officer (EMO) signs the custody record cards when he receives the tools and test equipment from the Operations Officer. The EMO then becomes responsible for them. He, in turn, issues them to the ET's. A memo receipt for equipment is signed by each ET when he receives a piece of equipment from the EMO, and the ET, in turn, becomes responsible to the EMO for the equipment.

All equipment is inventoried once a year. The inventory is completed within the first quarter of the fiscal year and within thirty days after the date it is started. The Equipment Stock Card and Custody Record (not to

be confused with Ship Electronics Installation Record, NavShips 4110) is used in making the inventory. The ET's may be called upon to assist the EMO in making this inventory, which consists of checking to make sure that the items listed on the Custody Record are in the department.

Additional information on NavShips 4110 can be found in *Reporting Electronic Equipment Installations*, NavShips 900,135(B). Briefly, the ship electronics installation record system utilizes NavShips Form 4110 for reporting the electronics equipment installations aboard a ship as of a certain date. The form is prepared and distributed by the Bureau of Ships from data submitted by ships and activities. The data is punched into IBM cards from which NavShips 4110 is printed. NavShips 4110 is used for budgetary, procurement, distribution, and installation planning.

USES OF ELECTRONICS ABOARD SHIP

Electronics Defined

ELECTRONICS is the science and technology that is concerned with devices involving the emission, behavior, and effect of electrons in vacuums, gases, and semiconductors.

ELECTRONIC MATERIAL, from a military point of view, generally includes those electronic devices employed in the field of detection and tracking (underwater, sea, land, and air), recognition and identification, communication, aids to navigation, weapons control, and electronic countermeasures. In every case, electronic devices are understood to include the nonelectronic components required to complete their individual operational efficiency, such as power supplies, hoist mechanisms, antennas, etc., but to exclude associated non-electronic equipment in certain over-all systems.

In the remainder of this chapter, brief descriptions of the various shipboard electronic equipments are given.

However, those equipments covered in other chapters of this training course and in *Basic Electronics*, NavPers 10087 are merely mentioned here. The purpose of this brief summary is to give the prospective ET 3 an overall view of the equipments that he may be called upon to service as he becomes more familiar with electronic equipment.

Electronic equipment is rapidly being improved upon, and therefore much of the equipment discussed in the following paragraphs will eventually become obsolete. However, equipments are not replaced suddenly just as soon as new equipments are designed. Before large numbers of new equipment are installed, extensive tests and evaluations must be made; this takes time. Therefore, although a piece of equipment may be on the way out it may still be used on certain ships for a considerable length of time.

Communications Equipment

Communications equipment may be classified in a general way as transmitters and receivers, the principles of operation of which are treated in *Basic Electronics*, NavPers 10087. Both transmitters and receivers are classified further according to the frequency range that they cover, or the power output in the case of the transmitter. Of course, the transmitter and its companion receiver must be capable of being tuned to the same frequency. The following shipboard communication equipments are frequently used aboard Navy vessels.

TRANSMITTERS.—The TBL (7 to 13) operates in the 175-kc to 600-kc (LF-MF) range and also in the 2-mc to 18.1-mc (MF-HF) range; it is capable of CW, MCW, or voice operation at 200, 100, and 50 watts, respectively. The standard installation includes speech input equipment and one or more remote radiophone units.

The TBK (7 to 20) operates in the 2-mc to 18.1mc (MF-HF) range. The output is 500 watts on CW only.

The AN/SRT (14, 15, 16 series) operates in the 0.3-mc to 26-mc (MF-HF) range on CW at 100 or 500 watts, and are described in chapter 12 in connection with common operating adjustments of electronic equipments.

The TED series operates in the 225-mc to 400-mc (VHF/UHF) range on telephone only; the TDZ also operates in the same frequency range on telephone or MCW.

RECEIVERS.—The AN/SRR (11, 12, and 13) operate in the 14 kc to 32 mc (VLF-LF-MF-HF-VHF) range. These sets are designed for general application in all types of vessels of the U. S. Navy. Circuits are provided for the reception of four classes of emission—A1 (CW), A2 (MCW), A3 (telephony), and F1 (frequency-shift) in the appropriate bands. Because of the versatility of these equipments, table 1, which lists some of the details, is included. These receivers are described in chapter 12 as typical examples of common operating adjustments of electronic equipments.

TABLE 1

RADIO RECEIVING SETS AN/SRR 11, 12, AND 13

Model	Frequency Covered	Type of Emission Received	Intended Use
AN/SRR-11	14 kc-600 kc	A1, A2, F1	LF shipboard communication service.
AN/SRR-12	0.25 mc-8 mc	A1, A2, A3, F1	MF shipboard communication service.
AN/SRR-13	2 mc-32 mc	A1, A2, A3, F1	HF shipboard communication service.

The AN/URR (13 and 35) operate between 225 mc and 400 mc (portions of the VHF/UHF bands). They are designed to receive A2 and A3 transmissions on naval vessels or at naval air and shore radio stations.

The AN/URR-27 performs essentially the same functions, except that it covers only a portion (150 mc to 190 mc) of the VHF band.

The RDZ is a general-purpose VHF/UHF receiver for voice reception. It may be used on naval vessels or at naval shore stations. This receiver may be operated locally or controlled remotely to tune to any of 10 preset crystal-controlled channel frequencies within its tuning range. Several remote stations may be employed.

Other receivers are the RBA, the RBB, and the RBC.

Radio Teletype Terminal Equipment

A brief description of radio teletype systems used aboard naval vessels is necessary before a description of the individual components can have any real meaning. More of the details are given in chapter 13 of this training course; also, the prospective ET 3 can obtain much valuable general information on the subject from the November 1955, April 1956, and September 1956 issues of the *Bureau of Ships Journal*. As a matter of fact, much of the information contained in the next several paragraphs is condensed from these issues.

The Navy uses two radio teletype systems afloat. One, the TONE-MODULATED system for short-range operations, is similar to the familiar AM radio. The other, the CARRIER FREQUENCY-SHIFT (CFS) system for long-range operations, is similar to standard FM radio.

TONE-MODULATED SYSTEM.—The tone-modulated system is illustrated in figure 1-6. The teleprinter (TTY) sends out a signal consisting of direct-current, on-and-off pulses. An "on" or "current" interval is called a MARK or MARKING impulse. An "off" or "no-current" interval is called a SPACE or SPACING impulse.

The marks and spaces, designated as M and S in figure 1-7, are generated in various code groups of five units each. The group shown in figure 1-7 is for the letter "H."

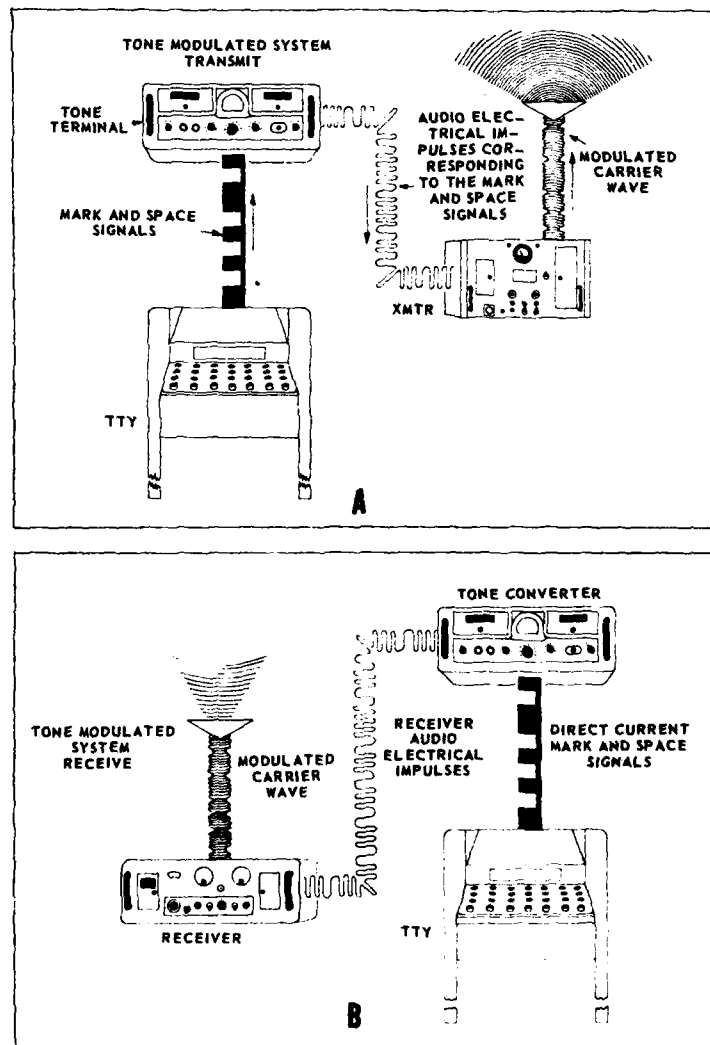


Figure 1-6.—Tone-modulated system.

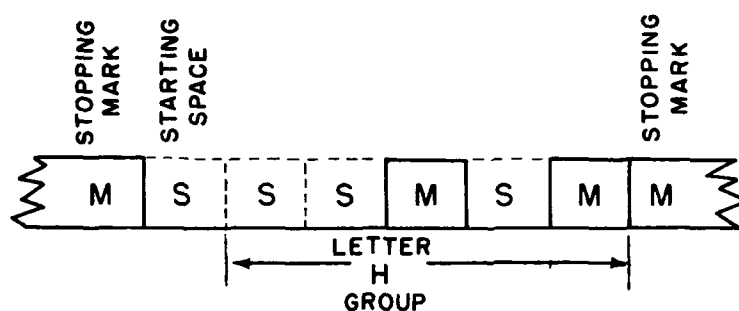


Figure 1-7.—Teletype code group.

A knowledge of the specific groupings is incidental to a basic understanding of the operation of the radio teletype system. The important thing to know is that the succession of direct-current "marks" and "spaces" in fixed-timed intervals conveys both intelligence and synchronization from one teleprinter to another.

To transmit messages by the tone-modulated system (fig. 1-6, A), a teleprinter, a tone terminal, and a transmitter are needed. The teleprinter sends out a direct-current signal of marks and spaces, and the signal is changed to either of two audio tones in the tone terminal. The tones may be 500 cycles for a space and 700 cycles for a mark. The transmitter impresses the audio tones on the carrier and sends out an amplitude or tone-modulated carrier wave.

To receive messages with the tone-modulated system (fig. 1-6, B), a radio receiver, a tone converter, and a teleprinter are needed. The tone-modulated carrier wave enters the receiver, which extracts the signal intelligence and sends the audio tones to the tone converter. The converter changes the audio tones into direct-current mark and space pulses for the teleprinter.

In practice, the same tone terminal is used for both the sending and the receiving circuits because it contains both a transmit "keyer" unit and a receiver "converter" unit.

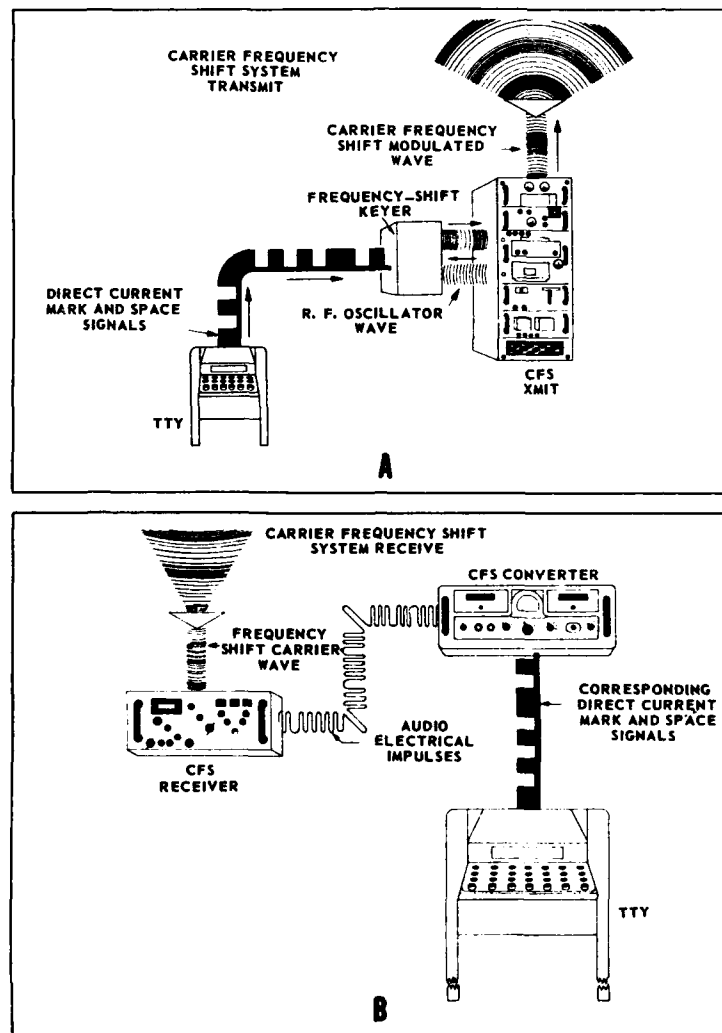


Figure 1-8.—Frequency-shift system.

FREQUENCY-SHIFT SYSTEM.—The frequency-shift system is illustrated in figure 1-8. At the transmitting end of this system (fig. 1-8, A) are a teleprinter; a frequency-shift keyer unit, which is built into the newer transmitters; and a transmitter (XMIT). In some older systems, the keyer unit is a separate piece of equipment.

When the teleprinter is operated, the direct-current teleprinter mark and space signals are changed by the keyer unit into frequency-shift intervals. The frequency-shift intervals are transmitted as carrier frequency-shift signals. The carrier shift is very small compared with the frequency of the carrier; it may be of the order of 850 cycles.

On the receiving side of this system (fig. 1-8, B) are a receiver, a frequency-shift converter, and a teleprinter. When the carrier frequency-shift signal enters the receiver, it is detected and changed into a corresponding frequency-shifted audio signal. The audio output of the receiver is fed to the converter, which changes the frequency-shifted audio signal into the direct-current mark and space teletype signals. The tone converter in the tone-modulated system is similar to the carrier frequency-shift converter in the frequency-shift system.

BASIC RADIO TELETYPE SYSTEM.—When the carrier frequency-shift system (long range) is combined with the tone-modulated system (short range), several more pieces of equipment are needed—a TELETYPE PANEL, a POWER SUPPLY, a SWITCHING CONTROL, a TRANSMITTER SWITCHBOARD, and a RECEIVER SWITCHBOARD, as illustrated in figure 1-9.

The teletype panel is capable of handling six channels, or "loops." The power supply furnishes the direct "looping" current for all teletype direct-current signals. Located at the teleprinter is the switching control, which is used to select the desired system. The transmitter and receiver switchboards are used to integrate the radio

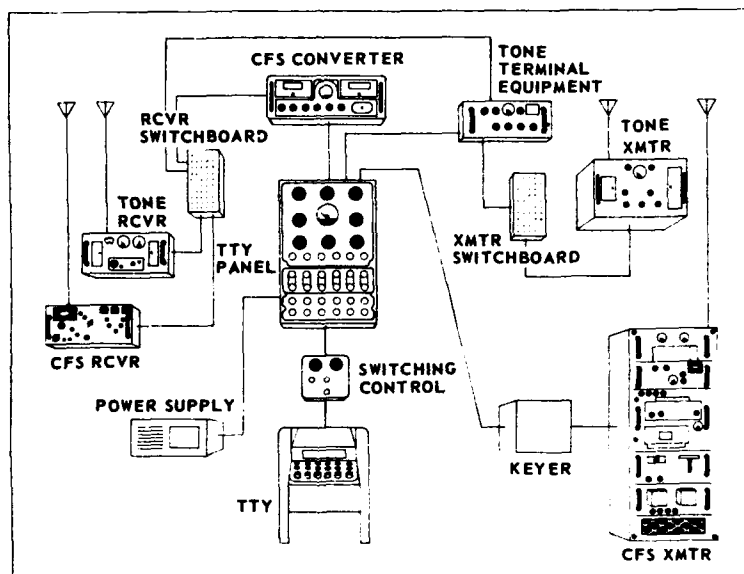


Figure 1-9.—Basic radio teletype system.

teletype systems with other communication systems on board ship.

As has been stated, the tone-modulated system and the carrier-frequency-shift system are integrated to form one teletype system in shipboard communications. The tone-modulated system is used only for short-range, or "line-of-sight," communications in the UHF band. Manmade and atmospheric static and signal fading are not major problems in this band, and no special equipment to counteract these effects is needed.

The frequency-shift system, used in the LF to HF bands, is the best way to send the rapidly keyed signals of the teletypewriter over long distances. Fading and interference are sometimes major problems in these bands.

Because a single r-f carrier usually does not fade simultaneously in areas separated by more than one

wavelength, and because fading of carriers of different frequencies usually does not occur simultaneously at the same point, the Navy has taken advantage of this situation by the use of two methods of DIVERSITY RECEPTION. (See fig. 1-10.)

In SPACE DIVERSITY reception one signal is transmitted, and this signal is received by two receivers. Antennas for these receivers are separated by a distance greater than one wavelength. The outputs of the receivers are fed into two frequency-shift converters and then into a

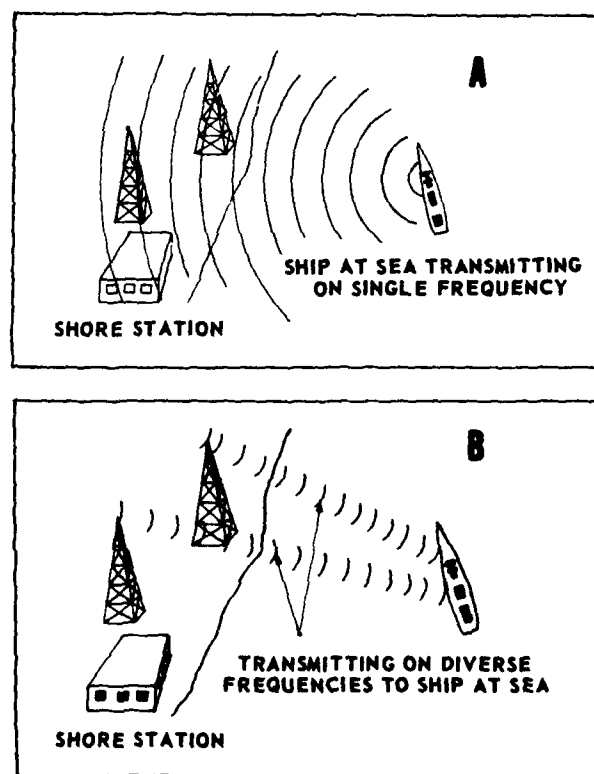


Figure 1-10.—Diversity reception.

COMPARATOR, which selects the best signal for the teletypewriters.

In FREQUENCY DIVERSITY reception, two or more identical signals are transmitted on different frequencies. Two receivers, two converters, and a COMPARATOR are used, as in space diversity. The receiving antennas need not be separated. As a matter of fact, a separation of one wavelength in the lower frequency bands involved might present a problem aboard ship.

For the tone-modulation system (higher frequencies), the transmitter may be the TED and the receiver may be the AN/URR-13; for the carrier frequency-shift system (lower frequencies), the transmitter may be the AN/SRT-14, and the receiver may be the AN/SRR-11, 12, 13 system.

A basic teletype system employing diversity reception is illustrated in figure 1-11.

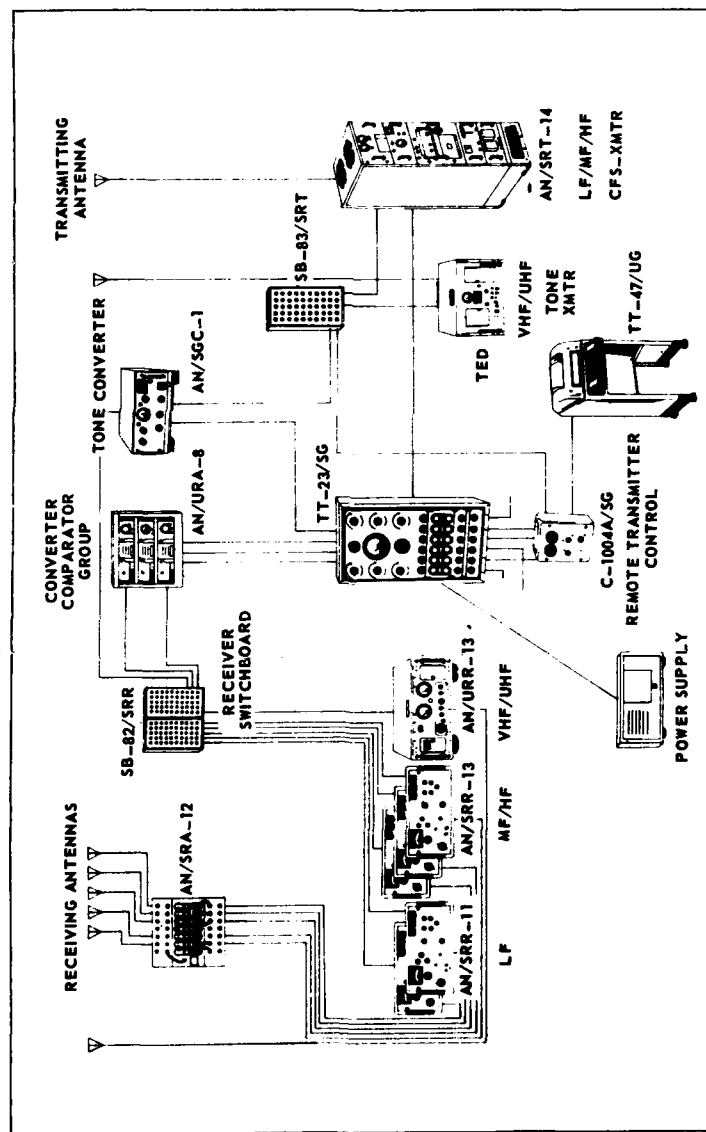
TIME-DIVISION MULTIPLEX.—As used by the Navy on teletypewriter circuits, time-division multiplex is the transmission of the intelligence of several teletypewriter circuits on a time-sharing basis in a character-by-character sequence. Figure 1-12 is a block diagram of the system.

Information is fed into the multiplex equipment simultaneously from four teletypewriters. The same information is then transmitted from one multiplex equipment to the other in a time sequence with one character from each channel at a time. The receiving multiplex equipment then distributes the information to the proper teletypewriter circuits at telegraph speed.

Four characters are therefore transmitted over a single circuit during the time ordinarily required by one.

Facsimile Equipment

Facsimile equipment is used to transmit still images over an electrical communications system. The images, called pictures or copy in facsimile terminology, may be



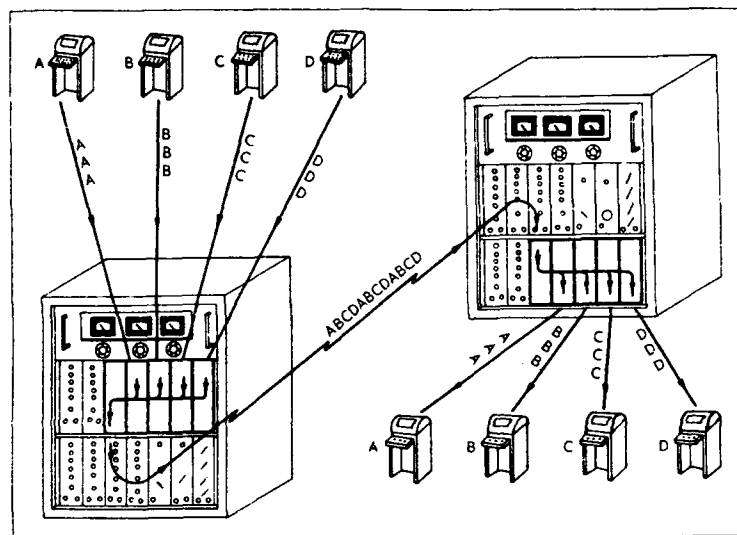


Figure 1-12.—Time-division multiplex.

weather maps, photographs, sketches, typewritten or printed text, or handwriting. The still image serving as the facsimile copy or picture cannot be transmitted instantly in its entirety. Three distinct operations are performed. These are (1) scanning, (2) transmitting, and (3) recording.

PRINCIPLE OF OPERATION.—The SCANNING operation is that of subdividing the picture in an orderly manner into a large number of elemental segments. This process is accomplished in the facsimile transmitter (fig. 1-13) by a scanning drum and photocell arrangement.

The picture to be transmitted is mounted on a cylindrical scanning drum, which revolves at a speed of 1 revolution per second and travels along a lead screw at the rate of 12.5 inches in 20 minutes. (The lead screw has 96 threads per inch.) Light from an exciter lamp illuminates a small segment of the moving picture and is reflected by the picture through an aperture to a photo-

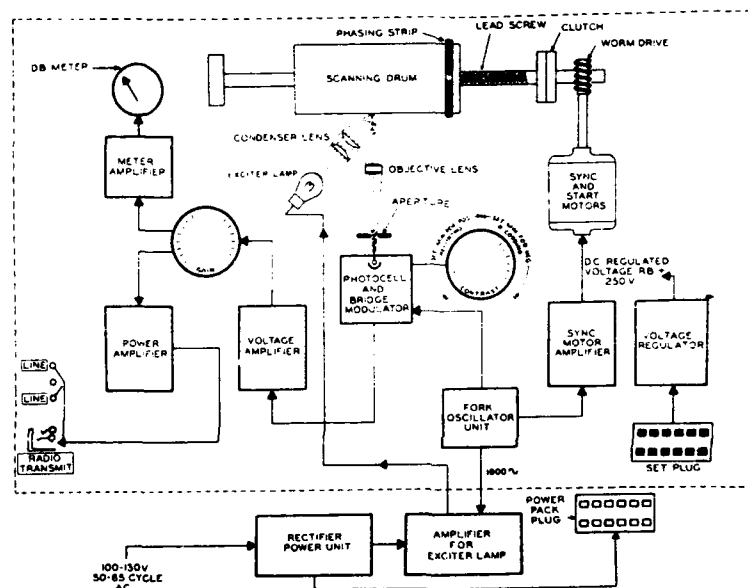


Figure 1-13.—Facsimile transceiver TT-1(*)/TXC-1 transmitting block diagram.

cell. During the transmission of a complete picture, the light traverses every segment of the picture as the drum slowly spirals past the fixed lighted area.

At any instant, the amount of light reflected back to the photocell is a measure of the lightness or darkness of the tiny segment of the picture that is being scanned. The photocell transforms the varying amounts of light into varying electrical signals.

The fork oscillator unit develops an output voltage (MODULATION VOLTAGE) that is applied across the bridge modulator. The frequency of this voltage is 1800 cycles. When the bridge is balanced (photocell dark), the output voltage is zero. When the amount of light falling on the photocell varies, the resistance of the cell varies. This action unbalances the bridge and produces an output voltage that varies in amplitude with the variations

in light. Thus, the 1800-cycle voltage is amplitude modulated in the bridge modulator.

The modulated signal is amplified in the voltage amplifier, the proper level is established in the gain control, and the signal is further amplified in the power amplifier before going to the radio circuits.

The fork oscillator unit, besides furnishing the carrier signal to the photocell bridge modulator, also supplies an 1800-cycle signal to the amplifier for the exciter lamp. This output keeps the exciter lamp at constant brilliancy. The fork oscillator output also supplies an 1800-cycle output to the synchronous motor amplifier. The output of the amplifier is used to operate the synchronous motor that drives the scanning drum at constant speed.

Electrical signals RECEIVED by the facsimile receiver (fig. 1-14) are amplified and serve to actuate a record-

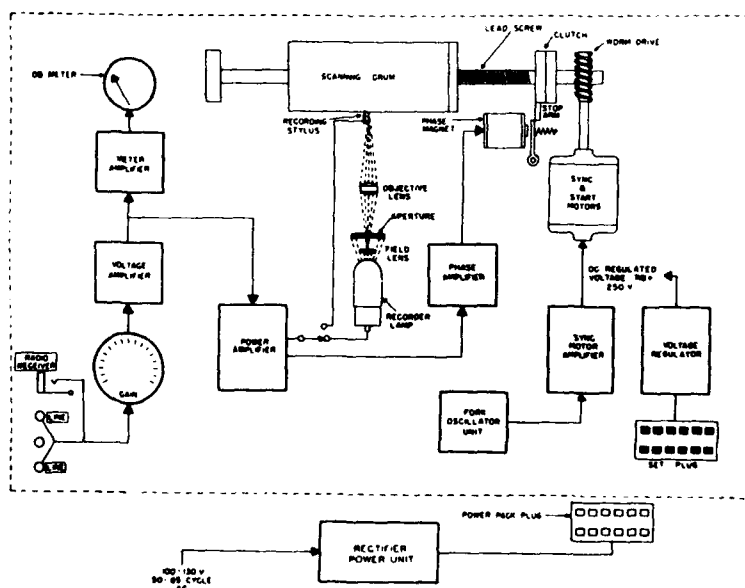


Figure 1-14.—Receiving block diagram, Facsimile Transceiver TT-1/TXC-1.

ing mechanism that makes a permanent recording (segment by segment) on recording paper on a receiver drum similar to the one in the facsimile transmitter. The receiver drum rotates synchronously with the transmitter drum. This action continues until the complete original picture is reproduced in its entirety. The recording mechanism may reproduce photographically with a modulated light source shining on photographic paper or film; or, the recording mechanism may reproduce directly by burning a white protective coating from specially prepared black recording paper.

Synchronization is obtained by driving both receiving and transmitting drums with synchronous motors operating at exactly the same speed.

Framing (orienting) the receiver drum with respect to the transmitter drum is accomplished by transmitting a series of phasing pulses just before a picture transmission is to begin. The pulses operate a clutch mechanism that starts the scanning drum in the receiver so that it is properly phased with respect to the starting position of the scanning drum in the transmitter.

A start motor mechanically coupled to the synchronous motor serves to increase the synchronous motor speed above synchronism during the starting period after which it coasts down to synchronous speed when operating on 1800-cycle power.

The facsimile signal from the radio receiver circuit is attenuated at the gain control, then amplified in the voltage and power amplifiers. The power amplifier output drives either the recording lamp for photographic recording, or the recording stylus for direct recording.

Another circuit from the power amplifier transmits phasing pulses to the phase amplifier, which operates the phase magnet and clutch during the phasing process just before each picture transmission.

The fork oscillator serves a single purpose on receiving. It generates an 1800-cycle signal, which is amplified

to operate the synchronous motor at the same speed as the motor in the transmitting transceiver.

BASIC SHIPBOARD SYSTEM.—Present radio facsimile transmission is accomplished by the carrier frequency shift (CFS) method (with a 400-cycle shift), which uses a standard radio transmitter and receiver.

Radio facsimile terminal equipment (fig. 1-15) at the TRANSMITTER consists basically of a facsimile transceiver TT-41()/TXC-1B, which generates an 1800 cycle amplitude modulated tone frequency in accordance with the black, white, and contrasting shades of the picture that is being scanned. The audio signal is fed to a keyer adapter, KY-44(A)/FX, where it is converted to a d-c voltage. This voltage is used to control the output of the frequency shift keyer, KY-75/SRT. The output of

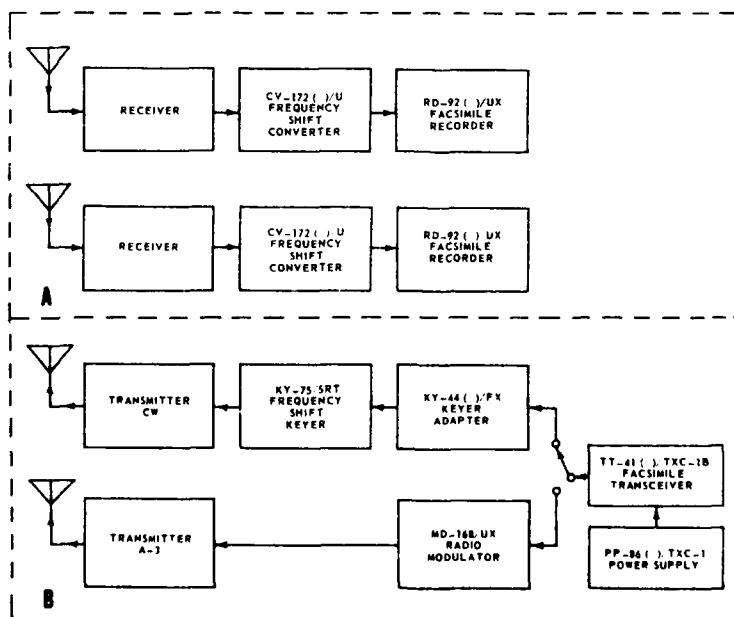


Figure 1-15.—Typical shipboard radio facsimile systems.

the keyer frequency modulates the r-f carrier of a c-w transmitter.

Radio modulator MD168/UX is used between a TT-41(B)/TXC-1B transceiver and an A-3 equipped transmitter. The modulator converts the 1800-cycle, a-m signal from the facsimile transceiver to constant amplitude fm or fs, which varies at frequencies between 1500 and 2300 cycles. This frequency variation is suitable for connection to an A-3 radio transmitter. This method is known as audio frequency shift (AFC) transmission.

To RECEIVE either CFS or AFS, a model RBB or RBC receiver is used with a CV-172()/U frequency-shift converter. The CV-172()/U frequency-shift converter changes the audio output (varying between 1500 and 1800 cycles) from the receiver back to an 1800-cycle, a-m signal suitable for operation of a facsimile recorder RD-92(A)/UX.

The facsimile signal is fed to or from the transceiver by way of a receiver switchboard similar to SB-82/SRR used in the teletype system illustrated in figure 1-11.

Single Sideband

Single sideband (SSB) communication systems are becoming increasingly important in Navy applications. The reasons for this will become apparent after the following brief discussion of the principles of SSB.

In order to understand what is meant by SSB transmission, the student should review the first several pages of Chapter 8 of *Basic Electronics*, NavPers 10087, which discuss conventional amplitude modulation (AM), or, more briefly, "A3" or "Voice." Because of the increased use of SSB, conventional amplitude modulation is sometimes referred to as double sideband (DSB) to distinguish it from single sideband (SSB).

BANDWIDTH.—The amount of r-f spectrum required to transmit the desired intelligence is called **BANDWIDTH**.

For conventional DSB voice transmission, a bandwidth of about 6 to 7 kc, plus separation on either side to prevent interference between adjacent channels, is normally required.

DETECTION.—In the DSB system the carrier is heterodyned with the two sidebands at the second detector of the communication receiver. The two separate, but identical, audio signals are recovered and combined in the audio system of the receiver. In principle, these two identical sidebands add in phase to produce usable a-f intelligence.

SUPPRESSED CARRIER.—The r-f carrier may be eliminated by using a balanced modulator in one of the early r-f stages of the transmitter so that the sidebands are produced, but no pilot carrier will be present. A simplified circuit of a balanced modulator is shown in figure 1-16.

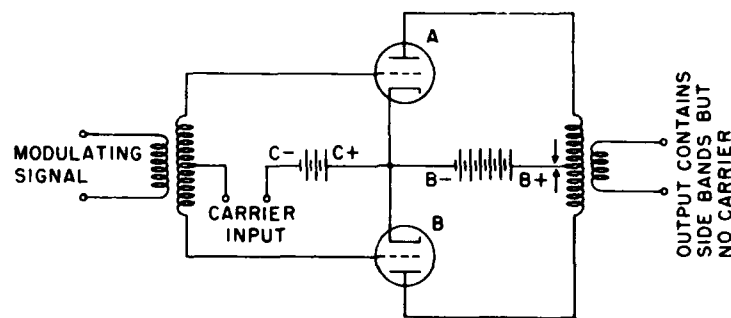


Figure 1-16.—Balanced modulator.

The carrier is applied with the same magnitude and instantaneous polarity to both grids of the push-pull circuit, and is therefore canceled in the output. The modulating signal, however, produces opposite instantaneous polarities at the grids of tubes A and B; the sideband components are likewise of opposite phase and appear in the output. If only one sideband is to be transmitted,

a suitable filter may be used to pass the desired sideband and suppress the other. That is, when speech is fed into the transmitter the carrier itself does not appear in the output. What appears at the output is sideband energy or "talk power."

TRANSMITTING SSB.—If one of the two sidebands is "filtered" or "phased out" before it reaches the transmitted power amplifier, the intelligence can be transmitted on the remaining single sideband. All of the power is then transmitted in one sideband, rather than being divided between the carrier and the two sidebands as in DSB. For example, in DSB (for 100 percent

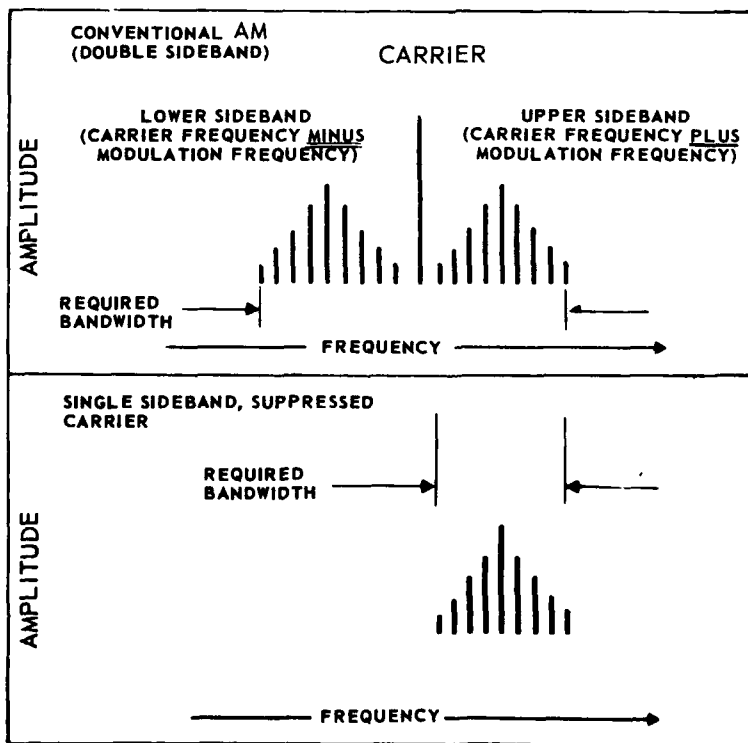


Figure 1-17.—Comparison of DSB and SSB bandwidths.

modulation), when the output power is 150 watts, 100 watts is contained in the carrier and 25 watts in each of the sidebands. In SSB, all of the power is put into one sideband.

Thus, theoretically, a radiated power of 25 watts at the transmitter employing SSB is equivalent to a radiated power of 150 watts at the transmitter when DSB is used. Equally important, the bandwidth required for a SSB voice circuit is approximately half that needed for DSB (see fig. 1-17).

RECEIVING SSB.—The SSB receiver must have rigid frequency stability, much more so than when DSB is used. The SSB receiving station has the problem of furnishing an artificial carrier, because the SSB signal does not have a carrier against which the sideband signals can be heterodyned in the receiver (during the demodulation process) to produce useful audio signals.

Normally, the artificial carrier is furnished by a beat-frequency oscillator in the receiver. This method of carrier reinsertion is not to be confused with those commercial SSB transmitters that transmit a residual (not totally suppressed) carrier signal, so that automatic frequency-control equipment may be used. Such is the type used in the Navy's fixed shore installations.

It is necessary that the SSB transmitter have the same high order of stability as the receiver. The transmitter and receiver must not drift apart more than a very few cycles for quality voice reception.

ADVANTAGES OF SSB.—In DSB, if the sidebands are not received in the proper phase (due largely to multipath skywave propagation conditions), the signal is fuzzy, distorted, and sometimes quite loud. However, with the suppressed-carrier type of SSB, this problem is greatly reduced.

There is, as has been stated, an increase in effective power because all of the power goes into the single side-

band, which carries the useful voice intelligence. The power gain in the SSB system is from 6 to 9 db over the equivalent DSB system. (For a discussion of decibels, see Chapter 8 of *Basic Electronics*, NavPers 10087.) The SSB transmitter provides about 6 db of gain, and about 3 db of gain results from the narrow-band, single-sideband receiver.

Essentially the number of available channels are doubled when SSB is used. Doubling the number of channels in the 2 to 30-mc range is especially important in fleet communications.

In some voice DSB communications systems the carrier remains on the air during periods when modulation is absent. If one station transmits while another (having nearly the same carrier frequency) is on, the result is interference (squeals).

In SSB, with voice break-in, as soon as the individual stops speaking into the microphone, "talk power" in the sideband leaves the air so that interference is reduced. A ship may enter the network as soon as the "talk power" leaves the air. Even when two stations transmit at the same time, a receiving station can read through the interfering station the same way you are able to choose one conversation from several going on around a conference table.

Navigational Equipment

Navigational equipments include a variety of electronic gear, each serving one or more specific purposes. Included among these equipments are radio direction finders, radar direction finders, radio compass equipments, radio and radar beacons, loran (LONG RANGE Navigation), and others. Only brief descriptions of the various equipments are given in this chapter. A more detailed treatment of these equipments is included in the ET 2 training course.

RADIO DIRECTION FINDERS.—Before the development

of radar and loran, radio direction finders provided the only electronic means of obtaining a position at sea. A ship entering port or steaming along the coast near a radio direction finder (RDF) station had two ways of obtaining a radio fix.

By the first method a ship would contact, by radio, an RDF station and request a position. The ship then transmitted a series of signals, and two or more RDF stations took bearings on these transmissions. By telephone or some other means all RDF stations sent their bearings to the designated control station, which plotted them on a geographical chart. When the exact location of the ship was plotted by the crossing of the various RDF bearings, the control RDF station transmitted this information to the ship.

By the second method a ship would take several bearings as rapidly as possible on several radio beacons or radio stations of known geographical location, or on a single beacon or station of known location, allowing, in the latter case, from 10- to 30-minute intervals between bearings. The ship would then plot lines through these bearings. The intersection of the lines would locate the ship. The plotting of these bearings would give a fix that was more or less accurate, depending on the accuracy of the bearing and their angle of "cut."

The first method, utilizing RDF stations, is more accurate and rapid. However, in some instances the second method had to be used because only one radio station was available.

The RDF (for strictly navigational use) finds little shipboard application today, although it is used to some extent in air navigation. Other devices, however, are very rapidly replacing the RDF, even in aircraft.

One of the main uses of RDF today is in the location of personnel afloat in liferafts or lifeboats, as long as they have a radio transmitter on which ships or planes can take bearings.

Essentially, the radio direction finder is a sensitive receiver to which a directional (loop) antenna is connected. Range information is not obtained with just one bearing alone. By taking bearings on at least two transmitters a position can be obtained.

Many older shipboard direction finders operated in the low-and medium-frequency bands because in these frequency ranges the bearing accuracy was increased. However, many of the newer special-purpose RDF equipments operate in the VHF, UHF, and SHF bands. One of the uses of these equipments is to enable the operator to obtain bearings on intercepted radio and radar signals of unknown origin.

RADIO COMPASS EQUIPMENT.—Radio compass equipment finds its greatest present-day usage in aircraft. With a network of radio beacons covering much of the earth's surface, the radio compass is essentially a radio direction finder that automatically indicates the plane's bearing at all times and thus helps the pilot to maintain his course and to locate his position. Where the beamed energy from the beacons cross, it is possible for the pilot or navigator to fix his position with considerable accuracy.

Ground-station radio beacons transmit either continuously or at automatically scheduled times; the pilot merely tunes his compass receiver to the frequency of the stations listed in the area through which he is passing. Indicators automatically show relative bearing information with respect to the station being received.

SECTOR BEACONS.—In military applications, aircraft are guided to carriers and shore bases by means of homing beacons located on the carrier or base. The sector beacon is a special type of homing beacon. It transmits a directional beam from a rotating array that is coded differently in various sectors of its angular sweep.

Each sector has a different code letter so that a pilot

can read the code to determine his approximate bearing with respect to the homing beacon.

The Navy makes use of the Model YG and Model YE homing-beacon transmitter equipments. A suitable receiver in the airplane receives the signals from the sector beacons. These transmitters are designed primarily for installation on aircraft carriers, but may be used on other vessels or at air stations.

Figure 1-18 illustrates the radiated signals that may originate in the YG transmitting equipment. The combination of letters may be changed daily or hourly for purposes of security. The shaded areas in the pattern illustrate that the identification signal is transmitted at certain angular displacements rather than continuously.

TACAN.—Tacan, an abbreviation of TACTical Air Navigation, is being placed in operation by the U. S. Navy and the U. S. Air Force. It is rapidly replacing the

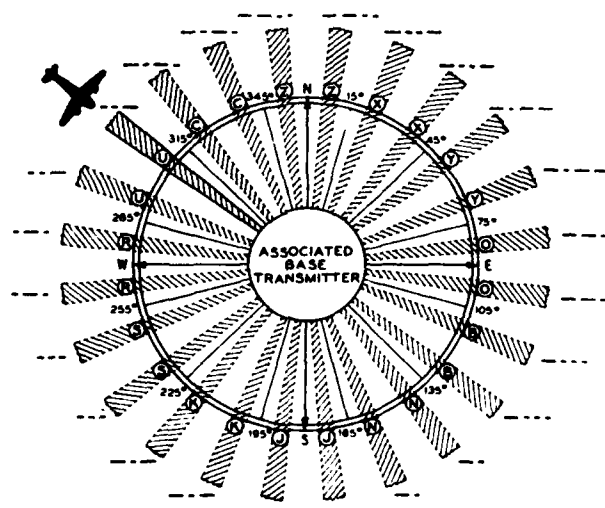


Figure 1-18.—Radiated signal sectors of the YG transmitter.

sector beacons discussed in the preceding section. Civilian airports will also use this equipment.

Tacan is an electronic navigation system with which an airplane pilot can instantaneously and continuously read the distance AND bearing of a fixed ground station or shipboard transmitter. It is one of the newest electronic aids to air navigation.

Because the beacon system has an azimuth accuracy of only 15° , a slow data rate, and no range information, it falls far short of postwar military requirements. The present tacan system resulted from the huge development program in which the Bureau of Ships joined to produce a highly accurate system of position finding that could be used tactically.

Tacan is a polar-coordinate system in which a ship or station installation of an AN/URN-3 (or the improved

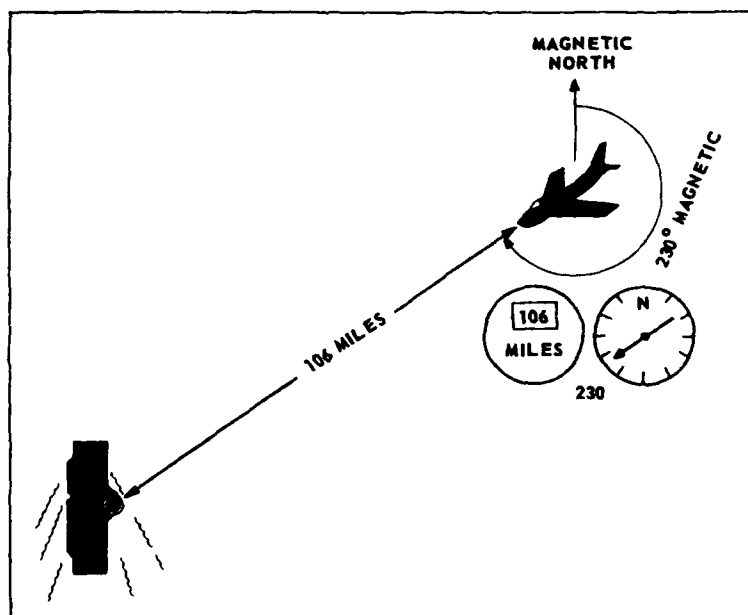


Figure 1-19.—Polar coordinate presentation of tacan data.

model, AN/SRN-6) transmitting set and an airborne AN/ARN-21 transmitter-receiver indicator gives bearing and distance information to an aircraft pilot, as indicated in figure 1-19.

In each aircraft that has the AN/ARN-21 the pilot can read on an azimuth indicator the position of the transmitting source in degrees of magnetic bearing from his aircraft. Also, the distance in nautical miles to the same reference point is registered in front of him as a numerical indication very similar to that of an automobile odometer (mileage indicator). In figure 1-19, the aircraft is 106 miles from the carrier and the ship is on a magnetic bearing of approximately 230° from the aircraft.

To provide a continuous navigation service through a large area, such as the continental United States, the system contains 126 selectable channels. As in television channel assignments, no two stations within interference distance of each other should be on the same channel.

The pilot can switch channels (as easily as he switches channels on his TV set) to select any tacan transmitter within maximum range that best suits his flight path.

To aid the pilot in his identification of a particular transmitter, the transmitter automatically transmits a three-letter tone signal in International Morse Code every 37.5 seconds. The aircraft receiver converts the signal to an audible tone that is heard in the pilot's headset.

Two frequencies are employed, as indicated in figure 1-20. One frequency (Y) is used for transmissions to the aircraft and another frequency (X) is used for transmission from the aircraft. The surface-to-air frequency carries bearing and range intelligence as well as station-identification information. The transmission from the aircraft-to-surface unit is required to trigger the distance-measuring system.

When the pilot closes the proper switch on his set

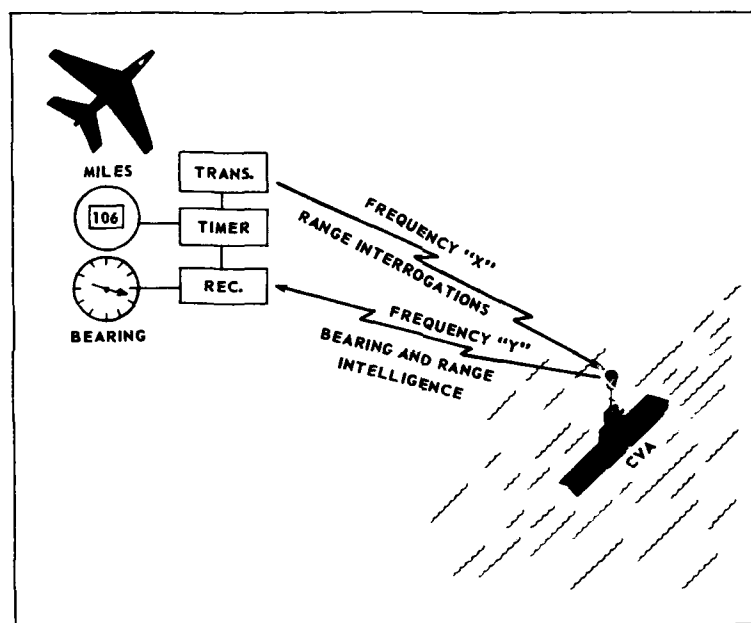


Figure 1-20.—Dual-frequency transmission.

control, his receiver-transmitter radiates a series of range interrogation pulses (frequency X).

The interrogation pulses are detected by any ship or station that is operating on the same channel. The pulses cause the transmitter to radiate a response, which is a series of pulses on frequency Y.

When the reply signal is received in the aircraft, it is fed to range circuits that determine the time that has elapsed during the round-trip of the two signals. Other circuits convert the time difference to equivalent dial indication in miles.

Bearing information is radiated continuously on frequency Y. The AN/URN-3 transmitter is keyed by 3600 pulse pairs a second, of which 900 pulse pairs are used for a reference signal (discussed later) and the

remaining 2700 are used as range interrogation responses or random filler pulses. The filler pulses are emitted during the idle periods between the other pulses.

All pulses have equal amplitude when they leave the transmitter; and they emerge from the fixed vertical conical antenna still at equal amplitude (see fig. 1-21, A).

A single parasitic antenna properly spaced from the omnidirectional conical antenna causes the resulting field-strength pattern to approximate a cardioid. The parasitic antenna rotates about the fixed conical antenna at 15 revolutions a second. Therefore, the cardioid pattern moves 360° in azimuth 15 times a second.

At point X, for example, on figure 1-21, B, an observer with a recording field-strength meter will detect a radio-frequency signal whose strength varies as the parasitic antenna is rotated. The recorded signal strength appears as a 15-cycle sine wave, as shown in figure 1-21, D and E. Similarly, a suitable detector circuit in the aircraft receiver will sense the sine-wave variations of the pattern as it sweeps past the aircraft.

However, the information can be useful only if some point of the rotating pattern can be referenced in azimuth simultaneously at both the airplane and the AN/URN-3 transmitter. The reference is established by a burst of specially timed pulses from the AN/URN-3 at the instant the pattern is moving through the position shown in figure 1-21, C. At this same moment, point M on figure 1-21, C, is a point of maximum rate of change of increasing signal strength.

On the signal strength vs time graph (fig. 1-21, D and E) M is the zero point of the sine wave.

To an aircraft at position P on figure 1-21, C, the reference burst of pulses would be received at the same instant the aircraft receiver was detecting the signal strength denoted by P on figure 1-21, D and E. This point is about 135° away from the zero point, M, of the

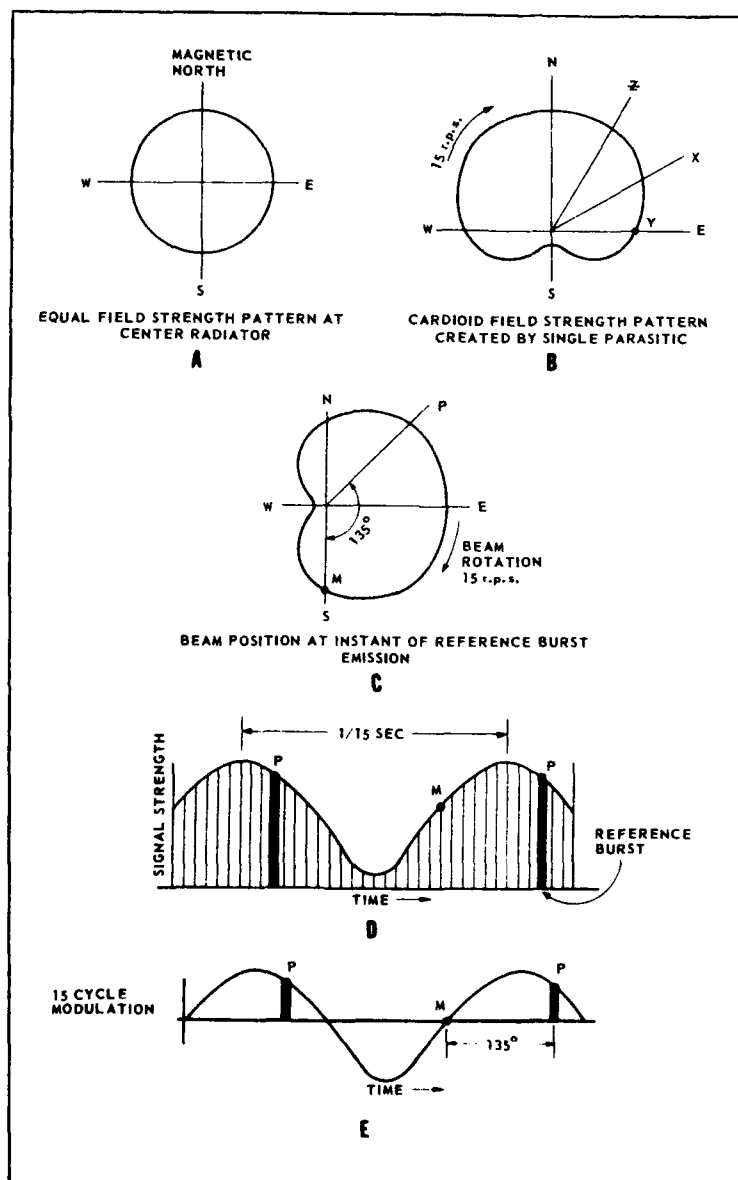


Figure 1-21.—Time pattern showing derivation of bearing signal.

15-cycle sine-wave signal. As long as the aircraft remains at the position angle, P, the reference signal will always be detected 135° out of phase with (or away from) the zero point, M.

Other airborne tacan receivers at various points in azimuth about a tacan transmitter will detect the reference burst of pulses at a difference point or degree on the 15-cycle signal.

The phase-measuring circuits of the airborne tacan receiver detect and measure the time difference to the zero point on the 15-cycle signal. The phase difference is then converted and used to position mechanically the azimuth indicator pointer.

To get a more precise bearing determination, an additional modulating signal of 135 cycles is used in a manner similar to the 15-cycle modulation signal. The 135-cycle modulation is produced by a set of nine more parasitic antennas properly spaced and rotated about the central conical radiator at 15 revolutions per second.

The 135-cycle modulation provides the vernier (or more accurate) bearing data. It is somewhat similar in purpose to the 36-speed synchro operating with the single-speed synchro. The 36-speed synchro furnishes 360° of phase shift for every 10° of rotation of the single-speed synchro. Similarly, by the use of 135-cycle modulation of the tacan signal, 360° of electrical phase shift is provided for every 40° of azimuth ($\frac{1}{9} \times 360^\circ$) to create the extremely high bearing accuracy of the system.

The details of the operation of this equipment may be obtained from the instruction book (NavShips 92348) when it becomes available. Additional information is included in the August 1957 issue of the *Bureau of Ships Journal*, from which the information given is condensed.

LORAN.—The loran system was designed to provide a means of obtaining navigational fixes by using low-

frequency radio signals. The word LORAN is a combination of the first letters of the words LONG RANGE Navigation. With loran, accurate fixes (locating one's position) can be obtained at much greater distances from transmitting stations than is possible with conventional radio direction finding. During the day, over sea water, fixes are possible up to 700 nautical miles from the loran transmitting stations. During the night

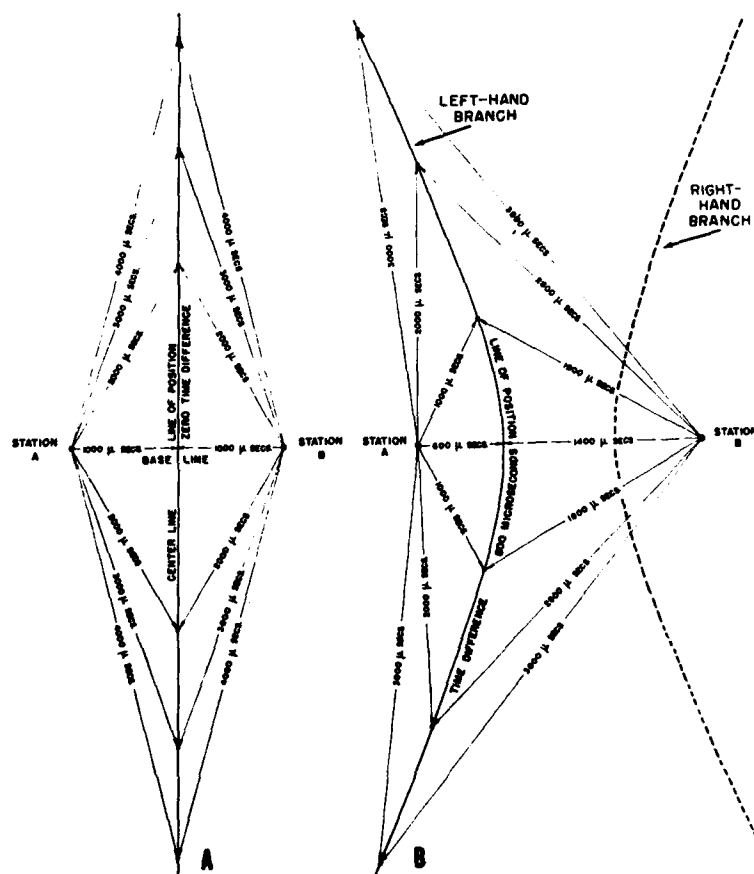


Figure 1-22.—Principle of loran simplified.

when sky waves are utilized, satisfactory operation may be obtained up to 1400 miles.

A loran fix compares favorably in accuracy with a celestial fix and it has certain advantages. It may be used as well in a heavy fog as in clear weather, and the readings can be made rapidly at any time.

The principle of loran is based on the difference in time required for pulsed radio signals to arrive from a pair of synchronized transmitters. Loran transmitters are installed on shore several hundred miles apart. The principle of loran is illustrated in figure 1-22. If in part A, stations A and B are pulsed simultaneously, the two pulses arrive at any point on the center line at the same time. This is evident from the geometry of the figure; and an observer, with the proper receiving equipment, could tell if he was on this line.

Suppose, however, that an observer is located closer to station A than to station B. Then the pulse from station A will arrive at his location before the pulse from station B. Assume that the time difference is $800\ \mu\text{s}$, as shown in part B. There are many points at which the receiving equipment will indicate a time difference of $800\ \mu\text{s}$; these points lie on a hyperbola. Connecting the points where the time difference is the same forms a line of constant time difference, or hyperbolic line of position. This line (solid curved line) forms the LEFT BRANCH of the hyperbola. It is concave toward station A.

If the observer knows that he is closer to station A than station B and that the time difference is $800\ \mu\text{s}$, he still does not know this exact position on the hyperbolic line of position.

Assume now that the observer is nearer station B than station A and that the time difference between the arrival of the two pulses is $800\ \mu\text{s}$. The line of constant time difference is then the righthand branch of the hy-

perbola, and appears as the dotted curve in figure 1-22, B.

(Stations A and B are the foci of the hyperbola.) If the pulses from the transmitters are identical, the observer has no way of telling which pulse arrives first. He then cannot determine on which branch of the hyperbola he is located. This difficulty is overcome, and at the same time the measurement made by the observer is simplified by delaying the pulsing of one of the transmitters by an amount that is more than one half the pulse-recurrence interval from the other station. For example, the interval between a pulse from A and the next pulse from B is always made greater than the interval between the B pulse and the next A pulse. Thus the navigator can tell that the pulse followed by the longer interval is always from station A.

From the foregoing explanation it follows that many lines of position may be obtained. By selecting several time differences for a given pair of stations, the result is a family of hyperbolas like those shown in figure 1-23, A. In figure 1-23A the pulses from both transmitters are identical and no time delay is introduced as indicated by zero on the center line.

In actual practice, one station of a loran pair (fig. 1-23B) is designated the master station. It establishes the Pulse Repetition Rate (PRR). The second, or slave station, receives the pulses of the master station and transmits its own pulses delayed in time but in synchronism with the master pulses. The time delay between the transmission of a pulse from the master station and the arrival of this pulse at the slave station depends chiefly upon the DISTANCE between the stations. This delay is caused by transit time.

After the pulse arrives at the slave station, there is a time delay of one-half the pulse-repetition period. This delay is necessary because of the two-trace method of cathode-ray-tube presentation at the loran indicator.

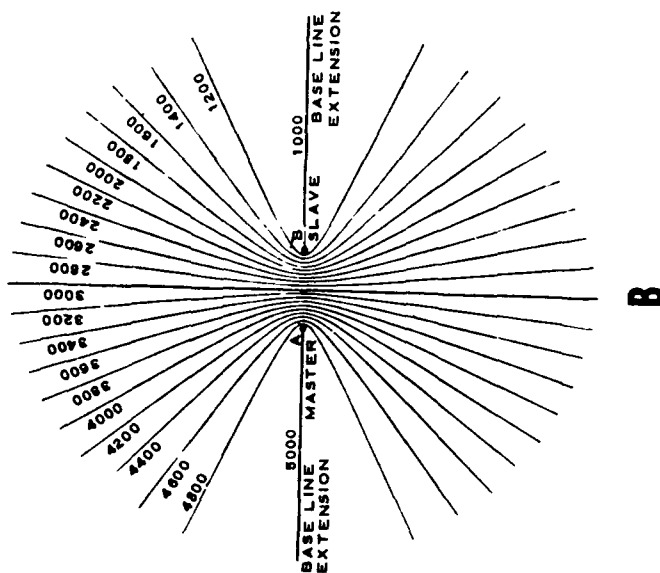
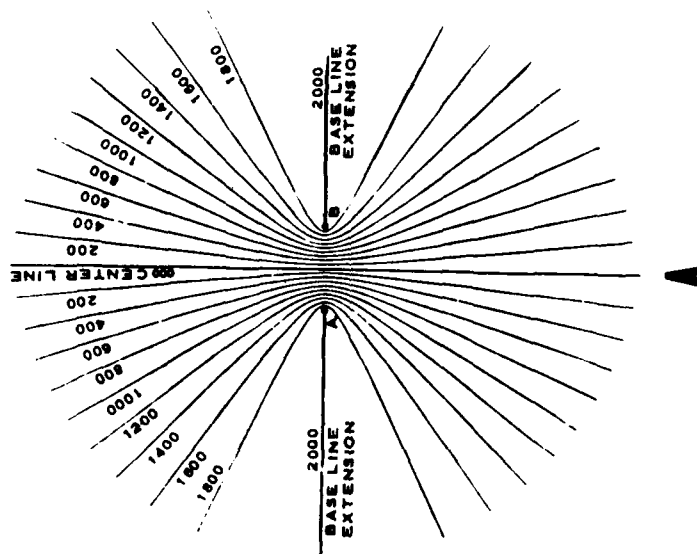


Figure 1-23.—Lines of position.

In addition to these two delays, another delay, called the CODING DELAY, is added. The sum of the three delays is called the ABSOLUTE DELAY. The absolute delay is the time between the transmission of a pulse from the master station and the transmission of a pulse from the slave station. The absolute delay in figure 1-23, B, is 3000 μ S, as indicated on the center line.

The PRR is different for different pairs of stations to enable the operator to identify the pair to which the receiver is tuned. There are four loran channels, numbered 1 through 4, corresponding to carrier frequencies of 1950, 1850, 1900, and 1750 kc, respectively. The BASIC PRR is either 25 cps (the LOW, or L, rate) or 33 $\frac{1}{3}$ cps (the HIGH, or H, rate). A third basic recurrence rate of 20 cps (the SPECIAL, or S, rate) is not in operational use, but is provided in new equipment to allow for expansion of the loran system.

The basic pulse recurrence rates are subdivided into SPECIFIC PRR. The specific low PRR is from 0 through 7, corresponding to 25 through 25 $\frac{7}{16}$ pulses per second in steps of $\frac{1}{16}$ of a pulse per second. The specific high PRR is from 0 through 7, corresponding to 33 $\frac{1}{3}$ through 34 $\frac{1}{9}$ pulses per second in steps of $\frac{1}{9}$ of a pulse per second.

To establish his position, the loran operator must have the proper loran charts, as well as the proper receiving equipment. A loran fix is the point of intersection of two lines of position. Two pairs of transmitting stations, or one master and two slave stations, are needed to establish the lines of position necessary for the fix. One pair of stations act as foci for one family of hyperbolas. The second pair of stations act as foci for another family of hyperbolas. As has been stated, a fix is the intersection of two hyperbolas, one from each family.

Figure 1-24, illustrates how a fix is obtained by using only one master and two slave stations. This is accomplished by causing the master station to transmit two

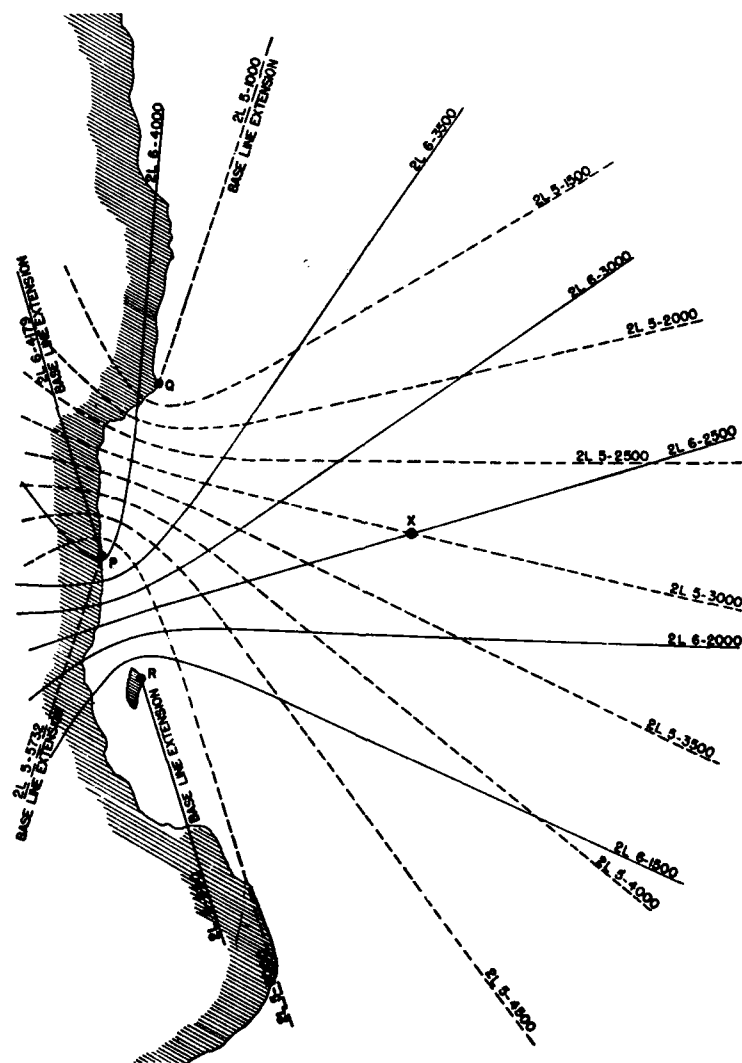


Figure 1-24.—Obtaining a fix with one master and two slave stations.

distinct sets of pulses. The double-pulsed master station transmits one set of pulses at the PRR of the pulse transmitted by the first slave station and the other set of pulses at the PRR of the pulses from the second slave station.

Lines of position are identified by a letter and several numbers. The letter represents the basic PRR—Low (L), high (H), or special (S). The first number represents the channel (1 through 4), or carrier frequency; the second number denotes the specific PRR; and the last number is the time difference in microseconds. For example, 2L 6-2500 indicates channel 2, which is 1850 kc; a low basic PRR of 25 cps; a specific PRR of 6, corresponding to $25\frac{5}{16}$ cps; and a time difference of 2500 μ s.

Loran charts for use aboard ships and aircraft are published by the U. S. Navy Hydrographic Office.

Radar Sets

An introduction to radar is given in Chapter 14 of *Basic Electronics*, NavPers 10087. Some representative radar sets are listed in the following paragraphs.

The SG-6b radar is a shipboard radar originally designed for surface and zenith scanning. The special dual antenna allows the operator to choose either surface search for targets on or slightly above the water or zenith search for aircraft approaching overhead. Targets are presented on the screens of a range scope and on the screens of the various repeaters, for example, the VJ.

The AN/SPS-6c radar is a shipboard radar designed for long-range search and is capable of detecting both aircraft and surface craft. Detected targets are indicated on a range indicator and on as many as four PPI indicators such as the VK, AN/SPA-4, AN/SPA-8, or similar types. Of course, with switchboards or other coupling devices the number of repeaters that may be used is unlimited.

The AN/SPS-4 radar is an improved version of the SG-6b radar. It operates at a lower frequency than the SG-6b and at a higher power output.

Radar Set AN/SPS-8 is a high-power, shipboard, height-finding radar system, designed for fighter aircraft direction. It presents target height, slant range, bearing, and beacon information on remote radar repeaters, Navy Model VK Plan Position Indicator (PPI) and Navy Model VL Range-Height Indicator (RHI).

Radar Repeaters

In the early days of radar, indicators were a part of the console of the radar itself. However, with the increase in numbers and purposes of radar sets aboard ship remote indicators (radar repeaters) became necessary.

At the remote indicator, a selector switch permits the operator to select any one of the shipboard radar presentations for viewing. The output of the radar receiver is fed through an electronic network, which is separate from the main indicator circuit, and therefore the range scale used at the repeater does not have to be the same as that used at the main (console) indicator. A typical switching network is treated briefly in chapter 9 of this training course.

Because repeaters represent an important part of the ET's work, some typical repeaters are described briefly in the following paragraphs.

AN/SPA-8A REPEATER.—The AN/SPA-8A Repeater may be used to display information from a variety of shipboard radars. When used with such radars, the PPI will be ship centered unless off-centering is introduced. Views of the top and front panels are shown in figure 1-25, A.

Provision is made on the indicator for an electronic cursor and range strobe. The electronic cursor appears on the PPI as a sharp, bright line whose direction may

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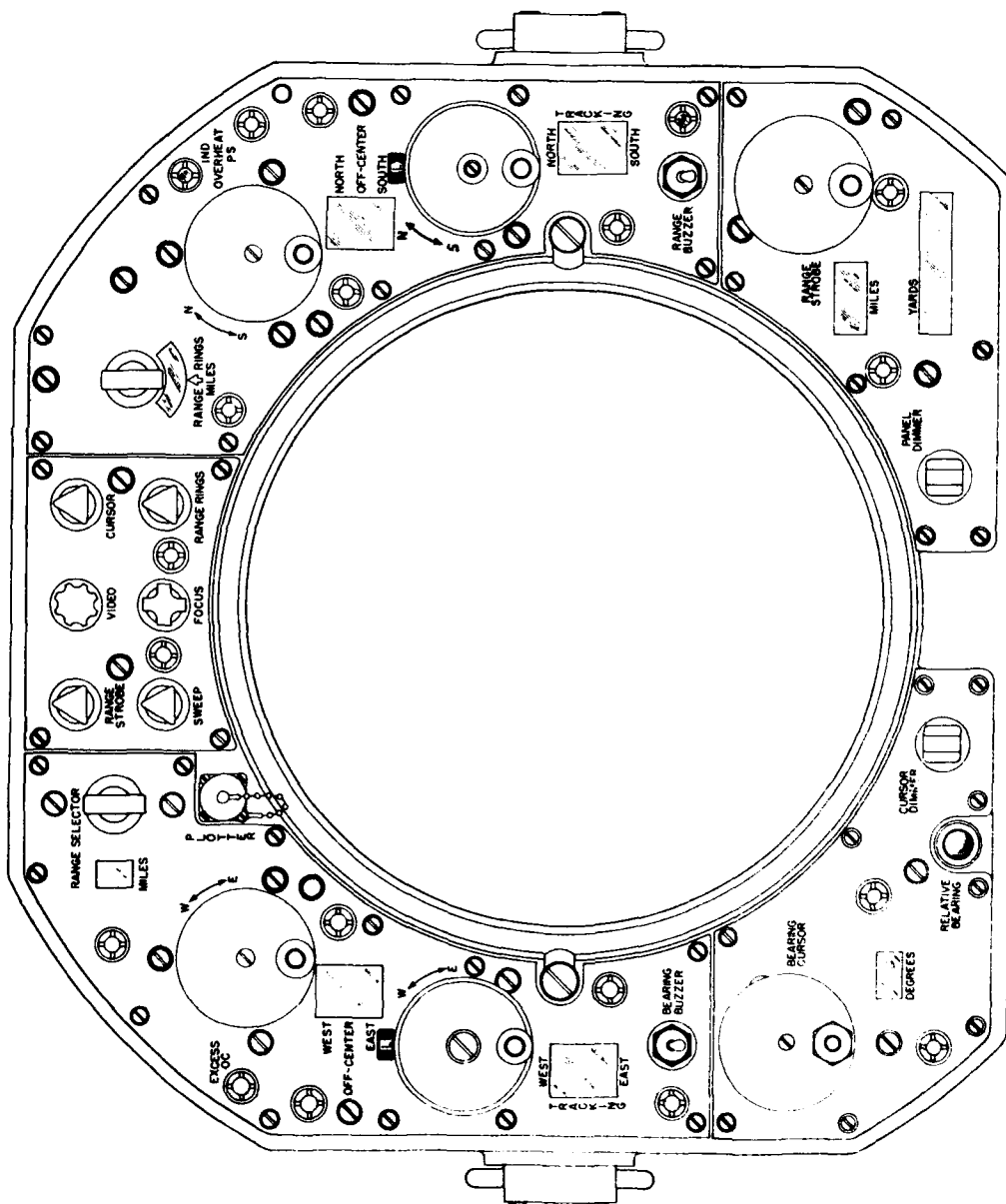


Figure 1-25.—Top and front panels of the AN/SPA-8A repeater

be set by the BEARING CURSOR control. The range strobe is a bright spot that may be moved along the cursor by the RANGE STROBE control. Range and bearing may be read directly from counters. This information is made available in two synchro channels for transmission to remote points.

This repeater can be designed to be used as a part of the airborne early warning (AEW) system. This system extends the range of standard shipboard radar by carrying the search radar in a high-flying aircraft and relaying the radar information back to the ship for presentation on the ship's indicators.

Two indicators, one for tracking and one for use as a final indicator, may be used as a pair to display such relayed information. When used with the AEW system, the presentation on the tracking indicator will be AEW plane centered. The final (or repeat) indicator may present a display that is centered about the AEW plane, own ship, or any other point that is tracked on the tracking indicator. Ordinarily, in AEW applications, own ship will be tracked, thus causing an own-ship-centered display to appear on the final indicator, as illustrated in figure 1-26.

The display features may be listed as follows:

1. EXPANSION OF DISPLAY—The indicator is provided with a continuously variable sweep-speed control (rubber range control), permitting exact selection of the most useful range for any particular condition. It is often desirable to observe the radar display by the use of a short-range sweep. Close scrutiny of a target is permitted by expanding the display, and, if necessary, off-centering the display so as to keep the target on the screen. A fully expanded sweep yields a display in which the detail is limited by the radar, rather than by the PPI.

2. MANUAL OFF-CENTERING—The indicator is equipped with manual off-center controls, which permit displace-

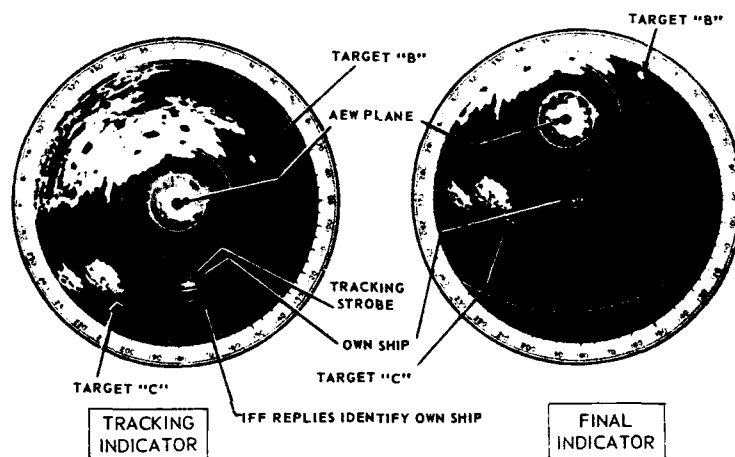


Figure 1-26.—Ships presentation of AEW radar.

ment of the entire picture so that any target within a 250-mile range may be brought to the center (or any other region) of the display.

When using an expanded sweep, only a small portion of the area being searched by the radar is presented on the PPI. This small area may or may not include the particular desired target. To bring a desired target on the indicator, or to prevent the target from passing from view, manual off-centering may be introduced. By the use of both the expanded sweep and the manual off-centering, a remote target may be observed on a short-range display.

3. DRA OFF-CENTERING—The indicator has a synchro channel for receiving off-centering information from the ship's dead reckoning analyzer (DRA). This information is mechanically fed into the manual off-centering system of the indicator. DRA off-centering has the effect of cancelling the effects of own ship's motion, thereby presenting a stationary display. Such a display will show all targets, including own ship, moving in their true courses, and land masses will be fixed.

4. OFF-CENTER COUNTERS—There are two pairs of off-center counters (north-south and east-west) on the indicator. The counters show (in miles) how far the picture has been shifted from its centered position by the use of the off-center and the DRA.

5. TRACKING STROBE—When the AEW track strobe is used, a bright spot, known as the TRACKING STROBE, will appear on the display. This strobe may be moved about at will by means of the tracking controls, and may be caused to follow (track) any target that appears on the PPI. Synchro information regarding the position of this strobe can now be furnished to remote points, specifically to a final (or repeat) indicator.

6. ELECTRONIC CURSOR—When the AEW track cursor is used, the origin of the bearing cursor on the indicator is not fixed at any point, but may be moved about so as to permit range and bearing to be taken between any two targets. When used in this manner, synchro data regarding the position of the origin of this roving cursor may be supplied to a final indicator just as though tracking were being performed with the tracking strobe. (Only one indicator at a time can be used for tracking.)

7. AEW OFF CENTERING—When an indicator is used as a final AEW repeater, a synchro channel is switched in for receiving off-center information from the tracking synchros of a tracking indicator. With such information, the location of the tracking strobe (or origin of the roving cursor) on a tracking indicator suitably wired to this indicator, will determine the location of the origin of the electronic cursor on the final indicator.

As many as five final indicators may be used with one tracking indicator without requiring auxiliary equipment.

AN/SPA-4A REPEATER.—The Range-Azimuth Indicator AN/SPA-4A (fig. 1-27, A) displays information supplied by any one of the ship's radar systems, provided the pulse repetition rate of the radar system is

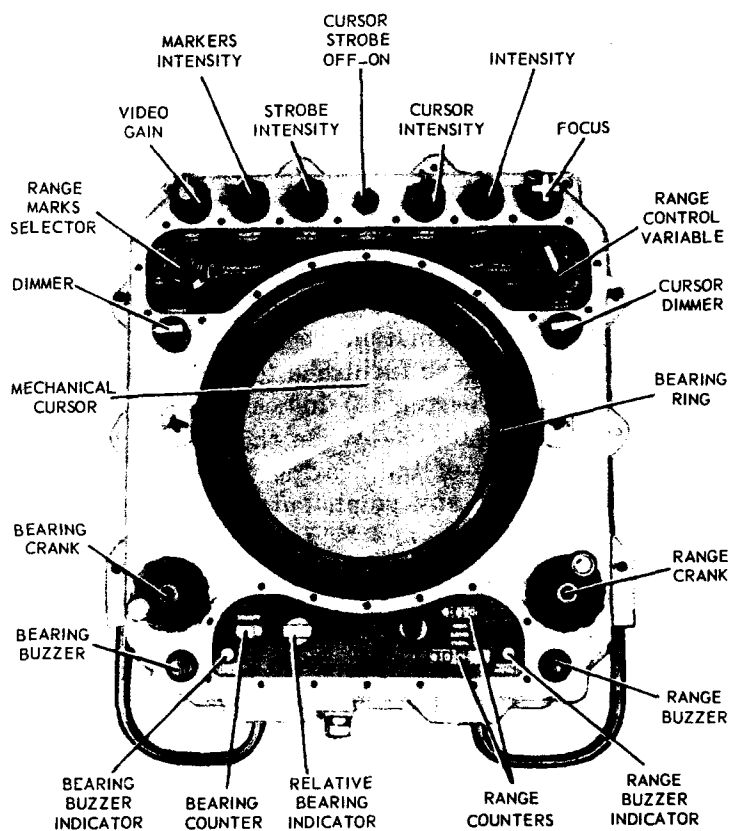


Figure 1-27.—Radar repeater AN/SPA-4A.

between 60 and 3000 pulses per second. The information is displayed on a 10-inch cathode-ray tube PPI.

The PPI sweep is rotated in synchronism with the associated radar antenna by means of a servo system. The cursor sweep can be rotated by a hand crank to any desired radial location. A spot of light (the range strobe), appearing on the cursor sweep may be superimposed on any target in the PPI display. The location of the range strobe may be changed by rotating

either the range hand crank or the bearing hand crank or both.

The range and bearing of the range strobe (and hence, the position of a particular target) is registered on mechanical counters. This information may also be repeated at remote points throughout the ship.

VF REPEATER.—The VF-1 repeater is of the precision type having two radarscope indicators. The PPI-scope has ranges of 4, 20, 80, and 200 miles. The B-scope presents any selected area of the PPI, 40° by 2 miles, in an enlarged form.

A true-bearing compass ring is integrated with the bearing circle of the PPI, and therefore either true or relative bearings may be read directly.

VG REPEATER.—The VG repeater is of the projection type used to provide an enlarged projected image of the radar picture on a horizontal glass screen. The tube is of very long persistence, and a target image will remain on the screen for a minimum of about 5 minutes. Air and surface plotting may be done directly on the plotting surface of the VG series equipment. This equipment is now obsolete.

VJ REPEATER.—The VJ series of repeaters is used extensively throughout the Fleet, and is the primary indicator for radar equipments that do not have master PPI units—such as the SG-6 and the AN/SPS-6.

Under normal conditions, the electrical information received from the master radar is presented on the PPI screen in the form of a circular map, the center of which represents the location of the radar antenna. The scale of the map (pattern) is determined by the setting of the range switch. The scale markings indicate in miles the actual distance represented by the radius of the pattern.

When the installation includes a special delay unit, a movable range ring, manually controlled and coupled to a range counter calibrated in yards and miles, is pro-

vided for determining target ranges. By making the movable range ring bisect the chosen target on the PPI screen, the target range may be read directly in yards or miles on the range counter.

VK REPEATER.—The VK repeaters have been improved through a series of changes. The VK-5 functions as a standard PPI repeater, off-center PPI repeater, or expanded off-center PPI repeater. It may be used on shore, shipboard, or submarine. It presents AEW (airborne early warning) and DRA (dead reckoning analyzer) information and designates selected targets to remote PPI repeaters.

Target ranges may be estimated with fixed range markers or with a dial-controlled range ring. Target bearing may be measured on a dial around the rim of the PPI presentation with the aid of a mechanical cursor, or it may be measured with either a screen-centered, display-centered, or wandering electronic cursor.

Off-center presentation may be used to increase the effective screen area and to display targets from AEW aircraft or a DRA relay receiver. The start of the PPI sweep may be shifted off center in any direction by manual means to locate the observer's ship on the center of the PPI screen. After initial off-centering, displays are automatically off-centered in AEW or DRA operation.

VL REPEATER.—The VL-1 repeater is a remotely controlled range-height indicator designed to repeat information obtained from any standard Navy height finding radar system. The scope displays patterns within ranges of 20, 40, 70, and 140 miles (the ranges can be changed to 20, 40, 100, and 200 miles, if desired).

The screen display forms a roughly rectangular area, with the trace originating at the lower left-hand corner of the display. Targets appear as bright spots on the screen. Height is shown vertically, and range is shown horizontally.

In operation, four equally spaced electronic range marks appear on the screen as bright, curved lines (arcs of concentric circles) associated with each range. These lines appear on their respective ranges as 5-, 10-, 20-, and 50-mile range markers.

The height of a selected target is measured by means of a mechanically controlled electronic height marker appearing as an approximately horizontal line across the scope screen. The height line is raised or lowered by a handwheel until it intersects the bright spot representing the selected target. The height of the target, in feet, is then read from a height counter.

STABILIZATION DATA SET.—Stabilization Data Set AN/SSQ-14 is a vital link in establishing a stabilized antenna platform. It supplies a synchro signal indication of the angular displacement of the ship's deck with respect to the horizontal as the ship pitches and rolls. Two gyro units, one associated with pitch and the other with roll, are mounted on a horizontal platform with their output axes vertical. The outputs of these gyro units, with their associated servo loops, maintain this platform in a horizontal position. The pitch and roll angular correction is sent to the desired destination (the system that keeps the radar antenna stabilized, for example) by means of transmitting synchros geared to the pitch and roll axes of the stabilized platform.

Sonar Equipment

Chapter 10 of this training course is an introduction to sonar. The following paragraphs list some of the typical sonar equipment used by the U. S. Navy.

Sonar Set AN/SQS-10 is a typical scanning sonar set. It provides a continuous display of acoustic reception in all directions and an audio response from any desired single direction.

Sonar Set AN/UQC-1B is a single-sideband, suppressed-carrier, receiver-transmitter designed to provide

underwater communication between submarines and surface ships at ranges up to 12,000 yards, or beyond, under favorable conditions.

Model NMC-2 Sonar Sounding Equipment measures ocean depths in fathoms by projecting a signal vertically toward the ocean bottom and measuring the elapsed time before the return of the echo. This equipment is being replaced by the AN/UQN-1B.

The QDA Target Depth Determining Equipment is designed primarily for installation on naval ships to determine the depth of submerged objects, such as submarines, by receiving the sound range reflections of directed underwater pulses at preset angles of the projector. It also permits listening to sounds from propellers and other sources. The QDA equipment is normally associated and operated with the horizontal range type of echo-ranging equipment that is equipped with the maintenance of close contact (MCC) feature.

Model OKA Sonar Resolving Equipment is designed for use aboard naval vessels equipped with both azimuth echo-ranging and depth-determining sonar equipments. Some of the functions it performs for and with the other equipments are:

1. It records the audio output of the azimuth echo-ranging equipment in a manner such that target range, measured along the sound-ray path, may be directly read from a chart.

2. It computes the vertical component of the velocity of sound and delivers this factor as a variable frequency, controlling the speed of the depth-determining equipment recorder stylus, thereby enabling that apparatus to measure true target depth.

3. It computes the horizontal range of the sonar target and provides this factor as a continuous graphical record from which the time for release of a barrage in an antisubmarine attack may be determined.

The AN/SQS-4 system is the one currently being used.

IFF Equipment

THE NEED FOR IDENTIFICATION EQUIPMENT.—The age-old problem of distinguishing a friend from an enemy in warfare was greatly increased when radar and aircraft came into combat use. Radar indicates the presence of possible targets (both sea and air) at much greater than visual ranges. Therefore, some method, other than visual recognition, must be used to properly identify the "target" as early as possible so that appropriate action may be taken.

As deadlier and faster aircraft have been developed, the identification problem has become more acute. With modern high-speed aircraft the captain of a ship cannot afford to wait until approaching aircraft are identified by visual means before he prepares his ship for battle. If the aircraft cannot be identified as friendly, he must assume that they are enemies and take steps to intercept them as far away as possible.

An electronic system has been developed that permits a friendly craft to identify itself automatically before approaching near enough to threaten the security of other naval units. This electronic system is called appropriately enough, identification, friend or foe, or IFF. In practice, the "foe" part of the name could be omitted because the foe does not carry the proper identifying equipment, and therefore he is identified by his lack of identification rather than by his identifying signals.

The IFF system consists basically of a pair of special transmitter-receiver units. One set is aboard the friendly ship and the other is aboard the friendly unit (ship or aircraft). Because space and weight aboard aircraft are limited, the airborne system is smaller and lighter (and requires less power) than the shipboard transmitter-receiver. The airborne equipments are automatic and do not operate until triggered by a signal from a shipboard unit.

IFF systems are designated by MARK numbers. In

order to avoid confusion between IFF systems and fire-control systems, the IFF mark number is a Roman numeral (Mark III); whereas, the fire-control number is an Arabic numeral (Mark 29).

THEORY OF OPERATION.—The IFF system operates as follows: An air-search radar operator sees an unidentified target on his radar scope. He turns on the IFF transmitter-receiver, which transmits an INTERROGATING, or "asking," SIGNAL to the airborne transmitter-receiver. The interrogating signal is received by the airborne unit, which automatically transmits a characteristic signal called an IDENTIFICATION SIGNAL. The shipboard system receives the signal, amplifies it, and displays it on the radar scope, or on a separate indicator scope. When the radar operator sees the identifying signal and identifies it as the proper one, he knows that the aircraft is friendly.

However, if the aircraft does not reply when interrogated, or if it sends the wrong identifying signal, the ship must then assume that the target is an enemy, and defensive action must be taken.

TYPES OF IFF EQUIPMENT.—Early IFF equipments comprised (1) the interrogator-responder, and (2) the identification set (transponder).

The interrogator-responder performs two functions: transmits an interrogating signal, and receives the reply. The transponder also performs two functions: receives the interrogating signal, and replies automatically to the interrogating signal by transmitting an identifying signal.

TYPES OF INTERROGATION.—The two types of interrogation are DIRECT and INDIRECT. The interrogation is direct when the interrogating signal that triggers the transponder is a pulse from the radar equipment. The interrogation is indirect when the interrogating signal is a pulse from a separate recognition set operating at a different frequency from that of the master radar.

Early IFF systems used direct interrogation. However, direct interrogation proved unsatisfactory because the transponder was required to respond to radars that differed widely in frequency. Therefore, the later IFF systems make use of indirect interrogation within a special frequency band reserved for IFF operation.

SECURITY ASPECTS.—Due to the security classification of current IFF systems, specific equipments and methods of operation are not included in this training course.

Countermeasures

Countermeasures (CM) may be classified generally as electronic or nonelectronic. There are further classifications such as radio countermeasures (RCM), radar countermeasures (Rad CM), and active and passive countermeasures. However, for the purpose of a brief description of countermeasures, this section of the chapter treats the subjects under the two general headings: electronic countermeasures and nonelectronic countermeasures.

In any case, countermeasures are employed to prevent the enemy from using his radar and communications equipment effectively, to produce false signals on enemy receivers, and to prevent the enemy from using countermeasures on our own radar and communications equipment (this is counter-countermeasures, or CCM).

ELECTRONIC COUNTERMEASURES.—Electronic countermeasures (ECM) may be classified as ACTIVE or PASSIVE. Passive ECM is merely the use of receiving equipment to intercept enemy radar or radio transmissions. Active ECM is the use of additional transmitting equipment that may be used to jam the enemy transmissions.

In order to use countermeasures most effectively against an enemy radar, as many as possible of the following characteristics should be known about the enemy radar facility: (1) the frequency, pulse width, pulse-repetition frequency, and peak power of the transmissions; (2) the receiver bandwidth and the time constants of the receiver coupling circuits; (3) antijamming

features; (4) amount of shielding; (5) type of indicator; (6) antenna beamwidth; (7) types of scan; and (8) use of the radar.

Likewise, in order to use countermeasures most effectively against enemy communications systems, the following information is needed: (1) the frequency of transmissions, (2) type of modulation, and (3) receiver bandwidth.

Some of the foregoing information is obtained by analyzing the enemy transmission, and the other information may be obtained by examining captured equipment.

Special equipment has been developed for use in analyzing r-f transmissions. This equipment includes SEARCH RECEIVERS, which search the various frequency bands for the various types of emissions; PANORAMIC ADAPTERS, which measure the frequency, strength, and type of modulation of a transmission in a selected band of frequencies; and PULSE ANALYZERS, which measure the pulse rate and width. The pulse analyzer and the panoramic adapter are used with the search receiver.

NONELECTRIC COUNTERMEASURES.—Units called CORNER REFLECTORS are used to present strong echoes to enemy radars. When suitably placed, they return strong echoes that appear to the enemy radar operator as a large naval force. Corner reflectors have other valuable uses also. For example, they can be used on liferafts to better enable friendly search radars to locate them.

ROPE was the code name for long streamers of aluminum foil. This foil, cut in lengths of about 400 ft., was dropped by aircraft that had flown within range of an enemy radar. The twisting and turning of the foil as it fell presented many different effective lengths to the enemy radar. Some of these lengths were highly resonant at the frequency of the radar, and therefore appeared as strong target signals.

WINDOW was the code name for short strips of aluminum foil. The foil was cut to slightly different lengths

so that it caused strong reflected signals at the frequency of the enemy radar. The strips were packaged and dropped over enemy territory. While fluttering to the ground, they presented a multitude of targets to the enemy radars. Thus, enemy search and tracking radars followed the strong echoes presented by the window and could not be made to track on the lesser echoes presented by the aircraft.

DECOYS consist of a wide variety of devices. Some of the most effective are balloons towing strips of aluminum foil. These strips, which vary in length, present strong reflections over a fairly wide band of frequencies. Other decoys are aircraft towing streamers of foil. Corner reflectors might also be considered decoys.

The RADAR PREDICTION DEVICE (RPD) also proved to be a very effective countermeasures device during World War II. The RPD was simply a relief map of the enemy territory with a flashlight bulb at the location of the enemy radar set. The shadows cast by mountains or other features of the terrain indicated weak or blind spots in the enemy radar beam. When a blind spot was found, aircraft used it to advantage in making the approach.

ANTIJAMMING MEASURES.—Antijamming measures, or counter-countermeasures (CCM), are used to reduce the effect of enemy jamming on our own equipment. In receivers some of the most important CCM devices are special filters that pass only the most important parts of echo signals, thus rejecting as much of the jamming signal as possible. In the transmitters, a great many radar equipments have tunable magnetrons whose frequency may be varied at intervals to prevent an enemy jamming transmitter from locking on the radar signal.

Radiac Equipment

Radiac equipment is becoming increasingly important in the Navy, and many ET's are being trained in the repair and calibration of this type of gear. The term,

RADIAC, is derived from the words, Radio, Activity, Detection, Identification, And Computation.

Chapter 11 of this training course covers some of the basic operating principles of the more common types of radiac instruments. Some typical equipments used by the Navy are also described.

QUIZ

1. Other than the routine duties required of petty officers, what is the PROFESSIONAL duty of the ET?
2. Why is it necessary for the ET to check the *Manual of Qualifications for Advancement in Rating*, NavPers 18068, before preparing for advancement in rating examination?
3. How will the ET be hindered in his work if the basic principles of electricity and electronics are not mastered?
4. The RMB, the CEMB, and the SB have been combined into what publication?
5. What two chapters of the *Bureau of Ships Manual* are of special interest to the ET?
6. What is the basic maintenance history card for electronic equipment?
7. What card provides for recording the insulation resistance of a unit or circuit?
8. Which record card will indicate to the ET the modifications that have been made on an electronic equipment?
9. What three cards make up the current ships maintenance project?
10. Which report furnishes first-hand information on electronic equipment under actual operating conditions?
11. Which report provides the Bureau of Ships with a presentation of the over-all gear, points out the weakest parts of any particular equipment, and forms the basis on which to procure maintenance parts?
12. The Navy uses two radio teletype systems afloat. Which system is used for (a) short-range operations and (b) long-range operations?
13. In space diversity reception, how far apart are the receiver antennas spaced?

14. What three distinct operations are performed in facsimile communications?
15. How is synchronization obtained in a facsimile system?
16. Why is there an increase in effective power of SSB transmission over DSB transmission?
17. In radio compass equipment, what information is supplied to the pilot by means of indicators?
18. What navigational information is supplied to the pilot of an airplane equipped with tacan?
19. Besides range and bearing intelligence, what information is supplied by the surface-to-air frequency in the tacan system?
20. In the tacan system, what is the function of the frequency emitted by the aircraft transmitter?
21. In figure 1-23, what is the purpose of the 3,000- μ s delay in a loran system?
22. The absolute delay in a loran system is the sum of what three delays?
23. What types of information are presented by the AN/SPS-8 radar?
24. What is the purpose of manual off centering in the AN/SPA-8A repeater?
25. What is the effect of DRA off centering on the AN/SPA-8A?
26. In the AN/SPA-8A system, what information is indicated on the off-center counters?
27. What is the purpose of Stabilization Data Set AN/SSQ-14?
28. What type of information is presented by Sonar Set AN/SQS-10?
29. What basic components make up an IFF system?
30. What two functions are performed by an IFF transponder?
31. What information is needed in order to use countermeasures most effectively against enemy communications systems?
32. What is the function of panoramic adapters?
33. What countercountermeasures device is often used in receivers to pass only the most important parts of echo signals and thus to reduce the effect of enemy jamming?

CHAPTER

2

ELECTRONICS SAFETY PRECAUTIONS

INTRODUCTION

Nothing in the ET training program can be more important to the individual ET than his own personal safety and the safety of his shipmates. Because this is such a personal matter, its importance should be obvious. In few other fields of work is the expression, "carelessness kills," more appropriate.

Electronic circuits are potentially dangerous even when the technician uses a great deal of care in his service work. The danger, however, varies inversely with the effectiveness of the safety precautions. Therefore, proven, recommended safety precautions must be used.

The accidental electrocution of an Electronics Technician aboard an icebreaker points up a **WARNING** and a **PRECAUTION**.

WARNING: When working on live equipment, watch what touches your body as well as what you touch with your hands.

The Electronics Technician in question was working on a TBM radio transmitter. While he was reaching into the equipment his body touched a coil having a potential of 2000 volts, carrying over two amperes. His elbow then touched the bulkhead, completing what was for the victim a fatal circuit.

PRECAUTION: Learn artificial respiration. If you know it, it may save your shipmate's life. If he knows it, it may save your life.

In this particular case, another technician present when the victim was electrocuted did not know how to give artificial respiration; and it was not given until a doctor arrived.

In cases of electric shock, artificial respiration must be given **IMMEDIATELY** to do any good. For example, power linemen are told to start artificial respiration before lowering the victim from the pole to the ground. This procedure saves valuable time.

Instructions for giving artificial respiration are included in the *Standard First Aid Training Course*, Navpers 10081.

Much material has been written on the subject of safety precautions; and much has been written especially for the benefit of electronics personnel.

All electronics personnel must become thoroughly familiar with *United States Navy Safety Precautions*, Opnav 34P1, including the latest changes; they should pay special attention to chapter 18. All electronics personnel must likewise become familiar with Chapter 67 of the *Bureau of Ships Manual*, NavShips 250,000, including the latest changes; they should pay special attention to part 12 of chapter 67.

Additional information that will be of value is contained in *Electric Shock, Its Cause and Prevention*, NavShips 250-660-42; Chapter 1 of the *Electronic Installation Practices Manual*, NavShips 900,171, and in some issues of the *Bureau of Ships Journal*—for example, the July 1955 and the May and August 1957 issues. Many issues of the EIB also include safety information—for example, No.'s 312, 406, 416, and 429.

Some of the information contained in the following paragraphs is condensed from the previously mentioned references.

PERSONAL PROTECTION

The technician must not work on electrical (or electronic) equipment when his hands or clothing are wet. He must not wear loose or flapping clothing or clothing with exposed zippers or metal fasteners when working on electronic equipment. The same is true of rings, wrist watches, bracelets, and similar metal items. Another very important item is the matter of shoes. Thin-soled shoes and shoes with metal plates or hobnails must not be worn when work is being done on electronic equipment.

No work must ever be done on live circuits regardless of the magnitude of the voltage except in case of emergency. Under emergency conditions when work must be done on live circuits, every precaution must be taken to prevent accidental grounds. Rubber gloves must be worn and properly insulated tools used; the deck must be covered with an approved insulating material; and at least one other person must be present at all times. All persons must be thoroughly familiar with approved methods of rendering first aid and artificial respiration. Specific instructions pertaining to work on live circuits are contained in Chapter 18 of *United States Navy Safety Precautions*, OpNav 34P1.

Danger signs and suitable guards must be provided to prevent personnel from coming in accidental contact with high voltages. Danger signs must also be used to warn personnel servicing electronic material aloft against the possible presence of explosive vapors in certain locations and against the POISONOUS EFFECTS OF SMOKE AND STACK GASES.

According to OpNav 34P1, on all circuits where the voltage is in excess of 50 volts, and where the deck or walls are of metallic construction, the worker must be insulated from accidental grounding by the use of approved insulating material. Whenever work of a nature other than electrical is performed in the vicinity of ex-

posed electrical circuits, suitable insulating barriers must be provided to prevent accidental contact with the circuits. Dry wooden stools or platforms are used to prevent the possibility of contact between the workmen's shoes and a wet or damp floor.

Other protective measures include (1) covering metal tool handles with rubber insulating tape; (2) ensuring that fuse boxes are securely closed except when work is being done on them; (3) checking the resistance between the metal bases, frames, and so forth of electronic equipment and ground at regular intervals and after repair work has been done; and (4) being sure that safety devices such as interlocks, overload relays, and fuses are not altered or disconnected except for replacement (no safeguard circuit is to be modified without specific authority).

In connection with insulating metal tool handles with rubber insulating tape, it is also necessary to insulate the shanks of certain screwdrivers (particularly those used inside electronic equipment) with insulating sheaths. Only $\frac{3}{16}$ of an inch of the blade need be exposed. Where it is not practicable to tape or otherwise insulate a surface, electricians' insulation varnish may be used.

There are certain special precautions against electric shock that must be taken. Certain pieces of equipment (for example, brushes, dusters, and brooms) not generally considered to be conductive can be dangerous, and the necessary precautions must be taken. Sufficient illumination is very important, and so is keeping one's attention directed to the work being done. Do not trust equipment insulation to protect you from high voltage when work is to be performed, and keep alert to the possibility of accidental grounds or shorts.

In working on live circuits, exercise as much care with low voltages as with high voltages; and never take a shock intentionally from any voltage regardless of how small it may be.

GENERAL ELECTRONICS SAFETY PRECAUTIONS

Because of the constant use of radio aboard ship the following precautions for radio-frequency circuits should be observed: (1) Energized high voltage output circuits should not be broken except when absolutely necessary and authorized by a qualified officer; and (2) when other transmitting equipment is in use at the same installation or close by, ET's should be on the alert to prevent shock, burns, or other injury to personnel due to energy picked up from adjacent antennas or equipment (certain circuits may have to be grounded for safety reasons).

Electronic detonators or igniters, electrically fired rocket motors, and electric fuzes (ordnance) must not be located in the same compartment with or be exposed within 5 ft of any exposed electronic transmitting apparatus, or exposed antenna, or antenna lead aboard ship or at a shore electronics activity. No danger due to r-f potentials exists with detonators of any type while they are in a properly covered metal container.

Capacitors are potentially dangerous. Before an ET touches a capacitor, which is connected to a deenergized (or which is disconnected entirely), he must short-circuit the terminals to make sure that the capacitor is completely discharged. A suitably insulated shorting stick should be used for this purpose.

The diagram of one type of shorting stick is illustrated in Chapter 1 of *Electronic Installation Practices Manual*, NavShips 900,171. It is reproduced in figure 2-1.

The primary function of the shorting stick is to pass the discharge current from a capacitor through the ground wire to ground, NOT through the body of the person discharging the capacitor. The hook enables the technician to fasten the stick to the high-voltage terminal so that it can serve as an added protection while work is in progress. It is necessary, of course, to connect the ground clamp to ground BEFORE using the hook.

Some shore stations have provided a shorting stick

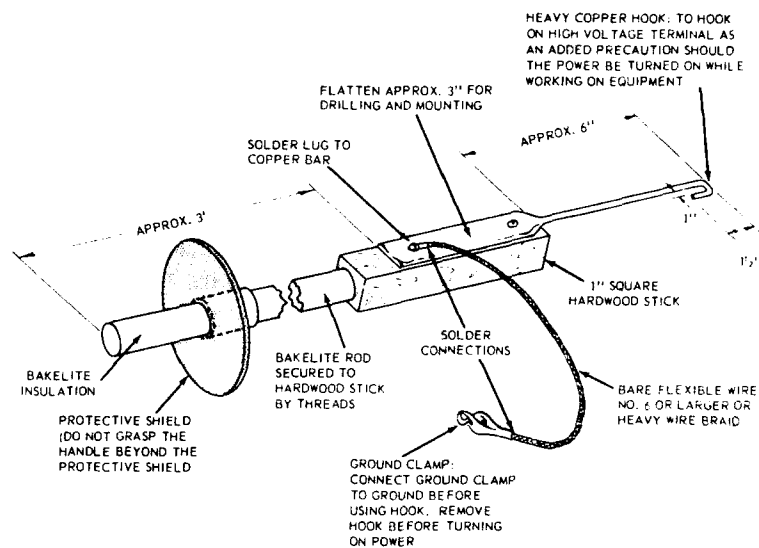


Figure 2-1.—Diagram of shorting stick.

at each transmitter enclosure. In each case it is so placed that the technician must remove the shorting stick before he can gain access to the equipment.

No person should reach within or enter energized electronic equipment enclosures for the purpose of servicing or adjusting, except when prescribed by official applicable technical manuals and then not without the immediate presence and assistance of another person capable of rendering aid in an emergency.

When the ship is in drydock, the electronic equipment on board may be energized only with the permission of the docking officer.

COMMON SAFETY FEATURES IN ELECTRONIC EQUIPMENT

The ET should be aware of the safety features that are generally included in electronic equipment. There is a tendency on the part of design people to pay more

attention to safety measures when the equipment is to be used by unskilled persons than when it is to be used by skilled persons, but there is always the possibility that an accident will happen to a skilled, but unalert person. This is a matter to keep in mind; and the ET must remember that safety devices cannot always be counted upon to function.

Some of the common safety features are interlock switches, bleeder resistors, current-limiting resistors, insulated controls, and power-line safety devices.

Interlock Switches

The interlock switch is ordinarily wired in series with the power-line leads to the electronic power supply unit, and is installed on the lid or door of the enclosure so as to break the circuit when the lid or door is opened. A true interlock switch is entirely automatic in action; it does not have to be manipulated by the operator.

Multiple interlock switches, connected in series, may be used for increased safety. One switch may be installed on the access door of a transmitter, and another on the cover of the power-supply section. Complex interlock systems are provided when several separate circuits must be opened for safety.

Because electronic equipment may have to be serviced without deenergizing the circuits, interlock switches are so constructed that they can be disabled by the technician. However, they are generally located in such a manner that a certain amount of manipulation is necessary in order to operate them.

Bleeder Resistors

A bleeder resistor is often connected across the output terminals of high-voltage d-c power supplies. It is used to bleed the dangerous charges off the filter capacitors because a high-grade filter capacitor can maintain its charge for a long period of time.

The bleeder current is an added drain on the power supply, but the system is designed to withstand this additional burden.

In some equipments where large, high-voltage capacitors cannot be effectively shunted by bleeder resistors, the technician must discharge these capacitors before working on the high-voltage circuits. For this purpose special shorting sticks are used.

The technician must keep in mind the possibility that the bleeder resistor may burn out and thus become useless as a protective device. Filter capacitors must be discharged as a matter of routine when repair work is to be done. Do not depend on the bleeder; it is merely an added protection.

Current-Limiting Resistors

A current-limiting resistor is often connected in series with the output lead of a high-voltage circuit to limit the current (actually, the terminal voltage) to a safe value when a short-circuit or an accidental contact occurs. One example is the 1-megohm resistor in the output circuit of high-voltage power supplies. Accidental contact loads the circuit in series with the resistor, and most of the high voltage is developed across the resistor instead of across the person making the accidental contact. Bear in mind that a very small current through the body may be fatal. Extreme caution should be exercised at all times when working on live circuits, regardless of the magnitude of the voltage.

Insulated Controls

Metal knobs, dials, switches, and adjustment screws are generally used only in equipment of the "cold chassis" type; they are not used with a-c/d-c devices.

Even when insulated knobs are used, short setscrews, which do not extend beyond the recessed opening in the knob, are used to prevent the operator's fingers from coming in contact with a possible live circuit. As an

added precaution, a spot of sealing wax or coil dope is added to fill in the open end after the setscrew is tightened.

Rheostats and potentiometers in high-voltage circuits are placed far enough back of the panel to permit an insulated shaft coupling between the device and the control knob. Common examples are the focus, intensity, and beam-centering controls of an oscilloscope.

Power-Line Safety Measures

Only approved line cords in good condition should be used. Such cords must be protected with insulating grommets at the point where they pass through the chassis or panel.

In addition to the external fuses, equipments are usually supplied with one or more internal fuses.

GROUNDING OF EQUIPMENTS AND COMPONENTS

Use of Grounded-Type Plugs and Receptacles

Navy specifications for portable tools require that the electric cord for such tools be provided with a distinctively marked ground wire in addition to the conductors for supplying power to the tool. The end of the ground wire within the tool must be connected to the tool's metal housing. The other end must be connected to a positive ground. For this ground connection, specially designed grounded-type plugs and receptacles, which automatically make this connection when the plug is inserted in the receptacle, must be used.

Portable tools not provided with the grounded-type plug, and miscellaneous portable electric equipments, which do not have a cord with a grounded conductor and grounded plug, must be provided with a 3-conductor cord and with a standard Navy grounded-type plug. The ground wire must be connected to a positive ground, and the total resistance from the tool enclosure to the ground

to which it is connected must not exceed a small fraction of an ohm.

Because the ET is responsible for the portable power tools assigned to his division, he must be familiar with the Bureau of Ship's approved methods of installing plugs and cords. The methods are spelled out in detail in Article 60-27 of the *Bureau of Ships Manual*. The following information is condensed from this article.

All 115-volt or 230-volt single-phase a-c and all 115-volt or 230-volt two wire d-c electrically operated equipment now on board ship that does not have a cord with a grounding conductor and grounded plug, and all such equipment subsequently issued to the ship without a cord that has a grounding conductor and grounded plug should be provided with a three-conductor flexible cable with standard Navy grounded plug, type D-2-G, shown on Bureau of Ships plan 9-S-4440-L. The three-conductor flexible cable should be type SO or ST color coded black, white, and green, as listed in the Navy Stock List of General Stores, group 61.

All 115-volt 3-phase electrically operated portable equipment now on board ship or subsequently issued that does not have a cord with a grounding conductor and grounded plug should be provided with a type FHOE four-conductor flexible cable color coded black, white, red, and green, with standard Navy grounded plug, type EEE-125, shown on Bureau of Ships plan 9-S-4861-L.

The length of the cord for portable tools should be 25 feet. The green conductor should be used for the grounding conductor.

Extreme care must be exercised to see that the ground connection is made correctly. If the grounding conductor (green), which is connected to the metallic equipment casing, is connected by mistake to a line contact of the plug, a dangerous potential will be placed on the equipment casing. This might easily result in a fatal shock to the operator. To guard against this danger, the connections must be tested after they have been made,

as outlined in *Bureau of Ships Manual*, chapter 60, article 60-27. The tests consist largely of ohmmeter and megohmmeter checks to make certain that the leads are connected properly and that a good ground is assured.

Grounding Electronic Equipment Cases

Ungrounded electronic equipment cases create an unnecessary hazard and frequently produce electronic interference. All missing ground connections must be replaced, and all ground connections must be checked with an ohmmeter.

Grounding Workbenches

Special precautions must be taken to ground workbenches (when used for the repair of electronic equipment) by providing two or more ground straps symmetrically placed at diagonally opposite corners or posts, using low-resistance flexible braid securely welded or bolted to steel deck or bulkhead. After completing the grounding of the bench, it is tested with a low-reading ohmmeter for positive grounding. Positive ground will be indicated by a low meter reading.

PRECAUTIONS AGAINST ACCIDENTAL ENERGIZING

Securing Switches

When electrical equipment is to be worked on, it must be disconnected from the source of supply by opening main or branch supply switches, circuit breakers, or cutouts so as to completely eliminate the possibility of current flowing to the equipment. Switches, circuit breakers, or cutouts opened for this purpose must be secured in the open position and must have tags attached. Only the individual placing the tag may remove it and re-energize the circuit. Specific instructions are given in *United States Navy Safety Precautions*, OpNav 34P1, chapter 18.

Induced Voltages

The use of electronic equipment in the frequency range of 30 megacycles and below will cause voltages to be induced in the standing rigging and other portions of the ship's structure, which, under certain conditions, are considered hazardous. Operation in the frequency ranges above 30 megacycles is not considered hazardous in this respect. The voltages caused by resonant circuits set up in a ship's structure or rigging will cause shock to personnel, or produce open sparks when contact is made or broken—for example, when the circuit is opened, or when metallic objects make contact with the structure.

Although there are too many variables to give even an approximation of the voltages that may be encountered, the following examples are cited: (1) Excessive r-f pickup from ship antennas has been noted on smokestack guys, davit head spans, and the like; (2) a similar high-frequency pickup has been observed on board ship, particularly carriers, when the length involved in reeling in or paying out wire cable and wire haulers becomes resonant to the emitted frequency; and (3) it has been discovered that flammable liquids may be ignited in close proximity to an energized radar antenna if the liquid is in a metal container or near metal objects.

PRECAUTIONS WHEN WORKING ON ANTENNAS

Personnel should keep clear of r-f fields of exposed antennas. Under no circumstances should personnel approach closer than 1 foot to a radio antenna unless it is definitely established that the antenna is not energized.

Specific instructions covering working aloft are given in Section 3, Chapter 18, of *United States Navy Safety Precautions*, OpNav 34P1, a portion of which is included in the following paragraphs.

"Before any work may be done aloft, authorization must be obtained from the commanding officer. (The OD

usually gives permission for the commanding officer.) While antennas are energized by radio transmitters, men shall not be permitted to go aloft except by means of ladders and platforms rendered safe by grounded hand-rails or similar structures. Before sending men aloft, except as noted previously, the commanding officer shall direct the communication watch officer to secure the proper transmitter in order to render safe this area, and shall notify the engineer duty officer that men will be working in a prescribed area aloft in order that the engineer duty officer may take the necessary precautions to prevent the boiler safety valves from lifting (these are vented up the stack). Until he has received a report from the communication watch officer that the proper transmitters are secured, the commanding officer shall permit no man to go aloft. After the work has been completed, a report shall be made to the commanding officer, and his authorization must be obtained before the circuit is again energized."

"Radar and other antennas which rotate or swing through horizontal or vertical arcs may cause men working aloft to fall. Therefore, the motor switches which control the motion of these antennas shall be locked open and tagged before men are permitted to ascend or go within reach of them."

In connection with antennas it is extremely important to maintain a safe distance (perhaps hundreds of feet) in the field of an antenna of a high-powered radar set. At least one instance has been reported in which an ET was fatally burned internally when he stood briefly in front of an energized high-powered radar antenna.

Under no circumstances should a person look into a waveguide of a radar set when the power is on. It is well to realize, too, that X rays are generated at the surface of cathode-ray tubes. At voltages of 20,000 volts or less, the glass is a shield. Above 20,000 volts the glass is progressively a poorer shield as the voltage goes up.

Looking directly at a 30,000-volt projection cathode-ray tube is definitely dangerous, especially at a short distance (2 ft).

PRECAUTIONS WHEN HANDLING ELECTRON TUBES

Cathode-Ray Tubes

The use of larger cathode-ray tubes has increased the danger of implosion, flying glass, and injury from high voltage. The danger is greatly reduced if the tubes are properly handled. If they are handled carelessly, struck, scratched, or dropped, they can very well become an instrument of severe injury or death. The following precautions should be taken: (1) Goggles should be worn to protect the eyes from flying glass particles, (2) suitable gloves should be worn, and (3) no part of the body should be directly exposed to possible glass splinters caused by implosion of the tube. (The coating on some tubes is poisonous if absorbed into the blood stream.)

Cathode-ray tubes must not be unnecessarily exposed to possible damage. When a tube is being unpacked, it should be removed from the packing box with caution, taking care not to strike or scratch the envelope. Insert it into the equipment socket cautiously, using only moderate pressure. When the tube must be set down, it is important that it be placed on a clean, soft padding. If special tube-handling equipment is available, it should be used according to instructions.

Radioactive Electron Tubes

Electron tubes containing radioactive material are listed in Section 7, Chapter 1, Change 9 (Jan 1956) of EMB. Future contracts negotiated by the Electronic Supply Officer for the tube types listed in the reference EMB will provide that the tubes be tagged: "Radioactive—Do Not Handle Broken Tubes" and "Do Not Remove From Cartons Until Ready For Use."

Poisoning from radioactive materials in the subject electron tubes may be of three types.

1. ASSIMILATION—Eating, drinking, or breathing radium or radium compounds or absorbing them through cuts. Radium-bearing dust, which may be present in certain tubes, is dangerous in this respect.

2. BREATHING RADON—Radon is a tasteless, odorless, colorless gas that is given off by radium and radium compounds at all times. When breathed into the lungs it may cause severe injury.

3. RADIATION—Radium and radium compounds give off harmful, invisible radiations that can cause dangerous burns.

Radium bromide is used in spark-gap, glow-lamp, and cold cathode tubes. Radioactive cobalt is used in TR tubes.

Glow lamps, cold cathode tubes, and TR tubes contain from 0.01 to 1.0 micrograms of equivalent radium per tube (see chapter 11). Spark gap tubes contain from 1.0 to 2.0 micrograms of equivalent radium per tube.

Radium bromide causes the formation of radon gas within the tube envelope, and it is dangerous to inhale this gas. Radium salts are cumulative poisons and, like other radioactive concentrations, are extremely hazardous if injected anywhere into the human system.

PRECAUTIONS TO BE OBSERVED WHEN PAINTING ELECTRONIC EQUIPMENT

Adequate ventilation must be provided for all enclosed compartments in which painting is to be done. Exhaust ventilators as well as power blowers should be used. Blowers should be so arranged as to ensure rapid and complete removal of all explosive, combustible, and/or toxic vapors which may be present. Vapors must be exhausted in such a way that they will not be sucked into any of the ship's supply vents which may be running, or in any way contaminate other areas.

Where paint vapors or fumes are known to be explosive, any electrical equipment used in the vicinity of the painting operations in enclosed compartments must be of the explosion-proof type. Do not permit smoking or allow any type of work that may produce flames or sparks to be performed within the danger area.

Maintain good housekeeping practices and keep all unnecessary objects and materials picked up and out of the way. Particular attention must be given to rags, sweepings, waste, etc., which may be paint-saturated or contaminated. These materials must be placed in covered metal containers or buckets containing water.

The exits to the compartment in which painting is being done must not be blocked in any manner. Adequate fire-fighting equipment must be at hand.

PRECAUTIONS IN USING SOLVENTS

Carbon tetrachloride is definitely toxic, actually about four times as toxic as carbon monoxide, and serious accidents have resulted from the improper use, storage, and handling of this solvent.

A new solvent, methyl chloroform, has been approved for cleaning electrical and electronic equipment. It is now available from General Stores, and should be used in place of the more dangerous carbon tetrachloride.

The Chemistry Branch of the Bureau of Ships initiated the test program that resulted in the introduction of the new solvent. The results of these tests were published in the September 1957 issue of the *Bureau of Ships Journal*.

Even though methyl chloroform is less toxic than carbon tetrachloride, the solvent does present some hazards to personnel, and the following precautionary note is required on the container label:

"Caution—Use with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid prolonged or repeated contact with skin. Do not take internally."

The solvent may be applied by wiping, brushing, or spraying. Methyl chloroform, like carbon tetrachloride, will attack electrical insulating materials, particularly the air-dried varnishes. Therefore contact time should be limited.

SOME SAFETY RULES TO REMEMBER

1. Do not rely on safety devices such as interlocks and high-voltage relays.
2. Do not work alone on high-voltage circuits.
3. Observe all warning signs.
4. Do not intentionally come in contact with an energized circuit.
5. Avoid working on energized circuits.
6. Do not smoke, eat, or drink while painting.
7. Remember that solvents are potentially dangerous.
8. Use a shorting stick for discharging capacitors.
9. Use approved fuse pullers.
10. The appearance of the work is a measurement of the worker's ability; the same is true of the work space.
11. Remember that personnel may be killed or injured by high-voltage equipment that is assumed to be off. Take nothing for granted. Make certain that the power is off by securing the power-line switch in the OFF position.
12. Observe carefully the instructions about tagging open switches. The following is quoted from Change No. 16 (March 1957) of the *Bureau of Ships Manual*: "When any electronic equipment is to be overhauled or worked on, the main supply switches or cutout switches in each circuit from which power could possibly be fed shall be secured in the open (or safety) position and tagged. The tags shall read 'This circuit was ordered open for repairs and shall not be closed except by direct order of ____' (usually the person making, or directly in charge of, the repairs). After the work has

been completed, the tag or tags shall be removed by the same person.

"When more than one repair party is engaged in the work, a tag for each party shall be placed on the supply switch. Each party shall remove only its own tag upon completion of the work.

"When switch-locking facilities are available, the switch shall be locked in the open (SAFETY) position and the key retained by the person doing the work so that only he, or a person designated by him, can remove the lock and restore the circuit."

13. Even after switches have been opened and tagged, make an additional check at the equipment with a voltmeter known to be in good working order to ensure that the correct switch or switches have been opened.

14. Remember that aboard ship a person must exercise the greatest precaution when working with electrical circuits because of the metal structure (good ground), dampness, and oftentimes crowded working conditions. This does not mean that a technician should be less cautious at shore stations. He should be cautious whenever he works with electricity; but, in general, the chances of being injured aboard ship are greater if the necessary additional precautions are not taken.

15. Be thoroughly familiar with OpNav 34P1 (*United States Navy Safety Precautions*), especially chapter 18; and part 12 (change 16 or a later change) of Chapter 67 of the *Bureau of Ships Manual*, NavShips 250,000.

QUIZ

1. How soon after a person is rendered unconscious by an electric shock should artificial respiration be given?
2. With what two publications concerning safety must the ET become thoroughly familiar?
3. What should the ET do with respect to rings, wrist watches, bracelets, etc when he works on electronic equipment?
4. How must personnel be warned against the poisonous effects of smoke and stack gases?
5. What safety precautions should be taken before an ET touches a capacitor?
6. Who may give permission to energize electronic equipment when the ship is in drydock?
7. Name five common safety features included in electronic equipment.
8. What is the purpose of a bleeder resistor?
9. Why should the technician NOT depend on the bleeder resistor as a safety device to discharge filter capacitors in a power supply?
10. What is the color of the conductor (used with grounded-type plugs and receptacles) that is connected between the housing of portable tools and a positive ground?
11. What test instrument is used to check the ground connections of electronic equipment cases?
12. When switches, circuit breakers, or cutouts are opened and tagged so that work may be done on the circuits, who is the only one that may remove the tag and reenergize the circuit?
13. In what frequency range may hazardous voltages be induced in the rigging or other portions of a ship's structure?
14. In what publication are specific instructions for working aloft included?
15. What may be the result of standing, even briefly, in the intense field of the antenna of a high-powered radar set?
16. What three precautions (personal protections) should be taken when cathode-ray tubes are handled?
17. What are the three types of poisoning that may occur as a result of improper handling or exposure to radioactive electron tubes?

18. How should rags, sweepings, waste, etc which may be paint saturated or contaminated, be stowed?
19. How much more toxic is carbon tetrachloride than carbon monoxide?
20. What are the requirements as to tagging open switch when more than one repair party is engaged in work on an electronic equipment?

CHAPTER

3

COMPONENT AND EQUIPMENT NOMEN- CLATURE AND DESIGNATIONS

INTRODUCTION

Although an Electronics Technician is not trained to be a repair parts Storekeeper, the more he knows about the Storekeeper's work the better he will be able to lend assistance, especially in the matter of selecting suitable substitute parts (when it becomes necessary to use them). Once an Electronics Technician understands the significance of the stock number and how important it is to be extremely accurate in submitting the correct stock numbers when repair parts are ordered, he can make the job easier both for himself and the Storekeeper.

Probably the most important phase of electronics supply is identification. There are at least 200,000 separate items in the Electronics Supply System and the number is rapidly increasing. The use of good (correct) stock numbers is the key that opens the door to rapid and efficient supply of electronic repair parts. To accomplish the task of breaking down repair parts boxes and binning like items together, it is necessary to apply a stock number to every item so that identical items may be identified and binned together under one number no matter who the manufacturer is.

Identification is of utmost importance on all levels. A ship may have 100 percent of allowance aboard, but if

the correct parts cannot be supplied to the technicians when those parts are needed, the ship might just as well not have repair parts. If the desired item can be identified on a requisition with a good stock number and a proper description, the time lapse in receiving the material will be appreciably lessened. The lack of a good stock number on a requisition often results in extensive and needless correspondence between the ship and the supply activity with a resultant delay in receipt of the required material.

Three types of identification numbers used in electronics supply are STOCK NUMBERS, CIRCUIT SYMBOL NUMBERS and REFERENCE NUMBERS.

STOCK NUMBERS (formerly, Standard Navy Stock Numbers (SNSN), but now being converted to Federal Stock Numbers (FSN)) by which items are identified within the Navy Supply System are used in all supply actions. Available stock numbers and their associated descriptions are used where applicable in the identification, procurement, receipt, stowage, and issue of all materials as well as in accounting records.

CIRCUIT SYMBOL NUMBERS are used in technical manuals (instruction books). They are code letters assigned by the manufacturer of the equipment to designate parts used in a particular circuit within the equipment. Circuit symbols are actually keys for identifying items in the circuits, and, as such, are of extreme importance to the technician. He must, of course, understand circuit symbols before he can read schematic diagrams.

The Electronics Supply Office has compiled *Stock Number Identification Tables* (SNIT'S) that cross-reference circuit symbol numbers, for a particular equipment, with stock numbers. These tables are of great importance to the ET because he will be working with them on practically every repair job involving a replacement.

A REFERENCE NUMBER may be a part, type, catalog, drawing, stock, or specification number; or it may be a

nomenclature designation that has been applied to an item by a manufacturer or a Government agency.

Because of the great importance of identification numbers (stock, circuit symbol, and reference numbers), the ET 3 must become generally familiar with them. A brief description of each is included in this chapter.

Component and equipment indicator letters should also become familiar to the ET 3 because components and equipments are "named" by means of these letters. Many of the electronic equipments now employed by the Navy use the NAVY MODEL LETTER SYSTEM, and a large number of the more recent equipments use the JOINT NOMENCLATURE SYSTEM (AN system). Both systems are explained in this chapter.

Other designations, such as terminal designations, are of great importance to the technician and are also included. For information on designations (and detailed descriptions) of r-f transmission lines and fittings the ET may consult *Armed Services Index of R. F. Transmission Lines and Fittings*, NavShips 900-102B.

STOCK NUMBERING SYSTEMS

Stock Number Identification Tables

Stock Number Identification Tables (SNIT'S) are a relatively new device developed by the Electronics Supply Office (ESO). They serve a dual purpose. SNIT'S are used to obtain the correct stock number for the replacement of a repair part in a specific electronic equipment. They are also used to identify parts in the repair parts boxes with a good stock number.

A SNIT is prepared for the parts list in the instruction book for a particular equipment. The SNIT lists the circuit symbol number shown in the instruction book, cross-referenced to the original stock number of the item and the stock number of the preferred item of replacement. When a repair part is ordered, the stock number

listed under the "replacement" column in the SNIT list is always used.

Federal Stock Numbering System

The new Federal Supply Classification (FSC) is designed to cover any item that may be needed by anyone in the Government services. Although emphasis is given to items commonly used by the military services, the whole Federal Government and even some of our Allies are expected eventually to use this system.

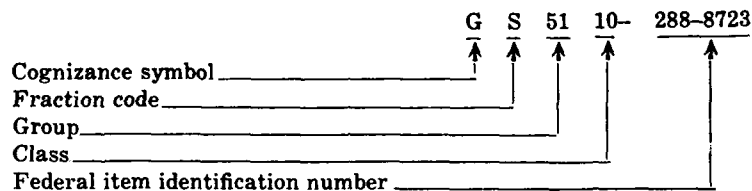
The Federal Stock Number uniformly consists of 11 digits. Take, for example, Federal Stock Number 5110-288-8723. The first two digits (51) of the four-digit classification, 5110, identify the broad GROUP of material—in this case, HAND TOOLS. The second two digits, taken in conjunction with the first two, indicate the CLASS within the group. In this case, Class 5110 means hand tools, EDGED, NONPOWERED. The remaining digits (288-8723) are the Federal Item Identification Number, used to complete the identification of the item—in this case, WIRE STRIPPERS. To facilitate reading, the FSN is always written with a dash after the fourth and seventh digits.

In order to adapt the FSN to use in the Navy Supply System, cognizance symbols and fraction codes will be used to prefix the stock number. Condition codes and other special designations also will be used as required. For example, Federal Stock Number 5110-288-8723 is adapted to the Navy Supply System as G5110-288-8723. The cognizance symbol, "G," indicates that the item is general stores material under the control of the General Stores Supply Office in Philadelphia. An "F" would indicate BuShips controlled items of major electronic equipment, and an "N" would indicate Electronics Supply Office controlled items of electronic repair parts. Following the cognizance symbol there will be an additional letter. This is the fractional code letter.

The principal fractional codes are: F—fast, high quantity demand; M—medium, medium-quantity demand;

S—slow, slow-quantity demand; R—insurance, essential item, unpredictable demand, long lead time, difficult to procure.

To summarize, the stock number GS5110-288-8723, can be broken down as follows:

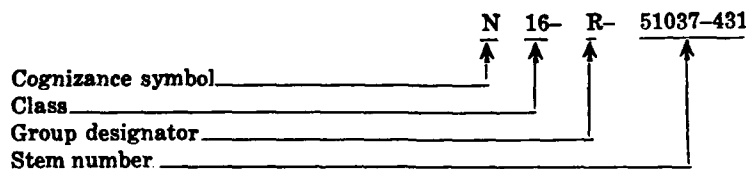


Standard Navy Stock Numbers

A Standard Navy Stock Number (now being converted to FSN) is a number assigned by the Navy Material Catalog Office. When Federal Stock Numbers are not available, SNSN'S and their associated descriptions are used in all cases (where applicable) in the identification, procurement, receipt, storage, issue, and accountability of all materials in the Navy Supply System.

There are four parts to a SNSN: a cognizance symbol, a class designator, a group designator, and a stem number. As an example of the formation of such a number, we may analyze the stock number, N16-R-51037-431. The "N" prefix indicates that ESO has inventory control over the item; an "F" would indicate Bureau of Ships control. The figure, "16," indicates the class in which the item is included. The letter, "R," designates the group (resistors are included in this group). The last portion of the number, the stem number, "51037-431," is the number that indicates the particular type of resistor being designated. In this case, it is a fixed composition resistor with a resistance of 1.8 megohms, $\pm 5\%$ tolerance and a rating of $\frac{1}{2}$ watt.

To summarize, the stock number, N16-R-51037-431, can be broken down as follows:



JOINT NOMENCLATURE SYSTEM (AN SYSTEM)

The Joint Nomenclature System (AN System) for electronic equipment was adopted in 1943. The system is designed to:

1. Be logical in principle so that the nomenclature type numbers will be readily understood, and the operation of the armed forces supply services will be facilitated.
2. Be flexible and sufficiently broad in scope to cover present types of equipment and new types and uses of equipment that will be developed in the future.
3. Avoid conflict with nomenclature at present assigned to the equipment used by the armed services.
4. Provide adequate identification on nameplates with or without the name part of the nomenclature.
5. Provide a ready means of identifying equipment in correspondence and other types of communication.

The system is designed so that its indicators will tell at a glance many things that pertain to the item. For example, it tells whether the item is a SET or a UNIT and such other information as where it is used, what kind of equipment it is, and what it is used for. (See table 2.)

Set Identification

To explain the system, a typical example of set nomenclature, Radar Set AN/APS-2, is included in table 3. Thus, Radar Set AN/APS-2 is a search radar set installed and operated in an aircraft.

Other equipments in the same category are the AN/APS-4 and AN/APS-6. Another set of a different cate-

TABLE 2
EQUIPMENT INDICATOR LETTERS

1	2	3	4	5	6
Installation	Type of Equipment	Purpose	Model Number	Modification Letter	Miscellaneous Identification
A--Airborne (installed and operated in aircraft) B--Underwater mobile, submarine C--Air transportable (inactivated, do not use) D--Pinless carrier F--Fixed G--Ground, general ground use (include two or more ground type installations) K--Amphibious M--Ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment)	A--Invisible light, heat radiating B--Pigeon C--Carrier D--Radio E--Nupac F--Photographic G--Telegraph or teletype I--Interphone and public address J--Electro-mechanical (not otherwise covered) K--Telemetering L--Countermeasures M--Meteorological N--Sound in air P--Radar Q--Sonar and underwater sound R--Radio	A--Auxiliary assemblies (not complete operating sets used with or part of two or more sets or sets series) B--Bombing C--Communications (receiving and transmitting) D--Direction finder and/or reconnaissance E--Ejection and/or release G--Fire control or searchlight directing H--Recording and/or reproducing (graphic meteorological and sound)	1 2 3 4 Etc.	A B C D Etc.	X }--change in input voltage, phase, or frequency Y } Z } Experimental indicators XA--Communications--Navigation Laboratory, WADC, Dayton, Ohio XB--Naval Research Laboratory, Washington, D. C. XC--Coles Signal Laboratory, Fort Monmouth, N. J. XD--Cambridge Research Center, Cambridge, Mass. XE--Evans Signal Laboratory, Fort Monmouth, N. J. XF--Frankfort Arsenal, Philadelphia, Pa. XG--U.S.N. Electronic Laboratory, San Diego, Calif. XH--Aerial Reconnaissance Laboratory, WADC, Dayton, Ohio

P—Pack or portable (animal or man)	S—Special types, magnetic, etc., or combinations of types	L—Searchlight control (inactivated, use "G")	XJ—Naval Air Development Center, Johnsville, Pa.
S—Water surface craft	T—Telephone (wire)	M—Maintenance and test assemblies (including tools)	XK—Flight Control Laboratory, WADC, Dayton, Ohio
T—Ground, transportable	V—Visual and visible light	N—Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach and landing)	XL—Signal Corps Electronics Research Unit, Mountain View, Calif.
U—General utility (includes two or more general installation classes, airborne, shipboard, and ground)	W—Armament (peculiar to armament, not otherwise covered)	P—Reproducing (inactivated, do not use)	XM—Squier Signal Laboratory, Fort Monmouth, N. J.
V—Ground, vehicular (installed in vehicle designed for functions other than carrying electronic equipment etc., such as tanks)	X—Facsimile or television	Q—Special, or combination of purposes	XN—Department of the Navy, Washington, D. C.
W—Water surface and underwater		R—Receiving, passive detecting	XO—Redstone Arsenal, Huntsville, Ala.
		S—Detecting and/or range and bearing	XP—Canadian Department of National Defense, Ottawa, Canada
		T—Transmitting	XR—Engineer Research and Development Laboratory, Fort Belvoir, Va.
		W—Control	XS—Electronic Components Laboratory, WADC, Dayton, Ohio
		X—Identification and recognition	XU—U.S.N. Underwater Sound Laboratory, Fort Trumbull, New London, Conn.
			XW—Rome Air Development Center, Rome, N. Y.
			XY—Armament Laboratory, WADC, Dayton, Ohio

gory is the AN/SRC-1 which, as indicated in table 3, is a shipboard radio communications set for receiving and transmitting.

TABLE 3
DESIGNATION FOR RADAR SET AN/APS-2

Radar Set	AN/	A	P	S-	2
Item name as pre-scribed	A major equipment	See the designated column in table —			Second equipment in this category (col. 4)
		Airborne (col. 1)	Radar (col. 2)	Search (col. 3)	

To identify a set that has been modified, but which still retains the basic design and is interchangeable with the unmodified set, a modification letter is used (see table 2, column 5). Thus, if Radar Set AN/APS-2 is modified, it becomes AN/APS-2A. The next modification would be the AN/APS-2B, and so on.

A special indicator (see table 2, column 6) is used when the only change to a set is in its input power. For example, if the same basic design is kept but the input power is changed from 13 volts to 26 volts, the letter, "X," is added to the nomenclature, as AN/APS-2AX. The second power input change would be identified by the letter, "Y."

A special indicator (T) for training sets is also available and is used in conjunction with the other indicators to show that it is a training set for a specific equipment. Likewise, it may be used to indicate a trainer for a special family of equipment. For example, the first training set for the AN/APS-2 would be AN-APS-2T1.

The system also provides for identifying a series of sets by the use of parentheses after the type number. Thus, the AN/APS-2() refers to the AN/APS-2 set

and all its modifications such as the AN/APS-2A, AN/APS-2B, as well as its experimental versions such as the AN/APS-2(XB-1).

Experimental sets are identified by the use of the development organization indicators (see table 2, column 6). A number is used to indicate a particular developmental or reproduction model. Thus, the first developmental model of the AN/APS-2 could be identified as the AN/APS-2(XB-1), assuming, of course, that the Naval Research Laboratory did the work.

Component Identification

So far, consideration has been given only to the indicators used in SET nomenclature. Indicators for major COMPONENTS of a set are now considered.

Components are identified by means of indicating letters (which tell the type of component it is) (see table 4), a number (which identifies the particular component), and finally the designation of the equipment of which it is a part or with which it is used. For example, the receiver for the AN/APS-2 would be identified (see table 5) as follows:

TABLE 4
TABLE OF COMPONENT INDICATORS

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
AB	Supports, Antenna -----	Antenna mounts, mast bases, mast sections, towers, etc.
AM	Amplifiers -----	Power, audio, interphone, radio frequency, video, electronic control, etc.
AS	Antennae, Complex -----	Arrays, parabolic type, masthead, etc.
AT	Antennae, Simple -----	Whip or telescopic, loop, dipole, reflector, etc.

TABLE 4—Continued

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
BA	Battery, primary type---	B batteries, battery packs, etc.
BB	Battery, secondary type--	Storage batteries, battery packs, etc.
BZ	Signal Devices, Audible--	Buzzers, gongs, horns, etc.
C	Controls -----	Control box, remote tuning con- trol, etc.
CA	Commutator Assemblies, Sonar -----	Peculiar to sonar equipment
CB	Capacitor Bank -----	Used as a power supply
CG	Cable Assemblies, R.F.---	R. F. cables, waveguides, trans- mission lines, etc., with terminals
CK	Crystal Kits -----	A kit of crystals with holders
CM	Comparators -----	Compares two or more input signals
CN	Compensators -----	Electrical and/or mechanical com- pensating, regulating or attenu- ating apparatus
CP	Computers -----	A mechanical and/or electronic mathematical calculating device
CR	Crystals -----	Crystal in crystal holder
CU	Couplers -----	Impedance coupling devices, direc- tional couplers, etc.
CV	Converters (electronic) -	Electronic apparatus for chang- ing the phase, frequency, or from one medium to another
CW	Covers -----	Cover, bag, roll, cap, radome, nacelle, etc.
CX	Cable Assemblies, Non-R.F. -----	Non-R. F. cables with terminals, test leads, also composite cables of R.F. and non-R.F. conductors
CY	Cases and Cabinets -----	Rigid and semirigid structure for enclosing or carrying equipment
D	Dispensers -----	Chaff dispensers
DA	Load, Dummy -----	R.F. and non-R.F. test loads
DT	Detecting Heads -----	Magnetic pick-up device, search coil, hydrophone, etc.
DY	Dynamotors -----	Dynamotor power supply
E	Hoists -----	Sonar hoist assembly, etc.
F	Filters -----	Band-pass, noise, telephone, wave traps, etc.

TABLE 4—Continued

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application or the component indicator)
FN	Furniture -----	Chairs, desks, tables, etc.
FR	Frequency Measuring Devices -----	Frequency meters, tuned cavity, etc.
G	Generators, Power -----	Electrical power generators with- out prime movers. (See PU and PD.)
GO	Goniometers -----	Goniometers of all types
GP	Ground Rods -----	Ground rods, stakes, etc.
H	Head, Hand, and Chest Sets -----	Includes earphone
HC	Crystal Holder -----	Crystal holder less crystal
HD	Air Conditioning Apparatus -----	Heating, cooling, dehumidifying, pressure, vacuum devices, etc.
ID	Indicators, Non-Cathode- Ray Tube -----	Calibrated dials and meters, indi- cating lights, etc. (See IP.)
IL	Insulators -----	Strain, stand-off, feed-through, etc.
IM	Intensity Measuring Devices -----	Includes SWR gear, field intensity and noise meters, slotted lines, etc.
IP	Indicators, Cathode-Ray Tube -----	Azimuth, elevation, panoramic, etc.
J	Junction Devices -----	Junction, jack and terminal boxes, etc.
KY	Keying Devices -----	Mechanical, electrical and elec- tronic keyers, coders, interrupt- ers, etc.
LC	Tools, Line Construction -----	Includes special apparatus such as cable plows, etc.
LS	Loudspeakers -----	Separately housed loudspeakers, intercommunication station
M	Microphones -----	Radio, telephone, throat, hand, etc.
MA	Magazines -----	Magnetic tape or wire, etc.
ML	Modulators -----	Device for varying amplitude, frequency or phase

TABLE 4—Continued

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
ME	Meters, Portable -----	Multimeters, volt-ohm-milliammeters, vacuum tube voltmeters, power meters, etc.
MF	Magnets or Magnetic Field Generators -----	Magnetic tape or wire eraser, electro-magnet, permanent magnet, etc.
MK	Miscellaneous Kits -----	Maintenance, modification, etc., except tool and crystal. (See CK, TK.)
ML	Meteorological Devices --	Barometer, hygrometer, thermometer, scales, etc.
MT	Mountings -----	Mountings, racks, frames, stands, etc.
MX	Miscellaneous -----	Equipment not otherwise classified. Do not use if better indicator is available
O	Oscillators -----	Master frequency, blocking, multivibrators, etc. (For test oscillators, see SG.)
OA	Operating Assemblies --	Assembly of operating units not otherwise covered
OC	Oceanographic Devices--	Bathythermographs, etc.
OS	Oscilloscope, Test -----	Test oscilloscopes for general test purposes
PD	Prime Drivers -----	Gasoline engines, electric motors, diesel motors, etc.
PF	Fittings, Pole -----	Cable hangar, clamp, protectors, etc.
PG	Pigeon Articles -----	Container, loft, vest, etc.
PH	Photographic Articles --	Camera, projector, sensitometer, etc.
PP	Power Supplies -----	Nonrotating machine type such as vibrator pack, rectifier, thermoelectric, etc.
PT	Plotting Equipments ---	Except meteorological. Boards, maps, plotting table, etc.
PU	Power Equipments -----	Rotating power equipment except dynamotors. Motor-generator, etc.

TABLE 4—Continued

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
R	Receivers -----	Receivers, all types except tele- phone
RC	Reels -----	Reel, cable. (See RL.)
RD	Recorder-Reproducers --	Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechan- ical, etc.
RE	Relay Assemblies -----	Electrical, electronic, etc.
RF	Radio Frequency Component -----	Composite component of R.F. cir- cuits. Do not use if better indi- cator is available.
RG	Cables, R.F., Bulk -----	R.F. cable, waveguides, transmis- sion lines, etc., without terminals
RL	Reeling Machines -----	Mechanisms for dispensing and rewinding antenna or field wire, recording wire or tape, etc.
RO	Recorders -----	Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechan- ical, etc.
RP	Reproducers -----	Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechan- ical, etc.
RR	Reflectors -----	Target, confusion, etc. Except antenna reflectors. (See AT.)
RT	Receiver and Transmitter	Radio and radar transceivers, composite transmitter and re- ceiver, etc.
S	Shelters -----	House, tent, protective shelter, etc.
SA	Switching Devices -----	Manual, impact, motor driven, pressure operated, etc.
SB	Switchboards -----	Telephone, fire control, power, panel, etc.
SG	Generators, Signal -----	Test oscillators, noise generators, etc. (See O.)
SM	Simulators -----	Flight, aircraft, target, signal, etc.
SN	Synchronizers -----	Equipment to coordinate two or more functions
ST	Straps -----	Harness, straps, etc.

TABLE 4—Continued

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
T	Transmitters -----	Transmitters, all types except telephone
TA	Telephone Apparatus --	Miscellaneous telephone equipment
TD	Timing Devices -----	Mechanical and electronic timing devices, range device, multiplexers, electronic gates, etc.
TF	Transformers -----	Transformers when used as separate items
TG	Positioning Devices ----	Tilt and/or Train Assemblies
TH	Telegraph Apparatus ---	Miscellaneous telegraph apparatus
TK	Tool Kits -----	Miscellaneous tool assemblies
TL	Tools -----	All types except line construction. (See LC.)
TN	Tuning Units -----	Receiver, transmitter, antenna, tuning units, etc.
TR	Transducers -----	Magnetic heads, phono pickups, sonar transducers, vibration pickups, etc. (See H, LS, and M.)
TS	Test items -----	Test and measuring equipment not otherwise included; boresighting and alignment equipment.
TT	Teletypewriter and Facsimile Apparatus -	Miscellaneous tape, teletype, facsimile equipment, etc.
TV	Tester, Tube -----	Electronic tube tester
TW	Tapes and Recording Wires -----	Recording tape and wire, splicing, electrical insulating tape, etc.
U	Connectors, Audio and Power -----	Unions, plugs, sockets, adapters, etc.
UG	Connectors, R.F. -----	Unions, plugs, sockets, choke couplings, adapters, elbows, flanges, etc.
V	Vehicles -----	Carts, dollies, trucks, trailers, etc.
VS	Signaling Equipment, Visual -----	Flag sets, aerial panels, signal lamp equipment, etc.

TABLE 4—Continued

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
WD	Cables, Two Conductor--	Non-R.F. wire, cable and cordage in bulk. (See RG.)
WF	Cables, Four Conductor--	Non-R.F. wire, cable and cordage in bulk. (See RG.)
WM	Cables, Multiple Conductor -----	Non-R.F. wire, cable and cordage in bulk. (See RG.)
WS	Cables, Single Conductor	Non-R.F. wire, cable and cordage in bulk. (See RG.)
WT	Cables, Three Conductor--	Non-R.F. wire, cable and cordage in bulk. (See RG.)
ZM	Impedance Measuring Devices -----	Used for measuring Q, C, L, R or PF, etc.

TABLE 5
DESIGNATION OF COMPONENTS

Radar Receiver	R	7	/APS-2
Item name as prescribed	From table 3	The 7th receiver to which an "AN" designation has been assigned	The set it is used with or is a part of

Thus, the R-7/APS-2 is a receiver that is used with or is a part of airborne radar search set No. 2. Another receiver, such as the R-8/ARN-8, would be indicated by the tables as a receiver used with or as a part of airborne radio navigation set No. 8.

To identify a component that has been modified but which still retains the basic design and is interchangeable physically, electrically, and mechanically with the modified item, a modification letter is used, as on sets. Thus, the R-7A/APS-2 would be a modified version of the R-7/APS-2.

Components that are part of or used with two or more sets are identified in the usual way, except that after the slant bar, there will appear only those indicators that are appropriate and without a set model number. Thus, a modulator that is part of or used with the AN/APS-2 and the AN/APS-6 might be identified as MD-8/APS.

NAVY MODEL LETTER SYSTEM

The assignment of a particular model letter to Navy equipments depends on the primary function of the equipment, such as receiving, direction finding, etc. This system of assigning model letters is applicable to all radio, radar, and sonar equipments and once learned, makes easy the recognition and identification of all Navy equipments.

In this system, the first letter indicates the basic purpose of the equipment. These designations, which are listed in table 6, are followed by another letter of the alphabet to indicate the order in which designations are assigned. Thus, TA was the first transmitting equipment assigned, TB, the next, etc. When the alphabet was exhausted, triple letters were used—for example, TAA. The order of assignment was then indicated by a change in the third letter. Thus, the model letter assigned after TAA was TAB. When the alphabet was again exhausted, a third series of model letters was formed by changing the second letter to B—for example, TBA, TBB-----TBS-----. Incidentally, TBS was popularly thought to mean "talk between ships"; and this is actually the purpose of the equipment, operating as it does in the VHF band. Numbers following model letters indicate a modification of the equipment or the award of a new contract. To indicate a change in equipment after delivery has been made, lower case letters are assigned.

TABLE 6
NAVY MODEL LETTERS

Model Letters	Primary Function of the Equipment
A	Airborne—used as a prefix to indicate airborne installation as: AR series—airborne radio receiving, etc.
B	IFF
CX	Commercial experimental
D	Radio direction finding
E	Emergency power
FS	Frequency-shift keying
G	Formerly aircraft transmitting (now superseded by "A" series)
J	Sonar listening (receiving)
K	Sonar transmitting
L	Precision calibrating
M	Combined radio transmitting and receiving
MARK	Fire-control radar
N	Sonar navigational aids including echo sounding
O	Measuring and operator training
P	Automatic transmitting and receiving
Q	Sonar ranging
R	Radio receiving
S	Search radar
T	Radio transmitting (includes combination transmitting and receiving)
U	Remote control (includes automatic keyers)
V	Radar repeaters
W	Combined sonar ranging and sounding
X	Naval experimental
Y	Navigational and landing aids
Z	Navigational and landing aids (airborne)—superseded by model Y series

In sonar equipment, the first letter indicates the general use of the equipment. The second letter of the "Q" series equipment designates the type of projector used, as indicated in table 7.

TABLE 7
NAVY MODEL LETTERS USED IN SONAR EQUIPMENT

Model Letters	Type of Projector Used
QA	Quartz steel
QB	Rochelle salt
QC	Magnetostriction
QD	Depth determining (not echo sounding)
QG	Magnetostriction—split-lobe type
QH	Scanning sonar

TERMINAL DESIGNATIONS

The following information, condensed from *Dictionary of Standard Terminal Designations for Electronic Equipment*, NavShips 900,186, will be helpful to ET's.

Terminal Boards

Terminal boards are marked with a three- or four-digit number preceded by "TB." This marking is easily identified by the technician. The first one or two digits of the "TB" number represent the unit number in an equipment. This number is assigned by the manufacturer in a logical order. The last two digits represent the terminal board number in a unit, starting with 01, 02, 03,----- 11, 12, 13 etc. Thus, a terminal board marked TB1003 indicates the third terminal board in the 10th unit of an equipment.

As an example, an equipment might be composed of a transmitter, a receiver, and a power supply, with the

transmitter having six external terminal boards, the receiver four external terminal boards, and the power supply two external terminal boards. The manufacturer will then assign numbers to the units—perhaps 1 for the transmitter, 2 for the receiver, and 3 for the power supply. Figure 3-1 shows how the terminal boards would then be marked.

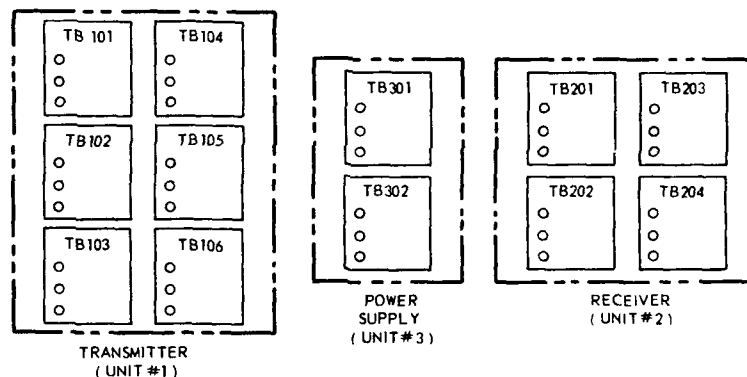


Figure 3-1.—Terminal board marking.

Terminal Marking

The marking of terminals on terminal boards indicates a specific function for the following circuits: (1) common primary power circuits, (2) ground terminals, (3) common servo and synchro circuits, (4) video circuits, (5) trigger circuits, and (6) audio circuits. The breakdown of these categories into specific functions, with the terminal designation of each, is listed in NavShips 900,186. These are RIGIDLY ASSIGNED DESIGNATIONS.

Terminals whose functions do not fall under the categories listed are assigned designations by the equipment manufacturer in accordance with NavShips 900,186. These are MANUFACTURER-ASSIGNED DESIGNATIONS.

Only those terminals that will be connected together externally will have exactly the same designation within any given equipment.

RIGIDLY ASSIGNED DESIGNATIONS.—Functional designations for circuits in the previously listed categories may be recognized by a one- or two-digit number preceded by a single or double letter (I and O are not used) such as S1, S2, S11, SS11, etc. These designations are stamped or engraved on the terminal board beside each terminal, as shown in figure 3-2.

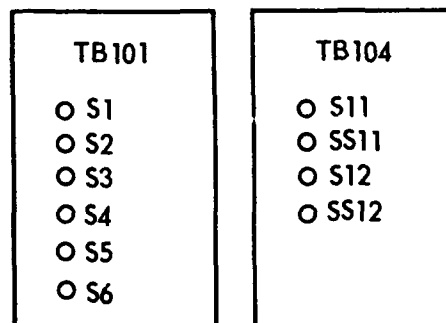


Figure 3-2.—Designations appearing beside terminals.

If the same function appears more than one time in an equipment it is distinguished by the addition of a letter or letters after the designation, beginning with "A," as shown in figure 3-3.

If more than 25 sets of terminals have the same function in an equipment, the letter following is then doubled (for example, S1AA). If these letters are used up, combinations of letters (for example, S1AB) are used.

MANUFACTURER-ASSIGNED DESIGNATIONS.—These designations begin with a number rather than a letter, as opposed to rigidly assigned designations.

When a "nonrigidly assigned" function is brought out to a terminal, the manufacturer assigns 1A to the first

TB101	TB102	TB103
○ S0	○ S0A	○ S0B
○ SS0	○ SS0A	○ SS0B
○ S1	○ S1A	○ S1B
○ S2	○ S2A	○ S2B
○ S3	○ S3A	○ S3B
○ S4	○ S4A	○ S4B
○ S5	○ S5A	○ S5B
○ S6	○ S6A	○ S6B

Figure 3-3.—Designating terminals of the same function.

such terminal and also 1A to the terminal that is to be tied to this point. The designation, 1A, does not appear again unless it is to be tied directly to either of the terminals already marked.

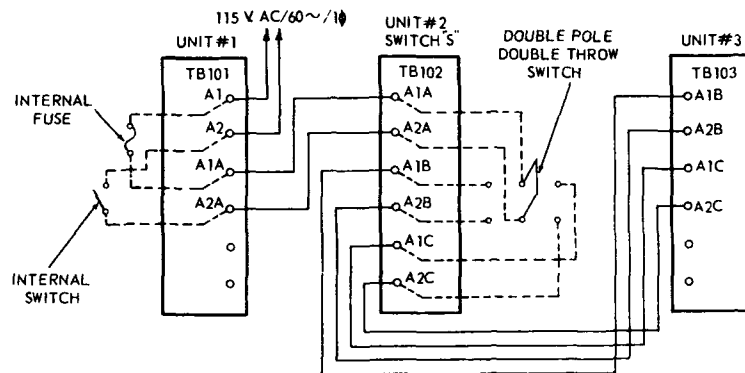
As more manufacturer-assigned designations are used, 2A, 3A,99A are used; then 1B, 2B,99B and up to 1Z, 2Z,99Z (omitting I and O) are used. If additional numbers are needed, the letters are doubled or combinations of two letters are used.

Switching and Fusing Designations

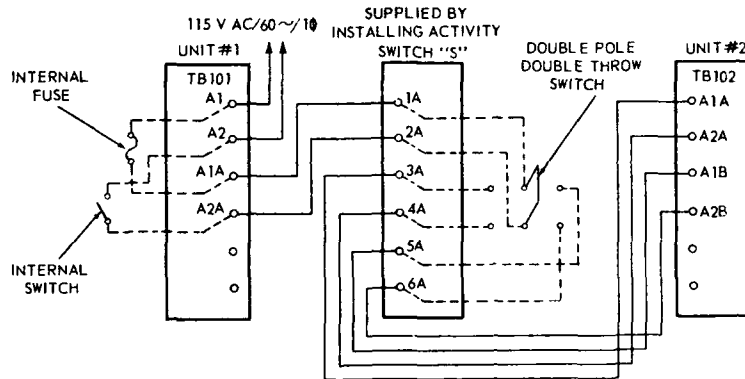
Possible switching designations are illustrated in figure 3-4. If switch "S" is designed to be used with the equipment, the markings would be as shown in part A. If switch "S" is Government supplied, the terminals would be marked differently, perhaps as 1A through 6A, as illustrated in part B.

Order of Terminals on Terminal Board

All circuits of a given function on a terminal board are grouped and arranged in a particular order. This grouping applies for rigidly assigned and manufacturer-



A MARKING OF MANUFACTURE-SUPPLIED SWITCH AND DESIGNATED INTERNAL SWITCHING



B MARKING OF TERMINALS WHEN EXTERNAL SWITCH IS NOT SUPPLIED WITH EQUIPMENT

Figure 3-4.—Possible switching and fusing designations.

assigned designations. Primary power circuits, unless connected to a separate fuse block instead of a terminal board proper, are the first connections on a terminal board. Synchro/servo circuits are arranged in sequence of reference or excitation. No particular position or area of any terminal board is reserved for a synchro function, but a logical order is illustrated in figure 3-5.

All circuits of each video, trigger, or audio function

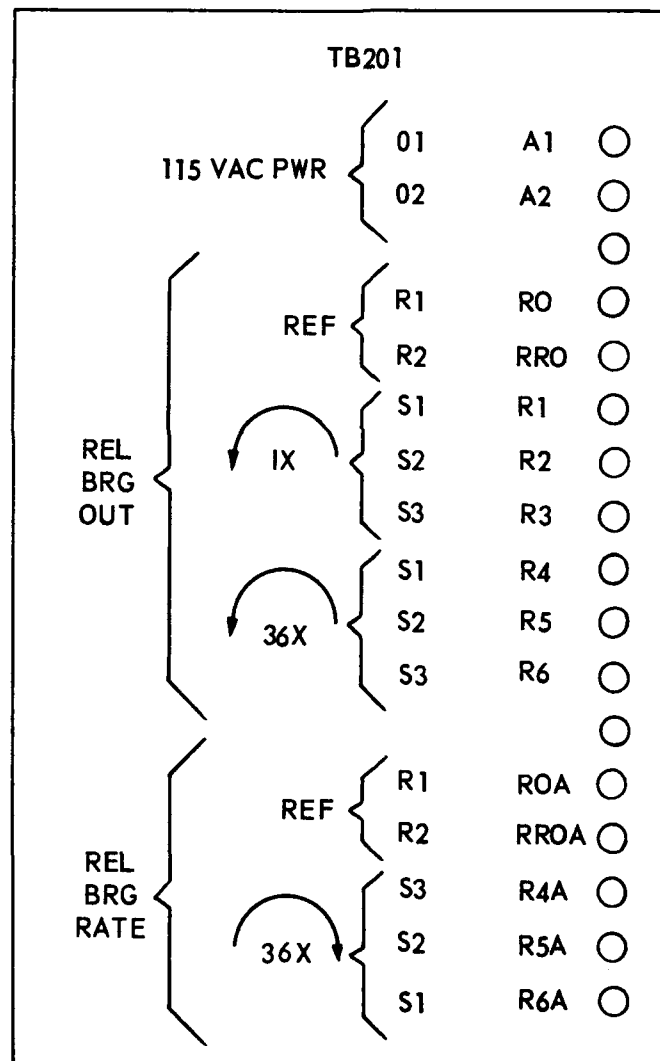


Figure 3-5.—Functional grouping of terminals, showing proper order within groups.

will appear in sequence, each with its associated ground where such ground is unique to that particular function.

Conductor Marking

On the conductor lead, at the end near the point of connection to a terminal post, spaghetti sleeving is used as a marking material and insulator. The sleeving is engraved with indelible ink, or branded with identifying numbers and letters by a varitype machine, and slid over the conductor.

The order of marking is such that the first appearing set of numbers and letters reading from left to right will be the designation corresponding to the terminal to which that end of the wire is connected. Following this, there is a dash and then the number (without the "TB") of the terminal board to which the other end of the conductor is attached. There is another dash and then the designation of the particular terminal to which the other end of the wire is connected. For example, assume that a conductor of a cable runs between units Nos. 1 and 2 of an equipment. The terminal boards are TB101 and TB201, and the terminals are designated A1 on both terminal boards. Figure 3-6, A, shows the order and method of marking spaghetti sleeving under these conditions. Figure 3-6, B, illustrates conductor marking between unlike terminals.

Lead Designations on Schematic Diagrams

Modern Navy receivers like the AN/SRR 11, 12, and 13 series are compartmentalized into assemblies and sub-assemblies. All circuits to an assembly (with certain exceptions) are disconnected when the assembly is lifted from the chassis and connected when the assembly is fitted into position. The individual subassemblies consist of a subminiature electron tube and the circuit for one stage. The subassembly plugs into an appropriate socket of the assembly. The circuits terminate in con-

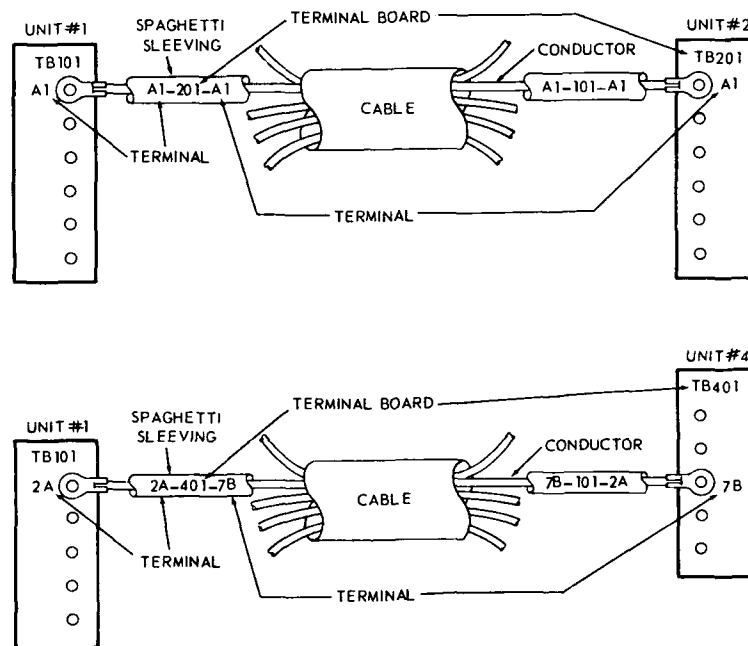


Figure 3-6.—Designating conductor marking between terminals.

nector receptacles, as illustrated in figure 3-7. Each terminal is identified by letter. Where connecting leads merge into a single cable the identity of the individual circuits is maintained by letter-number designation. For example, the Out-Hi lead to terminal L of J126 is connected through the matching connector receptacle plug-jack arrangement to L of J253. The outgoing lead is marked J254-B. This lead is marked at terminal B of J254 as J253-L. Thus the outgoing lead is identified with the letter-number designation of the connector in which that lead terminates J254-B. At this termination the lead is identified with the letter-number designation of the connector in which that lead originates (J253-L). This system facilitates servicing and trouble-

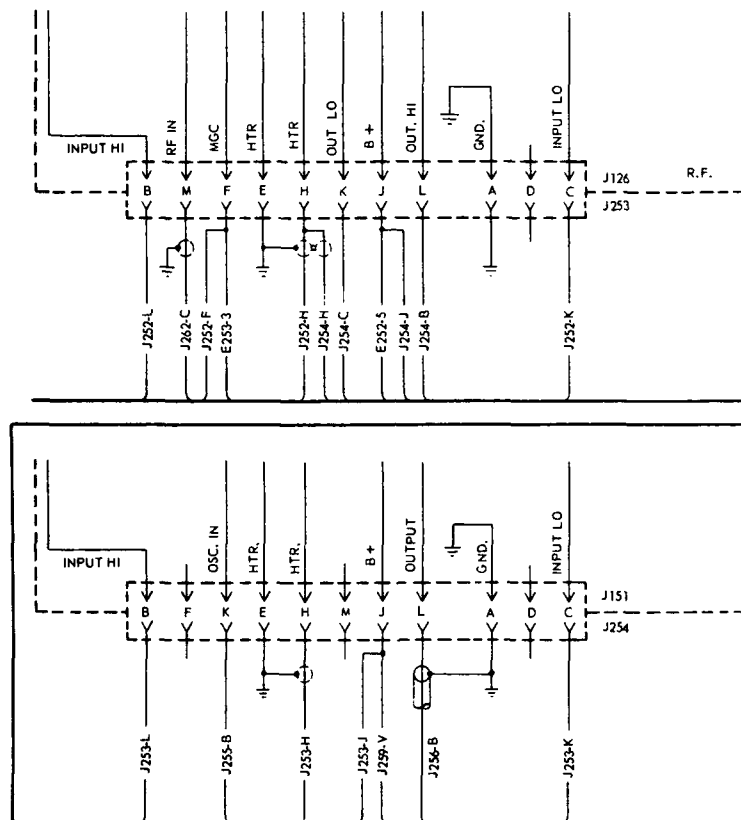


Figure 3-7.—Illustration of lead designations on schematic diagrams.

shooting. Simplified schematics can easily be developed from this method of designating leads.

DESIGNATIONS FOR ATTENUATOR NETWORKS

Attenuator networks are illustrated in figure 3-8. They are used to attenuate signal voltages, and in many cases to effect an impedance match as well. The name of the network appears just above the schematic diagrams in the figure.

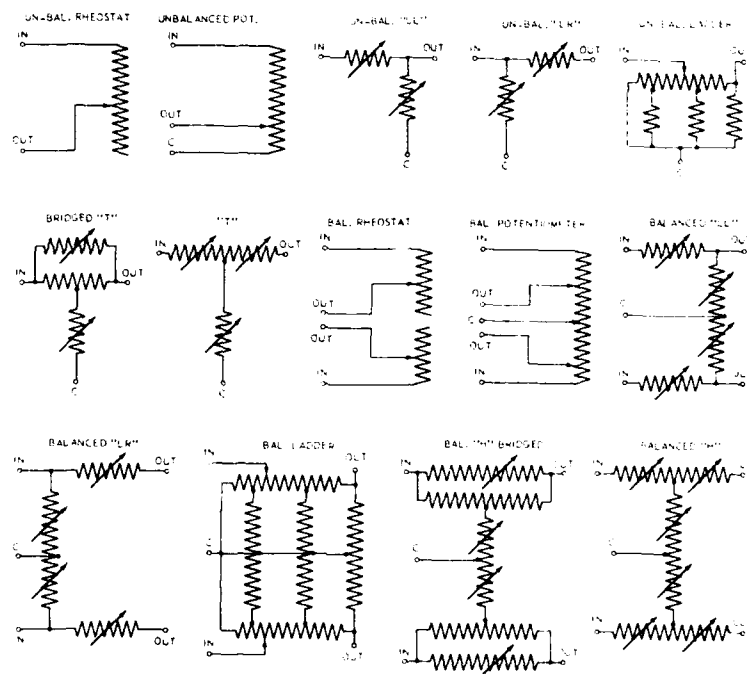


Figure 3-8.—Attenuator networks.

A **BALANCED** circuit is one in which both lines are at equal potential above ground. An **UNBALANCED** circuit is one in which one line is at ground potential.

WIRING COLOR CODE FOR ELECTRONIC EQUIPMENT

To aid in testing and locating faults in electronic equipment, and in subsequent repair, the Department of Defense has set up a military standard (MIL-STD-122), which establishes a uniform wiring color code for all military electronic equipment. This standard is used in manufacturing and should also be followed in maintenance practices when circuit changes and part replacements are involved.

The standard colors used in chassis wiring are listed in table 8.

TABLE 8
WIRING COLOR CODE FOR ELECTRONIC EQUIPMENT

Circuit	Color
Grounds, grounded elements, and returns-----	Black
Heaters or filaments, off ground-----	Brown
Power supply, B plus-----	Red
Screen grids -----	Orange
Cathodes -----	Yellow
Control grids -----	Green
Plates -----	Blue
Power supply, minus -----	Violet (purple)
A-c power lines -----	Gray
Miscellaneous, above or below ground returns, AVC, etc. -----	White

QUIZ

1. What is probably the most important phase of electronics supply?
2. What are the three types of identifications numbers used in electronics supply?
3. What are two purposes of Stock Number Identification Tables?
4. The Federal Stock Number uniformly consists of how many digits?
5. What are the four parts in a Standard Navy Stock Number?
6. What does the SPS portion of Radar Set AN/SPS-8 nomenclature designate?
7. What indicator letter is used to show that a piece of equipment is to be used for training purposes?
8. How would the receiver for the AN/APS-2 be identified if it is the 7th receiver to which an AN designation has been assigned?
9. What is the function of the first letter in the Navy model letter system?
10. What is indicated by the terminal board marking, TB 1003?
11. What circuits are marked on terminal boards according to rigidly assigned designations?
12. In general, what are the first connections on a terminal board?
13. What information may be obtained from the spaghetti sleeving of a conductor lead near the point of connection to a terminal board?
14. According to military standards, what is the wiring color code for:
 - (a) Grounds, grounded elements, and returns?
 - (b) Power supply B+?
 - (c) Control grids?
 - (d) Plates?

CHAPTER

4

THE USE OF HAND TOOLS IN ELECTRONICS

INTRODUCTION

Skill in the use of hand tools comes only with experience. However, much valuable background information may be obtained from a study of the types, use, and care of the tools commonly used by Electronics Technicians.

If an ET is skilled he need not announce this fact; the method by which he selects, handles, and cares for hand tools does this for him. Good tools cost money, but there is something in the feel of a good tool that inspires a technician to turn out better work. This fact alone justifies the additional investment needed to obtain good tools. Of course, cheap tools become defective much more readily than quality tools. When quality tools are provided, it is only reasonable to give them quality care.

There are several safety measures that should be taken whenever the technician uses hand tools. One of the most important is—do not be in too big a hurry to get through; take enough time to be careful. Excessive hurry is dangerous, and it often results in poor-quality work. Other safety measures are (1) use a vise or clamp to hold the work when a drilling or cutting tool is used (avoid using the hand as a holding device);

(2) use a guard over a grinding wheel, and goggles to protect the eyes during grinding operations; (3) when using a rest to grind parts or tools, place the rest close to the grinding wheel; (4) do not scatter tools around where someone can trip over them or where there is a chance of their falling on someone; (5) do not lay tools in or on equipment during the course of your work, replace them in the box or tool carrier when they are not actually in use (the ship's roll and pitch or the jar of gun fire may cause the tools to move and cause damage to the equipment); (6) carry an inventory list of tools in your tool box so that upon the completion of a job you can check to see that no tools are left in, on, or in the vicinity of the equipment; and (7) report all injuries promptly.

Some general precautions are (1) do not throw hardened steel tool files together because this will injure their cutting edges, (2) do not use a wrench as a hammer, (3) do not jam a piece of finished work in the jaws of a vise (use aluminum or copper jaws when needed), and (4) watch out for rust; it is the enemy of steel. Perspiration is corrosive; therefore, micrometers and gauges should be wiped clean after use and a thin coating of oil applied before they are put away.

The following treatment of the use of hand tools in electronics work is necessarily brief. Much could be said on the subject, but it certainly can be assumed that the prospective ET 3 will have at least a general familiarity with the common tools of the trade.

Additional valuable information may be obtained from Chapter 3 (Hand Tools) of *Electronic Installation Practices Manual*, NavShips 900,171. Good general information (not tied specifically to electronics) on the use of hand tools is included in *Basic Hand Tool Skills*, NavPers 10085.

Some of the information contained in this chapter is condensed from *Unit Course Mechanic Learner—Radio*

put out jointly by the U. S. Army Signal Corps and the U. S. Office of Education, various issues of the *Bureau of Ships Journal*, and NavShips 900,171.

Table 9 lists the various hand tools commonly used in electronics work and gives the group number and part number where they may be found in the Navy Stock List of General Stores.

TABLE 9
GROUP AND PART NUMBERS CORRESPONDING TO HAND
TOOLS FOUND IN THE NAVY STOCK LIST OF GENERAL
STORES

Tool	Group number	Part number
Soldering equipment -----	34	3
Hand drills -----	51	2
Circle cutter and chassis punches -----	51	2
Files -----	51	2
Hacksaws -----	51	2
Wire strippers -----	51	2
Hammers -----	51	3
Screwdrivers -----	51	3
Wrenches -----	51	3
Pliers -----	51	3
Punches -----	51	3
Crimping tools -----	51	3
Fuse pullers -----	51	3
Portable electric drills -----	51	4

HAMMERS

Hammers are generally familiar to most people and need not be illustrated here. The general types are the claw hammer, the ball peen hammer, and the soft-faced hammer. The ball peen hammer is used for setting rivets, and the soft-faced hammer is used when work is done on soft metals or other surfaces that may be easily marred or dented. These hammers have faces of raw-

hide, plastic, copper, or lead. The regular claw hammer is generally familiar to everyone.

The hammer head should always be tight on the handle for safety reasons. When a hammer is used on a machined surface, the surface should always be protected with a piece of soft brass, copper, lead, or a hardwood block.

SCREWDRIVERS

Screwdrivers are designed to loosen or tighten screws. The three main parts of a STANDARD screwdriver are illustrated in figure 4-1, A. This type of screwdriver is made in a variety of sizes and finds considerable use in electronics work. The handle may be wood or plastic.

The HEAVY DUTY screwdriver (fig. 4-1, B) has a square shank. It is the only type of screwdriver designed so that it may be used with a wrench. The handle is not insulated.

CLOSE-QUARTER, or STUBBY screwdrivers (fig. 4-1, C) are used where space will not permit the use of a standard-size screwdriver.

The PHILLIPS (CROSS-TIP) screwdriver (fig. 4-1, D) has a cross-tip blade that fits the two slots that cross at right angles to each other in the Phillips-head screw.

SELF-HOLDING screwdrivers (fig. 4-1, E) are so designed that they will hold small screws when it becomes necessary to start a screw in a limited space. The screw is "locked on" by means of a special holding device. When the screw is nearly in, the turning pressure releases the driver from the screwhead. A standard screwdriver is then used to tighten down the screw.

The CLOSE-QUARTER COMBINATION flat tip and Phillips tip (fig. 4-1, F) has the obvious advantage of fitting two types of screwheads.

SCREWDRIVER HANDLE AND BIT SETS (fig. 4-1, G) are also available. The technician simply chooses the bit

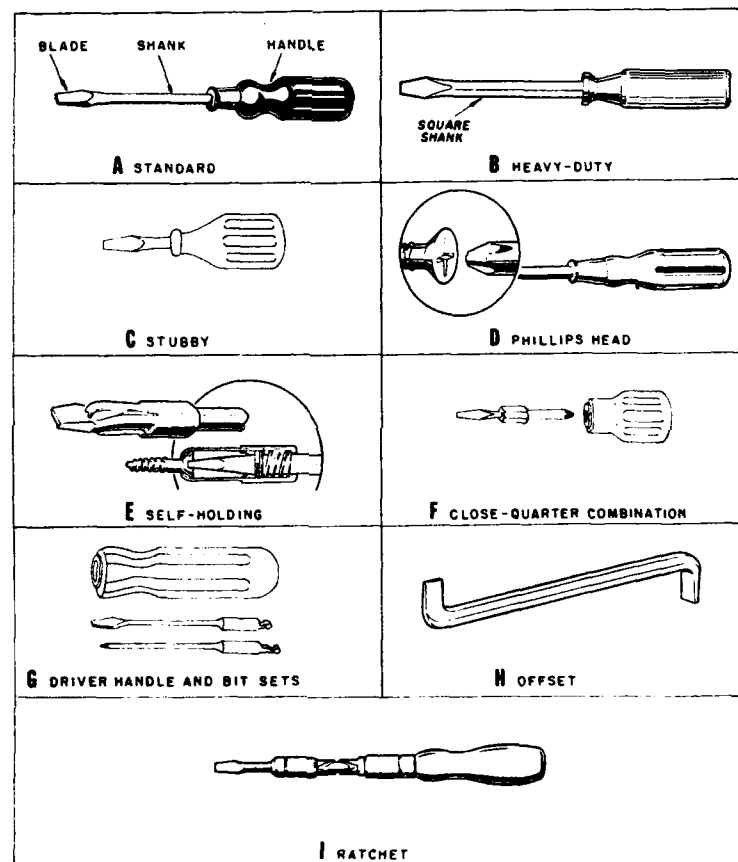


Figure 4-1.—Types of screwdrivers.

of the correct size and pushes it into the handle; he is then ready for business.

The **OFFSET** screwdriver (fig. 4-1, H) is used where space will not permit the use of a standard-size screwdriver. It has one blade in line with the shank and one blade at right angles to it. When the working space is limited, the wrench can be reversed after each swing to tighten or loosen the screw.

When many screws have to be put into a chassis, the RATCHET screwdriver (fig. 4-1, I) is a great time saver. Some makes have removable blades so that an assortment of blade sizes may be used.

It is important to select a screwdriver that will fit snugly into the screw slot. This will prevent the screw slot from becoming burred and the screwdriver blade from becoming damaged; also the force required to keep the screwdriver in the slot will be reduced.

If the blade of the screwdriver should become damaged, it may be restored to service by grinding. Of course, goggles should be worn whenever grinding is being done.

Figure 4-2, A, illustrates a correctly ground blade. Part B illustrates an incorrectly ground blade. The first step in the correct procedure is to grind the end of the blade at a right angle to the shank. After the end of the blade is ground, each face is dressed off a little at a time. The faces are kept parallel for a short distance from the tip, or they may be tapered very slightly as shown in the figure. The faces should not be ground so that they taper to a sharp edge at the blade end.

The general care of a screwdriver consists largely of NOT doing certain things. Do not hammer on a screwdriver if something is obstructing the screw slot; instead, apply a driving force with the heel of the hand, or remove the obstruction some other way. Do not use a screwdriver as a pinch bar, lever, or chisel. Never use a wrench on a screwdriver with a round shank, and do not use pliers on a screwdriver under any circumstances.

There are certain safety precautions involved in the use of the screwdriver. Never use a screwdriver to check an electrical circuit. Danger of severe burns, blindness, and even death can occur if the screwdriver is shorted across a high-potential or current-carrying

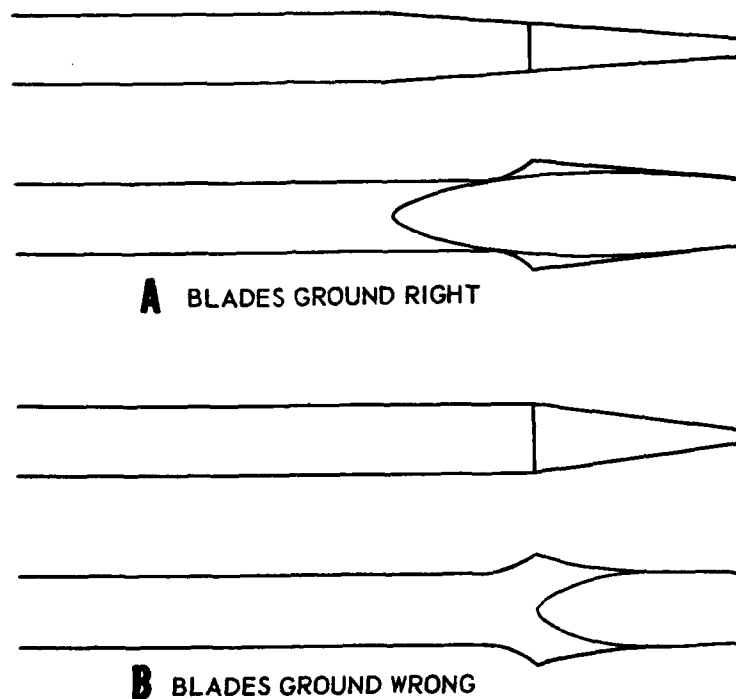


Figure 4-2.—Correctly and incorrectly ground screwdriver blades.

source. However, screwdrivers having plastic handles may be used to discharge SMALL capacitors.

WRENCHES

Several types of wrenches are used in electronics work. They include open-end, box, and combination wrenches; socket wrench sets and spin-type socket wrenches; adjustable wrenches; Allen and Bristol wrenches; spanner wrenches; monkey wrenches; and slugging wrenches.

Some of the more commonly used wrenches are illustrated in figure 4-3. Most of the wrenches illustrated in this figure come in sets having a range of sizes.

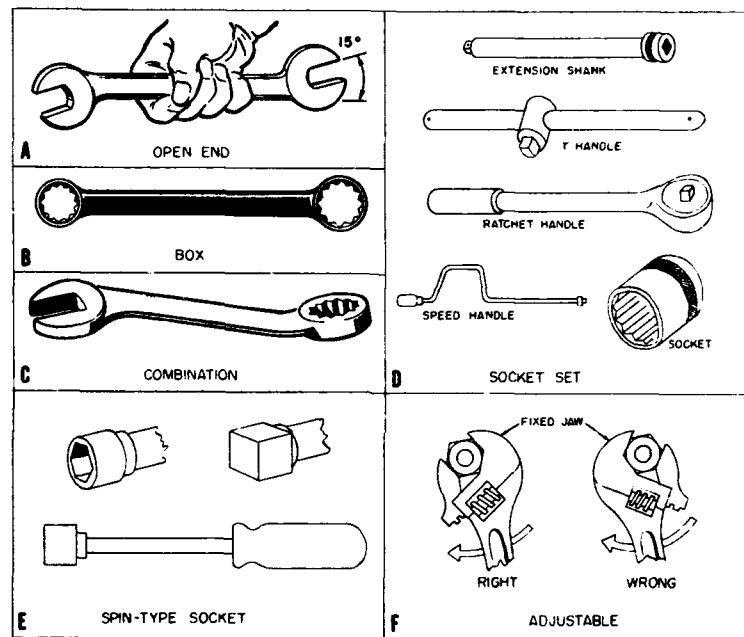


Figure 4-3.—Common types of wrenches.

OPEN-END wrenches (fig. 4-3, A) are solid, nonadjustable wrenches with openings at each end. The smallest wrench in the average set has a $\frac{5}{16}$ -inch opening in one end and a $\frac{3}{8}$ -inch opening in the other. It is therefore called a $\frac{5}{16}$ by $\frac{3}{8}$ open-end wrench.

The openings actually measure from 5 to 15 thousandths of an inch larger than the sizes marked on the wrenches. This makes it easier to apply the wrench to a bolthead or nut.

The BOX wrench (fig. 4-3, B) derives its name from the fact that it completely surrounds the nut or bolt-head. Modern box wrenches have 12 notches within the box circle and are referred to as 12-point wrenches. This type replaces the older 6-point type. These wrenches are popular because they do not slip off the nut or bolt when they are turned.

COMBINATION wrenches (fig. 4-3, C) are simply a combination of an open-end and a box wrench.

SOCKET wrenches (fig. 4-3, D) come in sets. The sockets are usually of the removable type and are of 12-point design. A socket set will include a T handle, ratchet handle, and a speed handle, plus one or two extension shanks. The speed handle resembles a carpenter's brace.

SPIN-TYPE socket wrenches (fig. 4-3, E) are very popular in electronics work. In some sets the socket is an integral part of the wrench; in other sets (like the one shown) sockets of various sizes may be attached to a common handle. To attach the socket to the handle, one simply pushes the socket in until the ball snap-on grip holds it in place.

ADJUSTABLE wrenches (fig. 4-3, F) are not intended to replace the standard open-end wrench and are generally used in cases where only one wrench is needed to fit a variety of nut or bolt sizes. It should never be used at its widest opening because this is the weakest position and the jaws may be spread. The right and wrong methods of using this wrench are shown in the figure.

Other wrenches are illustrated in figure 4-4.

ALLEN, or HEX, wrenches (fig. 4-4, A) are designed to fit hexagonal socket setscrews. They are made of tool steel and bent in an L shape and either end may be used.

BRISTOL wrenches (fig. 4-4, B) are somewhat like Allen wrenches. They are fluted to fit into the special fluted Bristol setscrew. These wrenches are not standard stock items because manufacturers normally supply these special wrenches when they are required for their equipment.

SPANNER wrenches (fig. 4-4, C) are special tools for special jobs. Three common types are shown in the figure. The hook spanner is used for rounded nuts that

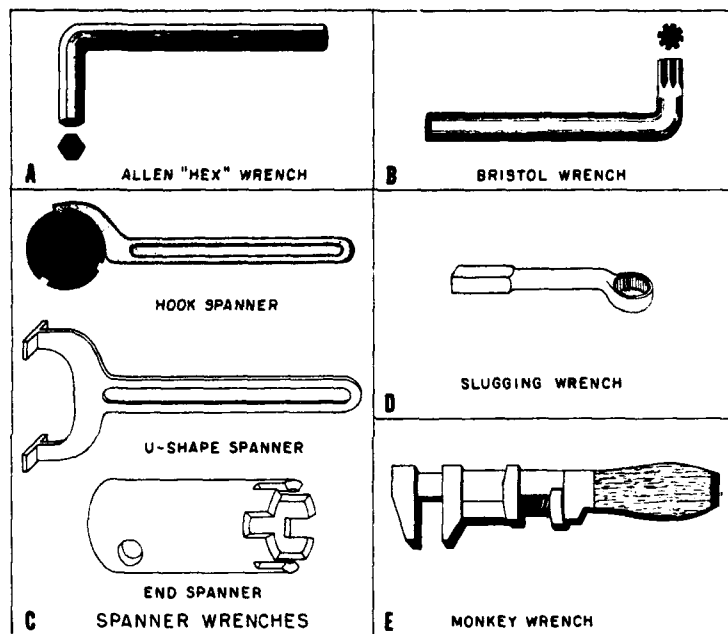


Figure 4-4.—Special types of wrenches.

have a series of notches on the outer edge. The U-shaped hook spanner fits notches on the face of a nut or screw-plug. The end spanner wrench has a series of lugs on the end that fit into notches in the nut or plug.

SLUGGING wrenches (fig. 4-4, D) are the only wrenches designed to be used with a hammer. Hammers should not be used with other wrenches.

MONKEY wrenches (fig. 4-4, E) require the same precautions in use as do adjustable wrenches (see right and wrong method of using the adjustable wrench).

PUNCHES

The center, starting, pin, aligning, and hollow-shank gasket punches are useful in electronics work. Punches

are made of tool steel, tempered and hardened at the point. Punches should never be used on extremely hard metals or to remove bolts by force because the point will be dulled. Several types of punches are illustrated in figure 4-5.

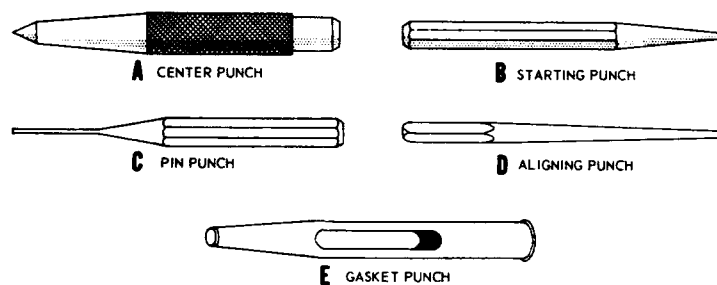


Figure 4-5.—Types of punches.

The CENTER punch (fig. 4-5, A) is used to make a punch mark for starting a drill. The point is carefully ground to an angle of 60° , which is the same as the angle of a standard twist drill. Drills will start quicker and have less tendency to wander if they are started in a punched hole.

The STARTING punch (fig. 4-5, B) is used to knock out rivets after the heads have been cut off. It is also used to start driving out straight and tapered pins because it can withstand the heavy hammer blows necessary to break loose the pin and start it moving. This punch is made with a long, gentle taper extending from the tip to the body of the punch.

The PIN punch (fig. 4-5, C) is made with a straight shank and is used to follow up on the job requiring a starting punch. After a pin has been partially driven out with a starting punch, which is limited in use because of its increasing taper, the pin punch with its slim shank is used to finish the job.

Never use a pin punch as a starting punch because a hard blow may cause the slim shank to bend or break. Always use the largest size starting and pin punch that will fit into the hole. Do not strike the pin punch with a glancing blow because the punch may be broken, and broken pin punches may be difficult to remove.

The ALIGNING punch (fig. 4-5, D) is from 12 to 16 inches in length and has a long taper. This punch is used for moving or shifting plates or parts so that corresponding holes will line up. It should not be used for a pry bar.

The hollow-shank GASKET punch (fig. 4-5, E) is used for cutting holes in gaskets and similar materials. The cutting end is tapered to a sharp cutting edge to make clean, uniform holes. The material to be cut should be placed on a soft background such as lead or hardwood so that the cutting edge will not be damaged.

HACKSAWS AND METAL SAWS

A common type of hacksaw is shown in figure 4-6, A. It is used for cutting metal, plastic, fibers, and other materials. It is a very useful tool when correctly used; however, it is often misused.

The frames are generally adjustable to take blades 8, 10, or 12 inches long.

The blades are of two general types—the flexible-back blade and the all-hard blade. Flexible-back blades are better suited for use on channel iron, tubing, sheet metal, copper, aluminum, babbitt, etc., because it does not break as easily as the all-hard blade. The all-hard blade is used on brass, tool steel, cast iron, etc. because it does not have a tendency to buckle or run out of line when pressure is applied to it.

Details on the use of the hacksaw are given in Chapter 3 of the *Electronic Installation Practices Manual*, NavShips 900,171 and in *Basic Hand Tool Skills*, NavPers

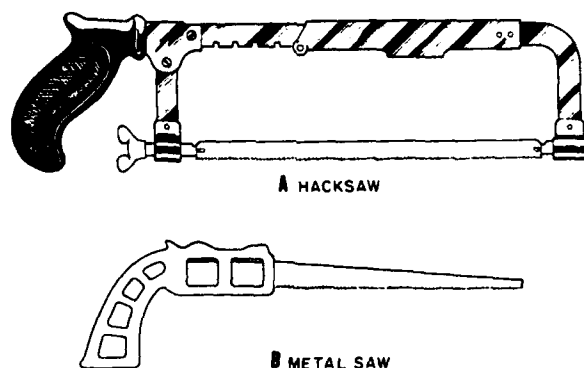


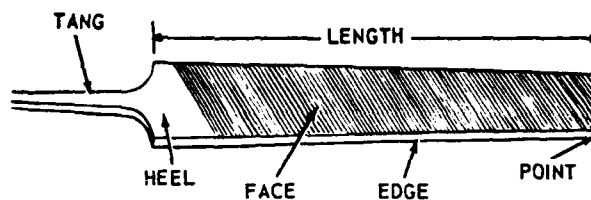
Figure 4-6.—Common types of hacksaw and metal saw.

10085. However, the following suggestions will be helpful: (1) Adjust the wing nut until the blade is tight enough not to twist (it may be necessary to tighten the blade as it heats and expands during work); (2) hold the work fairly close to the vise to avoid spring and chatter; (3) hold the work securely to avoid loosening; (4) the forward stroke is the cutting stroke, and pressure should be relieved on the return stroke; (5) do not try to cut too fast; (6) do not use excessive pressure, and reduce the pressure when cutting thin material; (7) saw carefully when the blade is almost through the cut; (8) if a saw blade breaks when the cut is only partly completed, start the new blade in another place on the bar to avoid binding; and (9) coarse blades with fewer teeth per inch cut faster and are less liable to choke up with chips, but finer blades with more teeth per inch are necessary when thin sections are being cut.

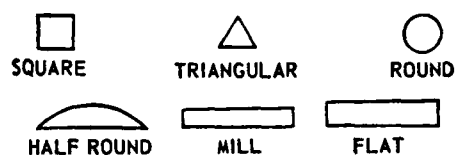
The metal saw (fig. 4-6, B) is used where it is inconvenient to use a hacksaw.

FILES

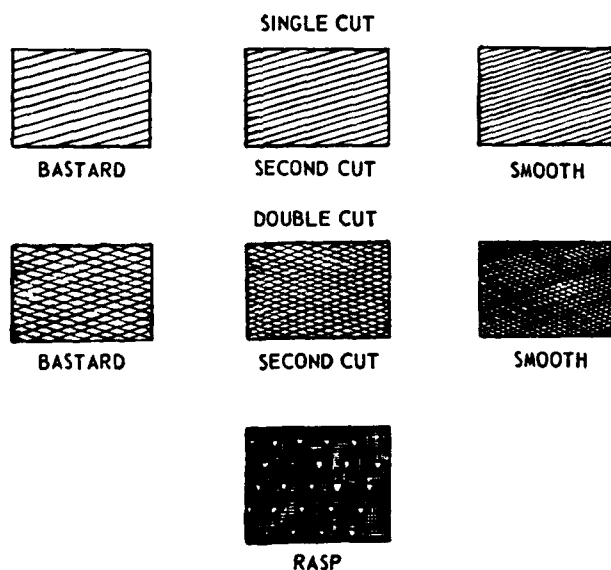
A flat file with the parts labeled is illustrated in figure 4-7, A. Cross-sectional areas of the various types



A PARTS OF A FILE



B CROSS-SECTION



C CUTTING TEETH

Figure 4-7.—Parts of a file, cross-sectional areas, and cuts.

of files are illustrated in part B, and the various cuts are illustrated in part C.

A detailed description of the various types of files are given in NavShips 900,171 and NavPers 10085, and therefore only a brief description of filing methods and file care is included here.

Proper filing methods come only with much practice. Of course, the first step is to choose the right file for the job. For example, a large, coarse, double-cut file should be used for heavy, rough cutting. When finishing the work, use a second-cut (40 teeth per inch) or a smooth single-cut (50 teeth per inch) file.

In working with cast iron, start with a bastard-cut and finish with a second-cut file; for soft steel, start with a second-cut and finish with a smooth-cut; for hard steel, start with a smooth-cut and finish with a dead-smooth one (100 or more teeth per inch); and for brass or bronze, file with a bastard-cut (30 teeth per inch) and finish with a second- or smooth-cut file.

Be sure to raise the file slightly on the return stroke in order to clear the work and avoid dulling the file by wearing away the back of the teeth, thus destroying the cutting edges. This procedure does not hold true in the filing of soft metals, such as lead and aluminum. Drawing the file back along these metals on the return stroke aids in clearing the teeth.

Sometimes the material being filed tends to become clogged between the teeth of the file, causing scratches on the work. This is called PINNING. When pinning occurs, the file should be cleaned with a file card.

The following precautions should be kept in mind: (1) Select the proper type of file, (2) do not rub the hand over work being filed, (3) always use a file handle, (4) apply downward pressure only on the forward stroke, (5) do not hammer on or pry with files because they are brittle and will break easily, (6) do not stow files in a box unprotected—especially do not pile them

all together, and (7) remember that rust is the enemy of files the same as it is the enemy of other hand tools.

PLIERS

Some typical pliers used in electronics repair work are shown in figure 4-8. The ROUND-JAW pliers (fig. 4-8, A) are used for bending and shaping wire. They are especially useful for shaping wires for attachment to screw terminals (when lugs are not used).

LONG-NOSE or NEEDLE-NOSE pliers (fig. 4-8, B and C) are used for removing and for replacing component

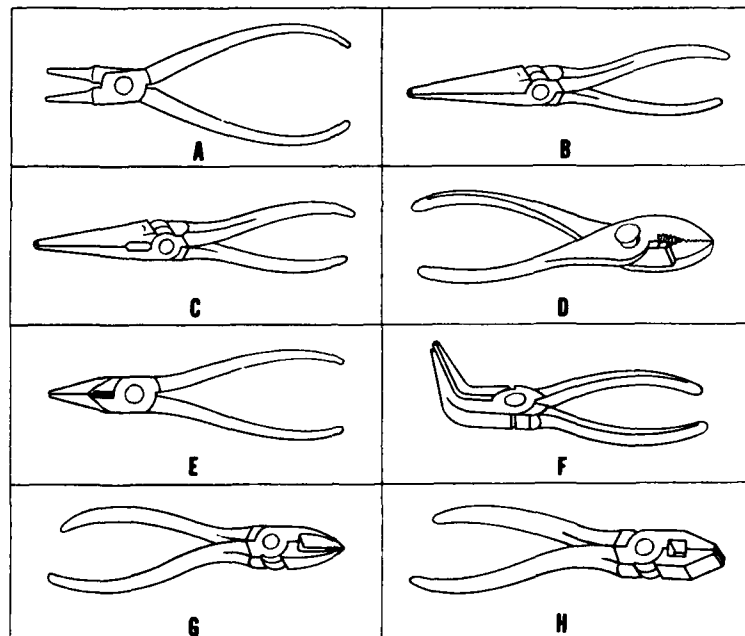


Figure 4-8.—Typical pliers used in electronics work. A, round-jaw, B, long-nose (without side cutters), C, long-nose (with side cutters), D, combination-jaw (gas pliers), E, short-nose (with side cutters), F, curved needle nose, G, diagonal-cutting, H, side-cutting pliers.

leads. Actually, they are a necessity in removing leads from tie points and terminal strips and also in replacing the leads. They are often used with the soldering iron. These pliers should NOT be used in the place of a wrench or for bending metal or stiff wires. The bending of metals or stiff wires are jobs for heavier pliers—for example, COMBINATION-JAW pliers (gas pliers) (fig. 4-8, D) or SHORT-NOSE pliers (fig. 4-8, E).

CURVED NEEDLE-NOSE pliers (fig. 4-8, F) are especially helpful in close spaces where the straight needle-nose pliers cannot reach.

In general, with the possible exception of the needle-nose type, pliers are rugged and require little care other than a drop of oil now and then and the proper cleaning. They should NOT be used for a hammer or a wrench. Hammering can loosen the jaws, and using pliers for a wrench can twist the jaws or loosen them sufficiently (especially the needle-nose type) to make them essentially useless.

Even the common "gas pliers" are not designed to be used as a wrench. Good technicians do not use pliers for wrenches.

Another very useful tool is the DIAGONAL-CUTTING pliers (fig. 4-8, G). Those shown in the figure have a cutting edge at a 15° angle to the plane of the handles. They are used for cutting small wire close to a flat surface. As a matter of fact, the ET will find them useful for doing most of his wire cutting. A small ($4\frac{1}{4}$ inch length) side cutter suitable for many types of work has the stock No. G5110-240-6209. The side cutters having stock No. G5110-224-1532 have special notches for splitting insulation and an insulation-stripping hole 0.052 inch in diameter.

SIDE CUTTING pliers (fig. 4-8, H) are generally used for wire cutting and splicing work. Because the jaws and cutting edges are tempered, extreme heat should be avoided.

CIRCLE CUTTER AND CHASSIS PUNCHES

A circle cutter and two types of chassis punches are illustrated in figure 4-9.

The circle cutter (fig. 4-9, A) will cut holes 1 to 5 1/4 inches in diameter in chassis material.

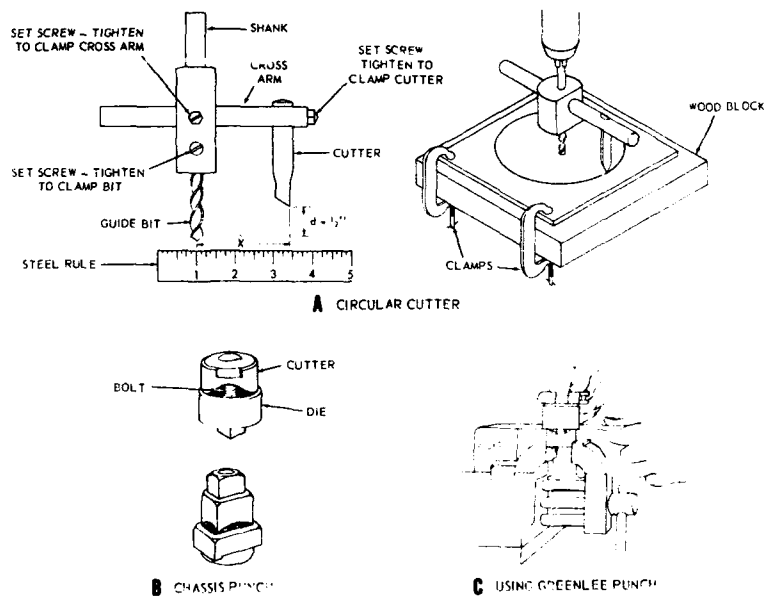


Figure 4-9.—Circle cutter and chassis punches.

The operation is relatively simple. First of all, the size of the hole to be cut is determined; the cross arm is then adjusted so that the distance (X) between the center of the drill and point of the cutter is one-half the diameter of the hole to be cut.

The work should be placed on a wooden block and center punched at the exact center of the section to be cut out. This is the spot where the tip of the guide bit is placed.

The wood block should remain in place while the cutting is being done. Some cutters are made to fit a drill press; others are made to fit into a hand brace. In any case, pressure is exerted until the cutter has cut through the material.

In cutting a hole in sheet metal it is often easier to turn the sheet over after the metal has been cut half way through and finish the cut from this side.

Two types of chassis punches are shown in figure 4-9, B. One cuts a square hole and the other cuts a round hole. This is the most convenient way to cut holes larger than $\frac{1}{2}$ inch in a chassis, provided the right size is available.

The round type is available in Navy stock in sizes from $\frac{1}{2}$ to $1\frac{1}{2}$ inches; the square type is available in $\frac{5}{8}$ -inch square and a $\frac{3}{4}$ -inch square sizes.

A chassis punch generally consists of three parts: cutter, die, and bolt, as illustrated in the figure.

The cutter has two cutting edges symmetrically located for the proper balance and is threaded so that it can be drawn up against the chassis when the bolt is turned. A pilot hole of the correct size must be drilled in the chassis to receive the bolt.

A neat appearing hole can be cut in the chassis by the use of this type of punch. The method of using the punch is illustrated in figure 4-9, C.

CRIMPING TOOL AND WIRE STRIPPERS

Solderless wire terminals serve a very important function in Navy electrical equipment. When these terminals are crimped with the proper tool, they have a pull-out resistance equal to the breaking strength of the wire. When properly installed, these terminals are thoroughly dependable, both electrically and mechanically.

The Bureau of Ships has developed a universal crimping tool, shown in figure 4-10, A, for use in installing

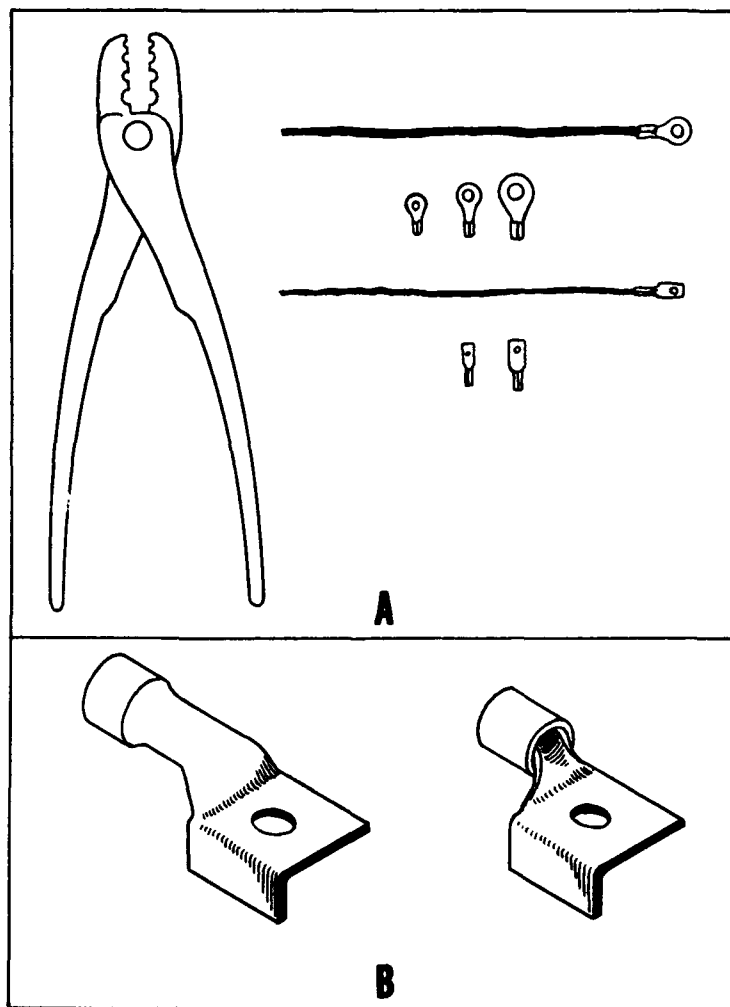


Figure 4-10.—Universal crimping tool.

solderless wire terminals. The tool makes a longitudinal crimp and is capable of attaching all approved type WT and WTG wire terminals (fig. 4-10, B) to wire sizes from 1000 to 9000 circular mils. It is also designed to attach telephone wire terminals to wire having sizes from 250 to 1000 circular mils. Provision is also made for compressing the insulation-gripping shroud of WTG terminals.

Technicians who attach solderless wire terminals should use this tool. They should also have a good wire stripper that will remove the insulation from the wire without cutting any of the strands. Penknives, pliers, or diagonal cutters should not be used for wire stripping.

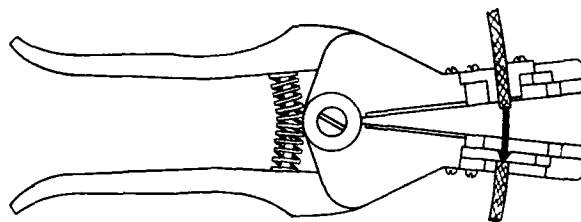


Figure 4-11.—Wire stripper.

One type of wire stripper is illustrated in figure 4-11. Various blades are used to accommodate the various sizes of wire.

HAND AND PORTABLE ELECTRIC DRILLS

A HAND drill and a portable electric drill are shown in figure 4-12. The hand drill (fig. 4-12, A) generally accommodates twist drills (drill bits) up to $\frac{1}{4}$ inch in diameter. To insert a twist drill, the chuck (the part that clamps the drill) jaws are opened sufficiently to insert the drill; after the drill is inserted, the chuck is tightened until the drill is held firmly. For heavy work, the larger hand-operated breast drill may be used.

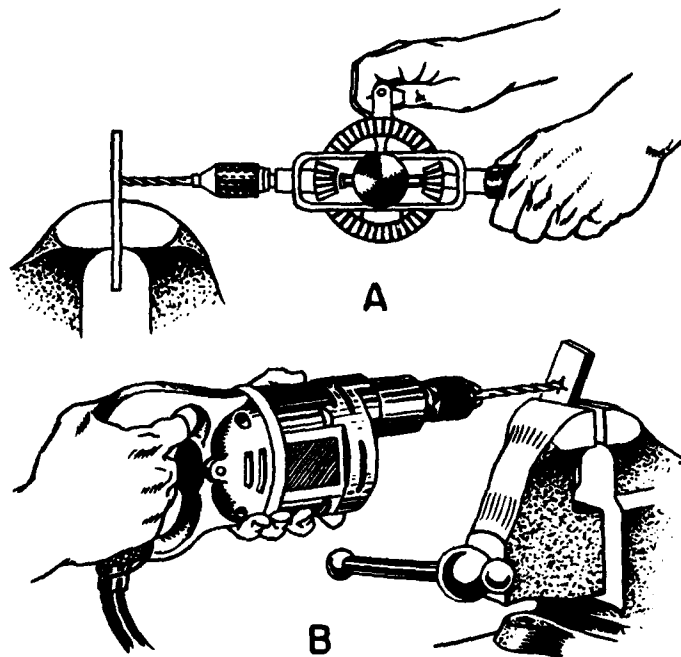


Figure 4-12.—Hand and portable electric drills.

A center punch should be used to provide a starting hole for the drill. This prevents the drill from wandering around and enables the drill to start cutting without excessive pressure, which might break the drill bit.

A PORTABLE ELECTRIC drill (fig. 4-12, B) is used whenever possible in drilling holes (except, of course, when it is desirable to use a drill press) because it is easier and faster to use than the hand drill. This drill consists of a small geared-down portable electric motor with a drill chuck attached.

Drill chucks may be of the three-jawed gear type using a pinion key for tightening the chuck, or they may be of the two-jawed type with a socket head setscrew using an Allen, or hex, wrench for tightening. Make sure that the key is NOT in the chuck before starting an electric drill.

There are certain precautions that should be exercised when you use an electric drill: (1) Be sure that the drill case makes a positive connection to ground, (2) do not overload the drill by using a larger size drill than the largest size recommended, (3) always use a center punch, (4) hold the drill perpendicular to the work, (5) use an occasional drop of oil to keep the twist drill cool (if drilling in thick metal), (6) exert even pressure while the cutting is being done, (7) do not let the drill continue running in the hole after drilling is complete (this will widen the hole), (8) do not hold the material you are drilling in your hand (clamp it down), (9) do not swing the drill by the power cord, and (10) do not lay a drill down or pull the plug while the drill is still running (use the switch on the drill first).

A TWIST DRILL is a cutting tool designed to cut holes in most materials. It is usually made of either carbon steel or high-speed steel. If carbon steel is heated excessively it loses its hardness. High-speed steel can become red hot without losing its temper. When hard grades of steel (Monel and stainless) or certain plastics are to be drilled, the high-speed drill should be used.

The following suggestions will be helpful: (1) Sometimes it may be desirable to drill a pilot hole to keep larger drills from running off center; (2) when drilling thin pieces, secure them to a board before drilling; and (3) a squeak may indicate an improperly ground drill or the need for oil.

SOLDERING AND SOLDERING EQUIPMENT

Electric Soldering Irons and Soldering Guns

Two of the most important hand tools used by the ET are the electric soldering iron and soldering gun. This is true because soldering is the common method of making electric connections within electronic equipment; and it is a necessary part of nearly all repair procedures

when a component, such as a resistor, capacitor, or inductor, is replaced.

Several general types of electric soldering irons are listed in the Navy Stock List of General Stores. Two of these soldering irons are shown in figure 4-13.

In part A is shown an a-c d-c soldering iron without thermostatic control. This is a standard type complete with copper tip and 6-foot cord. It operates on 110 volts a-c or d-c. The iron is available with pyramidal or chisel-shaped tip and at various wattage ratings.

For radio duty, the iron is rated at 85 watts and has a pyramidal tip.

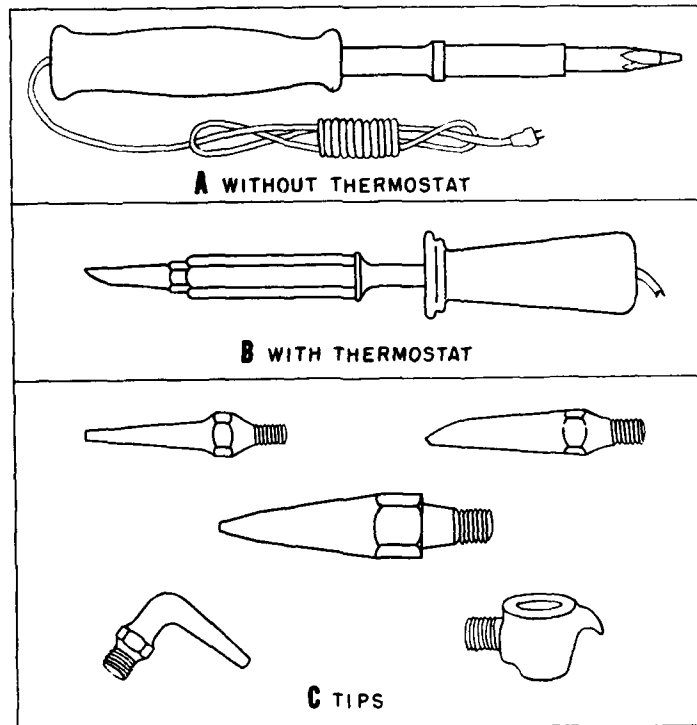


Figure 4-13.—Electric soldering irons.

In part B is shown an electric soldering-iron set equipped with built-in thermostat set to maintain heating element temperature between 700° and 775° F. The set includes handle, a full set of tips, and a resting stand. The tips are shown in part C.

The soldering gun (fig. 4-14) is extremely handy for light work. A soldering gun is a light-duty, fast-heating unit with built-in automatic spotlight. The tips are replaceable. The two-position switch (connected to the trigger) affords dual heat; the first position is 100 watts and the second position is 135 watts. The gun contains a transformer; its use is restricted to 115-volt 60-cycle operation only. It is NOT to be used on d-c.

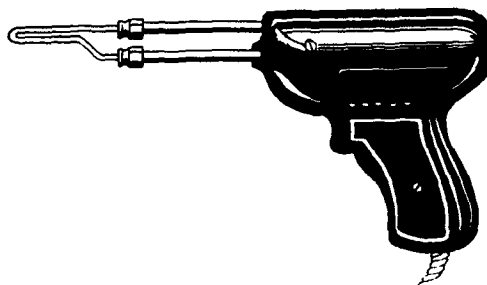


Figure 4-14.—Soldering gun.

The tip of the soldering gun is in the form of a narrow loop and makes a closed circuit with the secondary of the transformer. The flow of current through the tip heats it to soldering temperature in a matter of seconds. The gun is turned on and off for each soldering operation.

The cross-sectional area of the secondary winding is considerably larger than that of the soldering tip, and this tends to decrease the heating in the transformer and to concentrate it in the point where it is needed.

Continuous use of the soldering gun will overload the transformer and create the danger of a burn-out. There-

fore, the trigger must not be held in the heating position continuously for long periods of time. Release it as soon as the soldering operation is over.

Gun tips should be maintained in the same manner as the tips of soldering irons.

Soldering

To a very large extent the efficiency and reliability of the electronic equipment used aboard ship depends on the quality of the soldering done during assembly and during repair operations. Because shock and vibration can loosen poorly made joints (and perhaps cause an equipment to fail at a time when it is needed most), it is essential that soldered joints be properly made.

The information given in the following paragraphs is not complete, but it will be helpful to the beginning ET. For additional helpful information dealing specifically with soldering in electronics work, see Chapter 3 of the *Electronic Installation Practices Manual*, NavShips 900,-171; the 28 March 1955 issue (No. 403) of the *Electronics Information Bulletin*, NavShips 900,022A; and Section 6 of the EIB, change 9 (Jan. 1956).

Be sure that the parts to be soldered are absolutely clean and free of oxide, grease, and insulation. The parts may be cleaned by scraping, filing, or sanding; but do not remove more of the material than is necessary. Avoid nicking or cutting the conductors because this will reduce the mechanical strength. The parts to be soldered must be mechanically secure and satisfactorily conductive before any soldering is done because solder has very little mechanical strength and has poor electrical conductivity. The primary purpose of the solder is to ensure long-lasting low-resistance contacts by preventing oxidation or loosening of the mechanical contact. As soon as possible after the joint has been prepared the soldering operation should be performed.

Solder is made of tin and lead. The best solder for

electrical work contains 60 percent tin and 40 percent lead and has a melting point of approximately 370° F (188° C).

Solder will not form a perfect bond with any metal if a film of oxide is present. FLUX (ROSIN CORE ONLY for electronic soldering), when heated, removes oxides and prevents oxide from forming during the soldering process. The general practice in soldering electronic circuits is to use rosin-core wire solder. This solder is in the form of a wire tube filled with rosin flux to form the core. Because the rosin has a lower melting point than the solder, the rosin flows out first to clean the surface when heat is applied. No residue of rosin should be left in the soldered joint. Excess rosin may be removed by the use of alcohol.

The general procedure in making a soldered joint is given as follows: (1) Prepare the joint, as indicated previously; (2) heat the iron sufficiently to melt the solder readily; (3) heat the joint and quickly apply the solder; (4) apply only enough solder to ensure a good joint; (5) do not splash or throw the solder around, it is needed only on the joint; and (6) do not wiggle or jar the joint while the solder is cooling. (Any motion between the two halves of the joint before it cools will produce a "cold" joint, which has a dull white appearance instead of a shiny silvery appearance. If relative motion between the two halves of a joint occurs, it should be re-heated.)

A good soldering job requires a well-kept iron. The following suggestions will be helpful in retinning an iron: (1) When the tip becomes "pitted" by the action of the rosin core in the solder, retin the iron; (2) use a fine metal-cutting file to remove the pits, retaining the original shape of the tip; (3) heat the iron, rub the tip on sandpaper, and apply solder; and (4) wipe off the solder with a cloth.

Always select the proper tip for the job being done, and occasionally loosen the tip (fig. 4-13.C) to ensure

freedom from rusting of the threads so that it will not be difficult to remove. Soldering irons can usually be kept clean by wiping with a rag before corrosion starts.

FUSE PULLERS

Fuse pullers (fig. 4-15) are made of either laminated bakelite or fiber and are used for pulling and replacing fuses.



Figure 4-15.—Fuse puller.

Fuses should never be pulled or replaced with the bare hands. Metal objects, such as a screwdriver, should never be used inside a fuse cabinet when attempting to remove or replace fuses. To be doubly safe, open the switch before pulling a fuse.

QUIZ

1. What announces an ET's skill for him?
2. Under what circumstances are stubby screwdrivers used?
3. Why is it important to select a screwdriver that will fit snugly into the screw slot?
4. Why should an adjustable wrench not be used at its widest opening?
5. What is the only type of wrench designed to be used with a hammer?
6. Why is the point of a center punch ground to an angle of 60°?
7. Why should the pin punch never be used as a starting punch?
8. On what types of substances is the all-hard hacksaw blade used?
9. Why may it be necessary to adjust the wingnut on a hacksaw as the work progresses?
10. What type of file is used for rough, heavy cutting?
11. In filing soft metals like lead and aluminum, what is the advantage of drawing the file back along the metal after the forward stroke?
12. What is the purpose of round-jaw pliers?
13. What may be the result of using pliers (especially the needle-nose type) in the place of a wrench?
14. Why should a center punch be used on the work before using a drill?
15. What type of drill bit should be used with hard grades of steel and with certain plastics?
16. Why is the cross-sectional area of the secondary winding of a soldering gun considerably larger than that of the soldering tip?
17. Why should not the trigger of a soldering gun be held in the heating position continuously for long periods of time?
18. What is the primary purpose of solder on a soldered joint?
19. Why should the tip of a soldering iron be loosened occasionally?
20. What instrument is used for pulling and replacing fuses?

CHAPTER

5

ELECTRONIC INSTALLATIONS

INTRODUCTION

The primary purpose of this chapter is to acquaint the prospective ET 3 with some of the problems involved in the installation of electronic equipment and with some of the methods employed to overcome these problems; it is not intended to be an installation handbook. Along with chapter 1, it will help the beginning technician to become better acquainted with the electronic equipment used aboard ship and with the way it is installed.

Some general information on cabling and the use of stuffing tubes and kickpipes, as well as the use of insulating materials, is included because each of these items bears a direct relationship to electronic equipment. Information is also included on moisture absorbing materials such as silica gel.

The types, use, and location of electric filters are important, and the prospective ET should at least know that such things exist. Some general information on filters, particularly the types and locations, is included in this chapter. Air filters are treated in the next chapter.

Methods of installing electronic equipment (and the reasons why certain equipments are installed as they are) are important to the ET and are also included.

The chapter concludes with brief descriptions of the following installations aboard ship: r-f transmission lines, motor-generator and amplidynes, power supply systems for electronic equipment, multicouplers, and antenna systems.

If the technician desires more detail, he may consult the various chapters of the *Electronic Installation Practices Manual*, NavShips 900,171 (now being revised) and *Shipboard Antenna Details*, NavShips 900,121A.

CABLING

Types of Cables

The various electronic systems aboard ship depend on power supplied by the ship's service generators. This power is distributed to the electronics spaces by a system of cables. Power cables are normally installed by shipyard forces, but the ET should know in detail the location and characteristics of the cabling, which supplies the equipment with which he works.

He should become familiar with the current-carrying capacity of cables; their insulation strength; and their ability to withstand heat, cold, dryness, bending, crushing, vibration, twisting, and shock. Several types of cables are used in the applications under discussion, with design characteristics suited to their location and purpose.

Type SGA (Shipboard, General use, Armored) cables are designed to have a minimum diameter and weight consistent with service requirements in fixed wireways on combatant naval vessels. This type supersedes the older, widely used type HFA (Heat and Flame resistant, Armored) cable.

Type SSGA cable (fig. 5-1) consists of stranded copper conductors (in this case, only one conductor—indicated by the "S" before SGA) insulated with silicone rubber and glass fibers around which is placed an im-

pervious sheath. The sheath is covered with braided metal armor, and then a coat of paint is applied.

The SGA cables are designated as follows: (1) SSGA, single conductor; (2) DSGA, twin (double) conductor; (3) TSGA, three conductor; and (4) FSGA, four conductor.

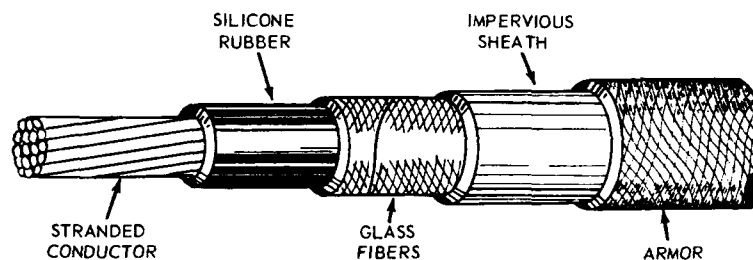


Figure 5-1.—SSGA cable.

The HFA cables (also composed of stranded copper conductors) are designated as follows: (1) SHFA, single conductor; (2) DHFA, twin (double) conductor; (3) THFA, three conductor; (4) FHFA, four conductor; and (5) MHFA, multiconductor.

Twisted-pair telephone cables are designated as TTHFWA.

Many applications aboard ship require cables that can be bent and twisted again and again without damaging the conductor insulation or the protective covering. For such applications, flexible cables are used.

Flexible cables have synthetic rubber or synthetic resin insulation and a flexible sheath that is resistant to water, oil, heat, and flame. However, these cables are not as heat and flame resistant as armored HFA and SGA cables. Flexible cables for general use are designated by the letters, HOF—for example, DHOF, THOF, and FHOFF. Flexible cables for limited use are designated

by the letters COP—for example, DCOP, TCOP, and FCOP.

Other types of cables used in electronics work are:

1. DRHLA—Double conductor, radio, high-tension, lead armored.
2. FHFTA—Four conductor, heat and flame resistant, thin-walled armor.
3. MCSP—Multiple conductor, shielded, pressure resistant (submarine applications).
4. TTRSA—Twisted-pair telephone, radio shielded, armored (characteristic impedance approximately 76 ohms).

Designation of Conductor Size

Generally, when the size of the individual conductors contained in the cable is indicated in the cable designation, the numeral (or numerals) following the letter designation indicate the approximate cross-sectional area of the individual conductors in thousands of circular mils to the nearest thousands. For example, TSGA-60 is a 3-conductor armored cable for general shipboard use, with each conductor having a cross-sectional area of 60,090 circular mils. However, when the numerals immediately following the letter designation indicate the number of conductors comprising the cable, the size of the individual conductors may be indicated by additional numerals enclosed in parenthesis. For example, MDGA-19(6) is a 19-conductor electrical power cable for shipboard nonflexing service, with each conductor having a cross-sectional area of 6,512 circular mils.

Multiple-Conductor Cable Designations

Multiple-conductor cable types and class designations are followed by a number that indicates the number of conductors. For example, MSCA-30 is a heat and flame resistant armored cable with 30 conductors.

For telephone cable, the number indicates twisted pairs. For example, TTHFWA-25 means that the cable

contains 25 twisted pairs; TTRSA-4 means that the cable contains 4 pairs individually shielded.

Selection and Installation of Cables

The ET 3 will, in all probability, not be called upon to select and install power cables. However, he should have some knowledge of the power cables in the electronics spaces. There are at least five items that must be considered when power cables are installed. They are (1) the maximum connected load in amperes, (2) the possible added load due to future installations, (3) the demand factor (that is, the average demand in amperes over a 15-minute interval divided by the total connected load in amperes), (4) the cable service rating (the physical characteristics required for a given type of service), and (5) the maximum allowable voltage drop in the part of the circuit under consideration.

The current-carrying capacity and voltage-drop limitations determine the cable size for a particular application. The current capacity is dependent upon the type and size of the conductor, the permissible temperature rise, and the physical characteristics of the space in which the cable is installed. The allowable voltage drop depends on the type of load connected to the circuit.

All connections to cables are made in standard appliances and fittings; splice connections are not made. However, cable splices are permitted as an emergency repair (by ship's force), and on a limited basis (by repair activities) where it has been determined that time and replacement cost is excessive, and existing cable is in good condition. Cables entering watertight equipment are brought into the equipment through stuffing tubes (stuffing tubes and kickpipes are discussed later). Where cables pass through decks and watertight bulkheads, stuffing tubes are used. Cables passing through decks are protected from mechanical injury by kickpipes or riser boxes.

Numbering Cables and Conductors

All ships' cables are identified by metal tags (see for example, figure 5-2) that give information about the cable. Permanently installed ships' cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cable tags are placed on cable runs at intervals not exceeding 50 feet.

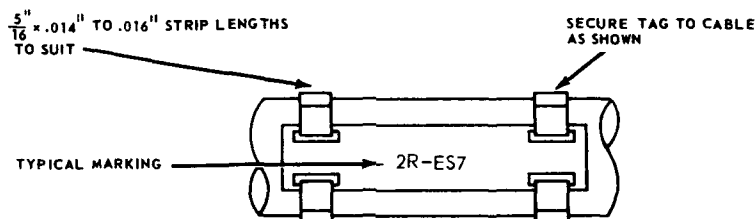


Figure 5-2.—Cable tag.

For color codes of cables, see the *Bureau of Ships Manual*, chapter 65. For new construction, red cable identification tags indicate vital circuits; yellow, semi-vital circuits; and gray, nonvital circuits. For construction prior to 1950, light blue meant vital circuits, and green meant semivital circuits. Additional information can be found in *General Specification for Ships of the United States Navy*, section S28-2.

A list of the circuit or system designations used in electronics is included in table 10.

The following example (see fig. 5-2) of electronics cable designation will illustrate the method of marking the cables between units of electronic equipment:

Example: 2R-ES7

The 2R-ES indicates the second surface search radar circuit on the vessel, R indicates electronics, ES indicates a surface-search radar circuit, and 7 indicates cable number 7 of the surface search radar.

TABLE 10

Circuit or System Designation	Circuit or System Title
R-AM	Radiation monitoring
R-AW	Aerological sounding and tracking
R-BC	Radio beacon
R-BN	Infrared beacon
R-BR	Radar beacon
R-BS	Sonar beacon
R-CI	Electronic countermeasures-intercept
R-CT	Electronic countermeasures-jamming
R-EA	Air search radar
R-EC	Carrier controlled approach-radar
R-EF	Height determining radar
R-EG	Guided missile radar
R-EM	Mortar locator radar
R-ER	Radar remote indicator
R-ES	Surface search radar
R-EW	Aircraft early warning
R-EZ	Hemispheric scanning
R-FB	Guided missile fire control radar
R-FG	Heavy machine gun battery fire control radar
R-FM	Surface battery fire control radar
R-FS	Double purpose battery fire control radar
R-GM	Electronic guidance remote control or remote telemetering.
R-IA	IFF used with air search radar
R-IC	Radar recognition
R-IF	IFF used with fire control radar
R-IM	IFF test equipment
R-IR	IFF used with radar remote indicators
R-IS	IFF used with surface search radar
R-IT	Radar identification
R-IU	IFF used with sonar
R-NC	Infrared communication
R-ND	Infrared detection
R-RA	Radio antenna (including frequency meter extension circuits).
R-RC	Radio channel selection
R-RD	Radio direction finder
R-RN	Radio navigation
R-RQ	Combined radio receiver and transmitter control circuits.

TABLE 10—Continued

Circuit or System Designation	Circuit or System Title
R-RR	Radio receiver circuits (including cabling between units of a receiving set).
R-RS	Radio synchronization
R-RT	Radio transmitter control (including cabling between units of a transmitting set).
R-RX	Radio facsimile
R-RY	Radio teletype
R-SA	Azimuth echo ranging sonar
R-SB	Underwater telephone
R-SC	Sonar computing
R-SD	Depth determining sonar
R-SE	Depth charge direction indicator and range estimator
R-SH	Sonar hoist-lower control
R-SK	Scanning sonar
R-SL	Listening sonar
R-SM	Sonar monitoring
R-SO	Bathythermograph
R-SP	Attack aid and auxiliary
R-SQ	Combination depth-azimuth sonar
R-SR	Sonar remote indicator
R-SS	Sounding sonar
R-ST	Attack teacher
R-SU	Underwater object locator
R-SV	Variable depth sonar

Cables that supply power to electronic equipment are designated, as specified in Article 60-270 of the *Bureau of Ships Manual*, for power and lighting circuits up to the first piece of electronic equipment or to the power receptacle to which the electronic equipment connects, except where electronic equipment is energized directly from the I. C. switchboard. In the latter case, the cable between the switchboard and the electronic equipment carries an electronics designation with the cable number preceded by a cipher (for example, R-RB-01). If the equipment is energized from the switchboard by way of

a local cutout switch, the cable between the local switch and the I. C. switchboard will carry an electronics designation with an additional cipher preceding the numeral (for example, R-RB-001).

Power cables between units of electronic equipment have electronics designations.

STUFFING TUBES AND KICKPIPES

Two classes of stuffing tubes are illustrated in figure 5-3. The class shown in part A is designed to be installed in the wall of an electrical appliance or fitting to permit the insertion of an electric cable. The cable is terminated in the appliance. The class shown in part B is designed to be installed in a deck, bulkhead, or hull to permit an electric cable to be passed through the structure. The cable is not terminated after passing through the tube but continues to some distant point.

Both classes of stuffing tubes are forms of packing glands and serve a common purpose in preventing the passage of liquids and gases at the point of cable entrance.

A kickpipe is a pipe used to pass cables through decks wherever cable protection from mechanical injury is needed. A typical kickpipe assembly is illustrated in figure 5-4. The minimum length of a kickpipe is nine inches and the maximum length depends on the requirements. If the length of the kickpipe is over twelve inches, the top of the kickpipe is secured by a brace.

More recently, nylon stuffing tubes have been developed by the Bureau of Ships. These stuffing tubes are extremely durable and will be used where practicable when the present supply of metal stuffing tubes is exhausted.

Specific information on the installation of stuffing tubes and kickpipes is included in Chapter 8 of the *Electronic Installation Practices Manual*, NavShips 900,171.

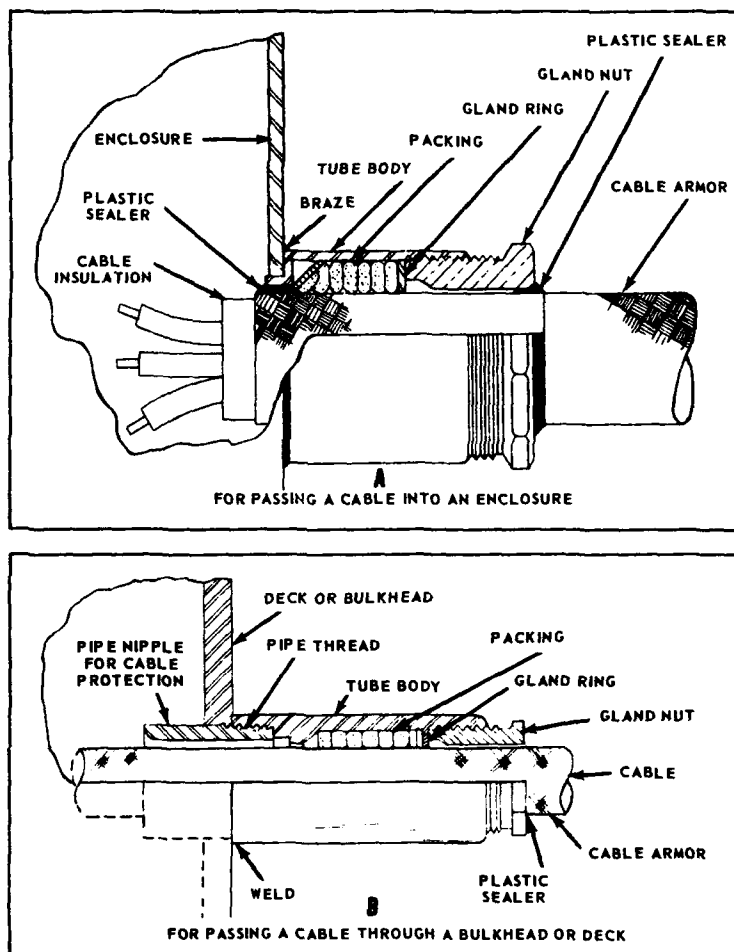


Figure 5-3.—Types of stuffing tubes.

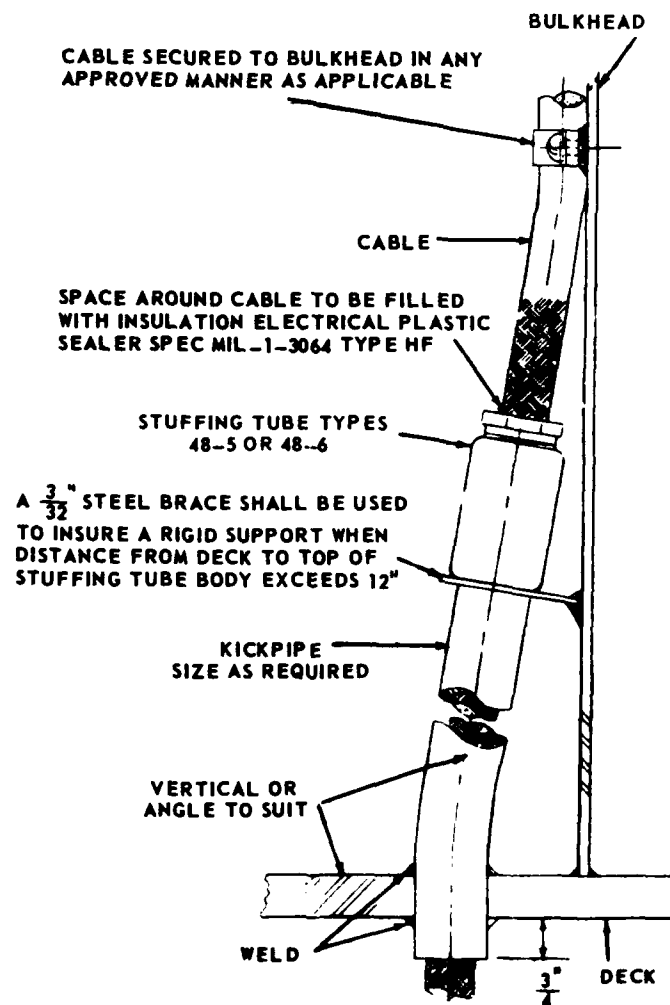


Figure S-4.—Typical kickpipe assembly.

FILTERS

The Need for Filters

Modern electronic receiving equipments are being made with greater sensitivities, and this has increased the problem of radio interference generated by electromechanical devices such as motors, generators, relays, etc. Likewise, the interactions between the various equipments can cause major interference problems.

Good installation practices will reduce or perhaps eliminate radio interference, but a filter may be needed to reduce certain types of interference to a tolerable level.

The major sources of radio interference are summarized as follows:

1. **ATMOSPHERIC NOISE** is caused by lightning. The reduction of this noise is accomplished by the use of noise limiters and f-m.

2. **PRECIPITATION STATIC** is a problem chiefly in aircraft caused by static discharges and corona on snow, dust, rain, etc. It is identified by a frying sound. Special measures are needed for its reduction or elimination. On surface vessels, proper grounding of equipments and mast structures will generally reduce this type of disturbance below the nuisance level.

3. **BACKGROUND NOISE** is due largely to shot effect (bombardment of the tube elements by irregularly spaced bunches of electrons), thermal noise (agitation of electrons in resistances because of heat), and microphonic noise (generally due to vibration of electron-tube elements).

4. **COSMIC NOISE** is the result of radiations from space. It is fast becoming a limiting factor in the design of more sensitive receivers.

5. **MAN-MADE NOISE** may be generated by a variety of sources. These sources include rotating electrical machinery, ignition systems, relays, pulse-type equipment (for example, radars), interaction between equipments, diathermy (also induction heating and welding) equip-

ment, hum pick-up at power or audio frequencies, and systems employing ionization of gas vapors.

6. Another type of interference that must be dealt with is that caused by operating several receivers from one antenna, as in MULTICOUPLER INSTALLATIONS. Various combinations of filters are used to feed the appropriate frequencies to the various receivers.

Signal or noise interference may be transferred from one circuit to another by several means. They include:

1. CAPACITIVE or ELECTROSTATIC coupling in which one circuit is linked to another by means of a capacitance that is common to both. This is especially true at radio frequencies.

2. INDUCTIVE or ELECTROMAGNETIC coupling in which a conductor is present in the electromagnetic field set up by the noise interference. This type is the hardest to isolate.

3. DIRECT RADIATION, which involves essentially the same principle as radiation from a transmitting antenna to a receiving antenna.

4. CONDUCTION ALONG LINES, which is the transfer of r-f energy along a conductor. It is this flow of signal or noise energy that is coupled by the methods mentioned in the last three paragraphs.

Conductive coupling (conduction along lines) can be reduced or eliminated by the use of the filter or filter network at the noise source (fig. 5-5).

Types of Filters

ATTENUATION is the amount that the signal or noise voltage is reduced in a filter. It is measured in decibels (db). Decibels are discussed in Chapter 6 of *Basic Electronics*, NavPers 10087. Band-pass and band-elimination filters are also discussed in chapter 1 of the same training course. See figure 5-6 for an illustration of the terms used in describing filters.

PASS BAND is the frequency range over which the filter passes signals with minimum attenuation.

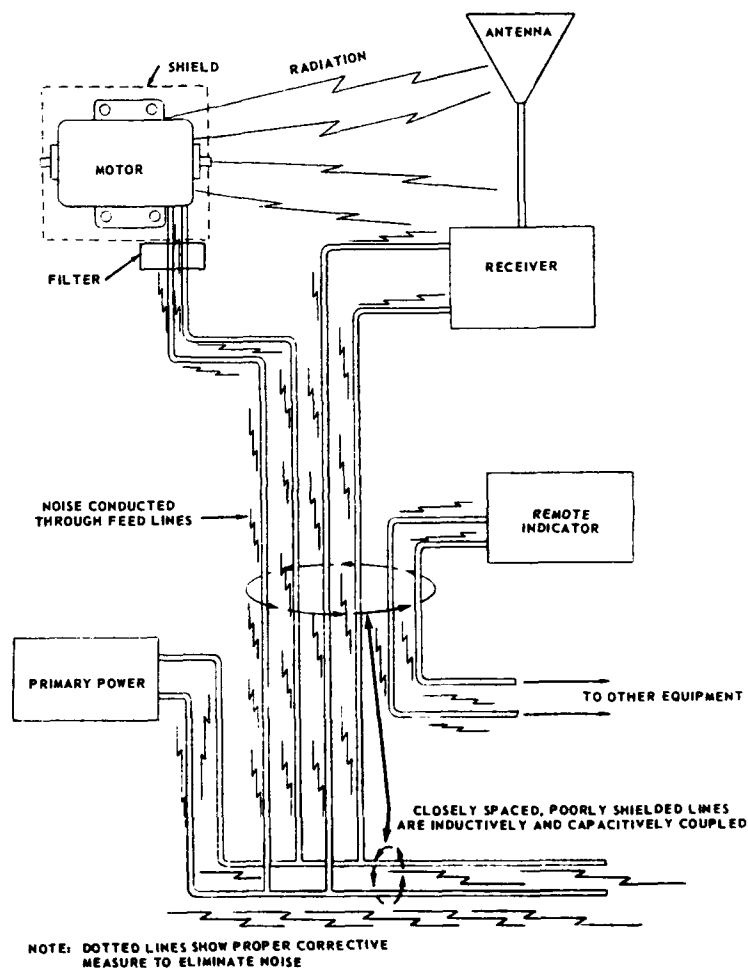


Figure 5-5.—Radio noise coupling showing position of filter for noise elimination.

STOP BAND is the frequency range over which the filter attenuates the applied signal.

CUTOFF FREQUENCY is the frequency at which the filter changes from a pass-band to a stop-band filter or vice versa.

GROUND means the equipment frame, the chassis, shielding, filter housing, etc; it is an important part of the circuit.

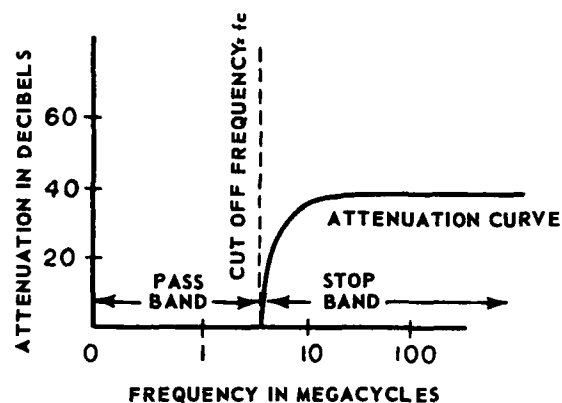


Figure 5-6.—Illustration of the terms used in filters.

LOW-PASS FILTER.—The low-pass filter passes all frequencies from zero frequency (fig. 5-7, A) (dc) up to the cutoff frequency (f_c). All power lead filters fall in this class. For example, if it is desirable to pass 60-cycle

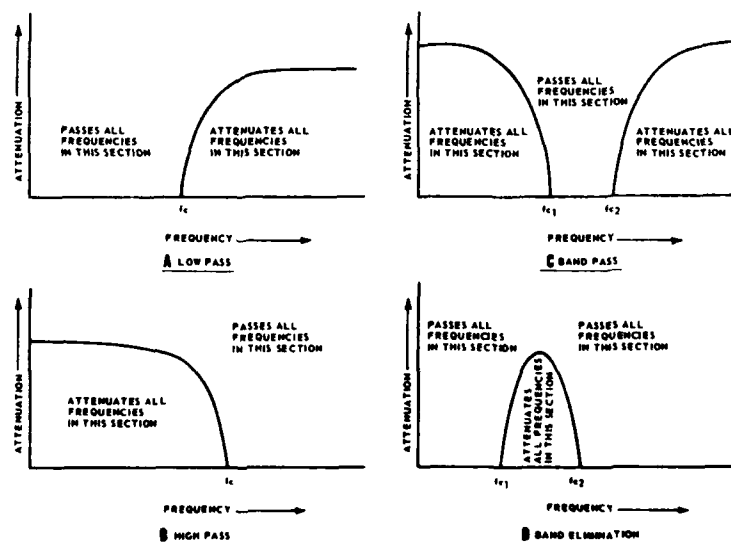


Figure 5-7.—Filter response curves.

power and to attenuate noise frequencies above (for example) 150 kc, a low-pass filter having a cutoff frequency of approximately 50 kc, may be used.

HIGH-PASS FILTER.—The high-pass filter attenuates all frequencies from zero frequency to the cutoff frequency and passes all frequencies above the cutoff frequency (fig. 5-7, B).

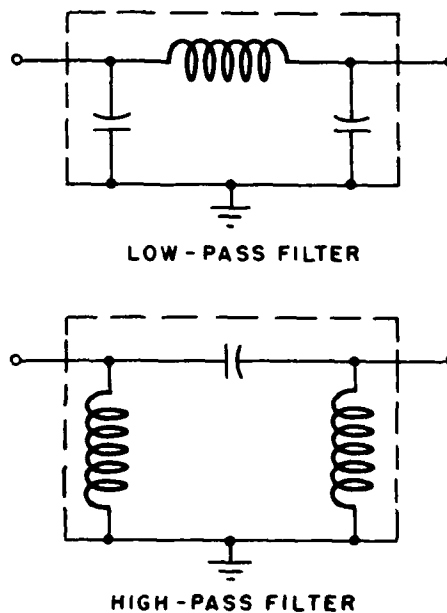


Figure 5-8.—Low-pass and high-pass filters.

BAND-PASS FILTER.—This filter passes all frequencies within a specified range and attenuates all other frequencies (fig. 5-7, C). Band-pass filters have special applications and are seldom used for noise elimination. One form of band-pass filter is the crystal filter used in communications receivers.

BAND ELIMINATION FILTER.—This filter attenuates a band of frequencies and passes all other frequencies (fig. 5-7, D). It is most commonly used as a simple

wave trap or absorption filter. Several wave traps are used in a television receiver.

Schematic diagrams of low-pass and high-pass filters are shown in figure 5-8.

Location and Installation of Filters

Filtering is done at the noise source whenever it is possible and practicable. This eliminates or reduces to an acceptable level all interference caused by the noise source. However, it may be impracticable to filter at the source in the following cases:

1. When the source is an antenna that interferes with other antennas under operating conditions.
2. When the source feeds many multiconductor cables and a filter would be required on every cable.
3. When the source is poorly shielded.

Schematic diagrams of three types of power-line filters are shown in figure 5-9. Filters may be mounted on bulkheads or on equipments.

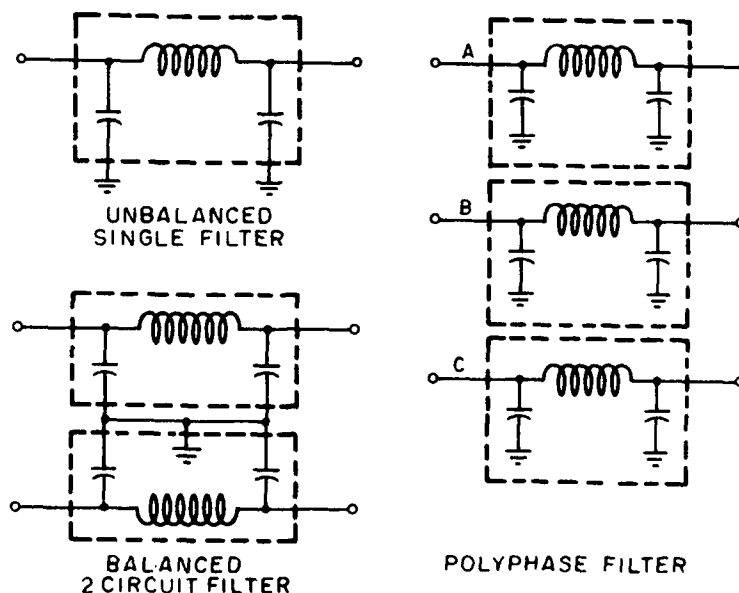


Figure 5-9.—Types of power-line filters.

The method of mounting a filter so that a bulkhead, chassis, or equipment case acts as an isolating shield between the input and output of the filter is referred to as bulkhead mounting. Very often, filters that are to be used in a component piece of equipment are designed to lend themselves to this type of mounting. Figure 5-10 shows some typical filter installations of this type. This same principle may be applied to filters enclosed in a box mounted on the side of the equipment. It does not lend itself to watertight installations because the space through which the leads pass into the equipment cannot be effectively sealed.

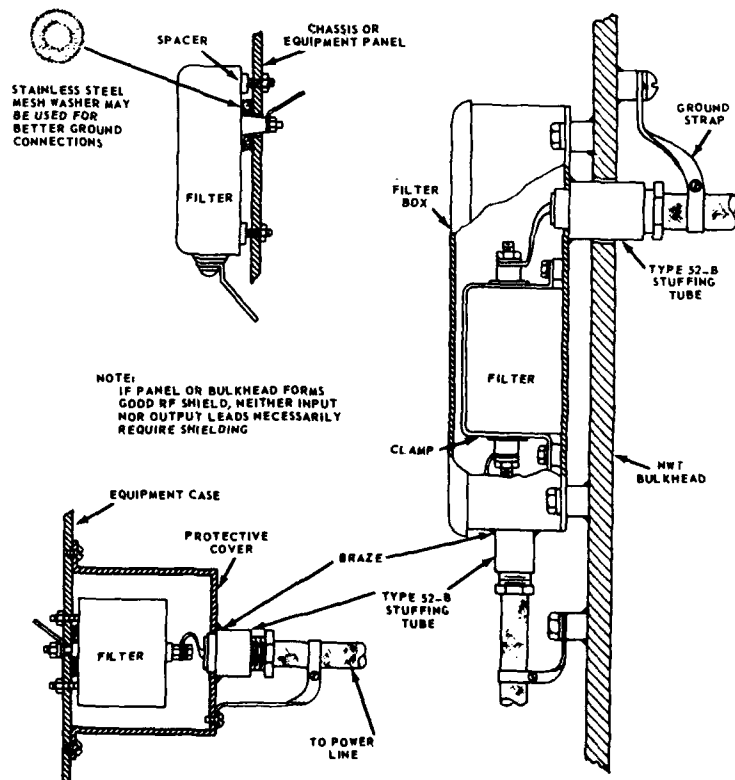


Figure 5-10.—Typical installations using bulkhead mountings.

Typical installations of filters mounted on machines or other noise sources are illustrated in figure 5-11. Much additional valuable information is included in Chapter 21 of the *Electronic Installation Practices Manual*, NavShips 900,171.

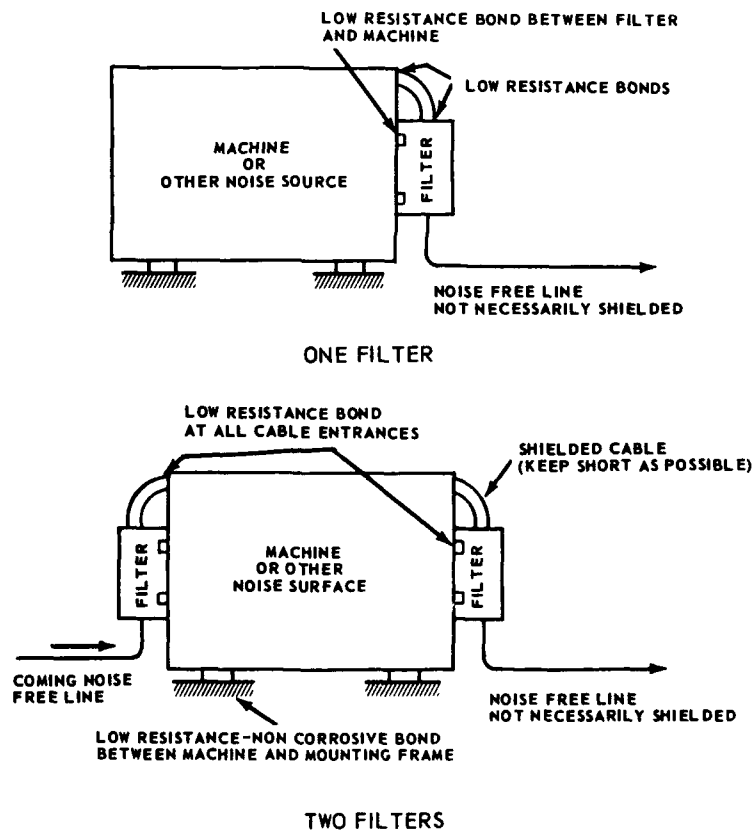


Figure 5-11.—Low-pass filter installations on a machine or other noise sources.

A good r-f connection is exceedingly important in filter installations regardless of whether it is a joint, a grounding surface, or a shield contact. Clean (to the bare metal), continuous r-f surfaces must be maintained throughout the installation. This means that all painted

surfaces, at the point where electrical connections are made, must be cleaned to the bare metal.

Low-pass filters are used on many radio receivers—for example, the AN/SRR 11, 12, 13 and the AN/URR-35. Figure 5-12 shows a rear (upside down) view of the low-pass filter used with the AN/URR-35.

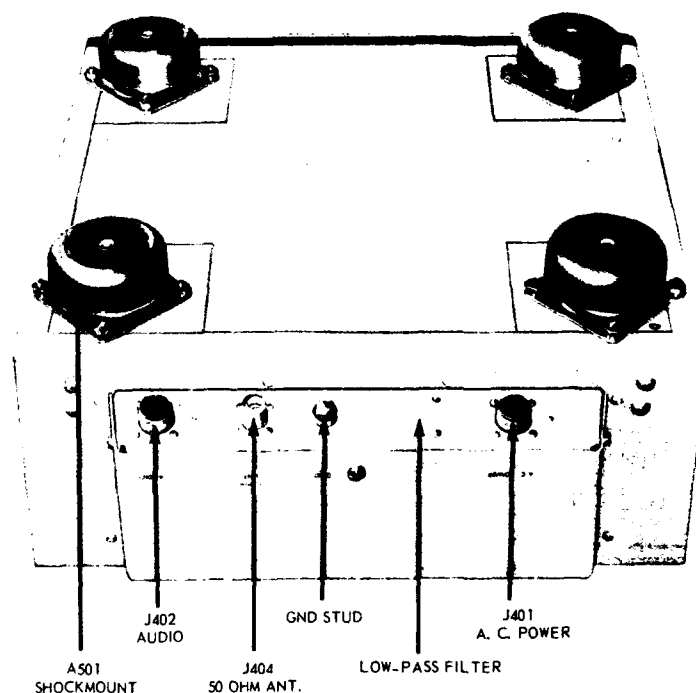


Figure 5-12.—Low-pass filter used with the AN/URR-35 radio receiver.

The schematic diagram of this filter is shown in figure 5-13. The filter allows the necessary connections into and out of the rear of the receiver, but eliminates unwanted signals from passing through the lines. There are three main circuits through the filter: the antenna lead, the a-c power lead, and the audio output lead.

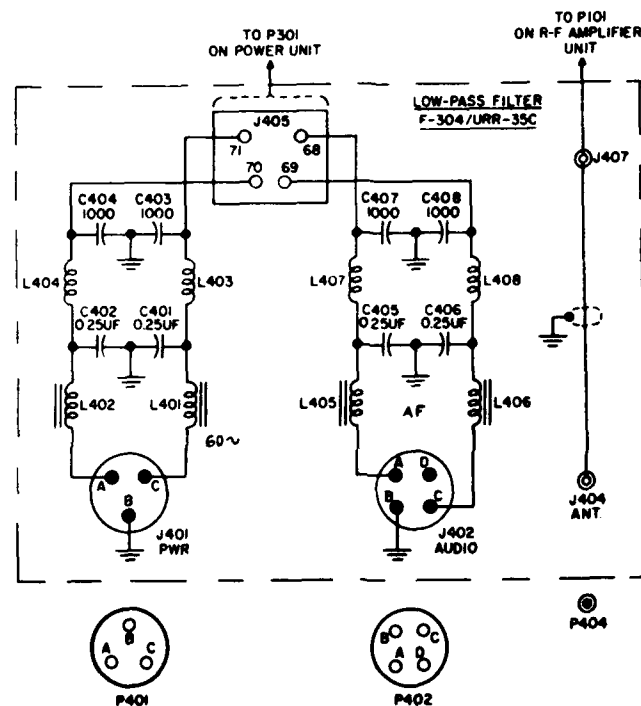


Figure 5-13.—Schematic diagram of the low-pass filter used with the AN/URR-35 radio receiver.

R-f signals from an antenna are brought through a coaxial lead and connected to the antenna jack. They pass through the low-pass filter to the r-f amplifier unit.

Power for the receiver is connected to the power jack. The two-section, r-f filter eliminates any r-f energy that may tend to come in through the power lines. After passing through the filter, the power is fed to the receiver through terminals 70 and 71.

The audio signal from the receiver output transformer is connected through terminals 68 and 69 to the low-pass filter. The audio signals then pass through the two-section filter to the audio output (to speakers, etc). The filter allows the audio signals to pass through, but prevents any feeding back of r-f signals through the audio lines from outside the receiver.

Antenna filter assemblies "multicouplers" are being used more and more in shipboard electronic installations. Both high- and low-pass filters are used in the antenna leads to separate the frequencies and to pass them to the appropriate receiver or receivers. See figure 9-25, chapter 9 of this training course, and the accompanying text.

EQUIPMENT INSTALLATION

The location of units of electronic equipment is normally governed by an installation plan. The installation is planned to ensure maximum efficiency of the electronic system as a whole—within the limitations imposed by a particular vessel.

The work of the ET is made easier when there is sufficient space to remove panels or chassis for adjustments and maintenance, and the electronic equipment spaces are well ventilated.

Equipments are installed on foundations or racks that are attached to the deck or bulkhead or a combination of both. Often it is necessary to make additional provisions for shock mounting the equipment. Adequate grounding should be made to the ship's structure according to the latest BuShips instruction.

Equipment Foundations and Racks

Foundations and racks are constructed from appropriate metal shapes, and they are generally of all-welded construction. A rack using a combination of deck and bulkhead for support is illustrated in figure 5-14, A. A deck foundation is illustrated in part B.

Bulkheads that are inadequately stiffened or subjected to direct stresses and shocks caused by gun blasts, explosions, etc, are not normally used to support electronic equipment containing vacuum tubes, relays, and geared mechanisms. Under these conditions these units are generally deck mounted or installed on suitable deck-mounted racks.

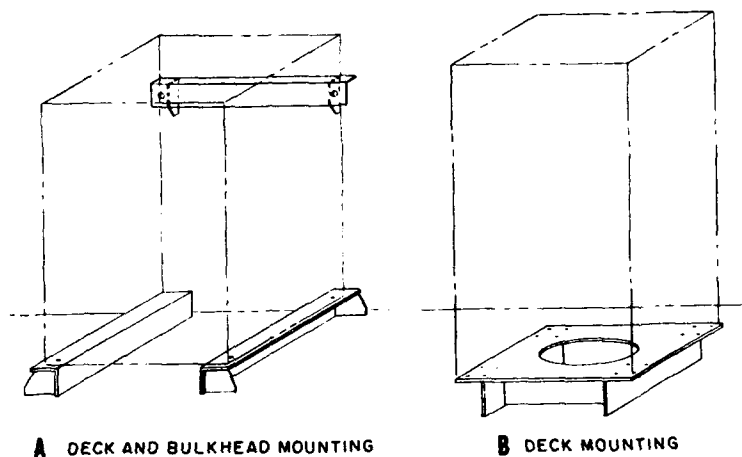


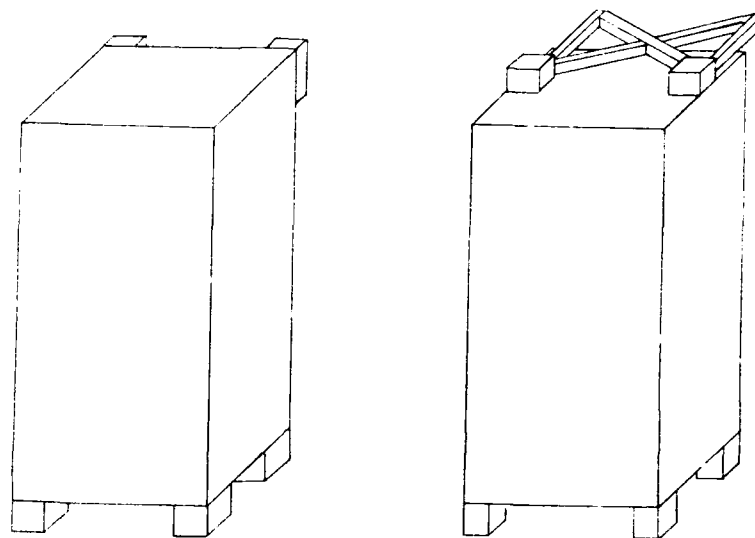
Figure 5-14.—Deck and bulkhead foundations.

Adequate equipment-to-bulkhead clearance is necessary on all deck-mounted electronic equipment to provide space for shock-mount movement, ventilation, and servicing.

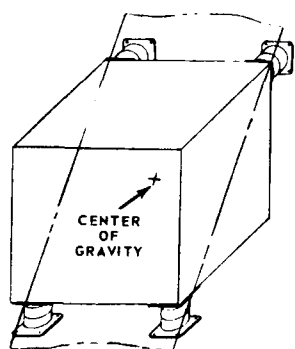
Tall and heavy units normally require that top foundations be used in addition to the regular deck foundations. Typical installations are shown in figure 5-15, A. A center-of-gravity mounting has four mounting points at diagonally opposite corners, and the plane of these points passes through or near the center of gravity of the unit, as illustrated in part B. When the equipment is low, a four-point bottom mounting (part C) may be adequate.

Shock Mounts

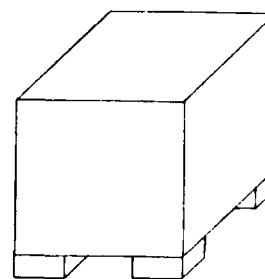
Shock mounts are used to protect equipment from the severe shock encountered in naval shipboard service. Most equipments are supplied with shock mounts by the manufacturer of the equipment, if required. There are several types of rubber shock mounts, but they all serve essentially the same function.



A TALL OR HEAVY UNITS



B CENTER-OF-GRAVITY MOUNTING



C FOUR-POINT BOTTOM MOUNTING

Figure 5-15.—Typical installations.

One type of shock mount, showing the method of grounding the equipment, is illustrated in figure 5-16.

In addition to the clearances required for the equipment, a clearance for the mount itself must be taken into consideration. The clearance in the direction perpendicular to the bolt axis should be at least equal to the thickness of the wall of rubber contained in the mount. All around the equipment sufficient clearances must be maintained so that motions due to shock do not cause the equipment to strike adjacent structures.

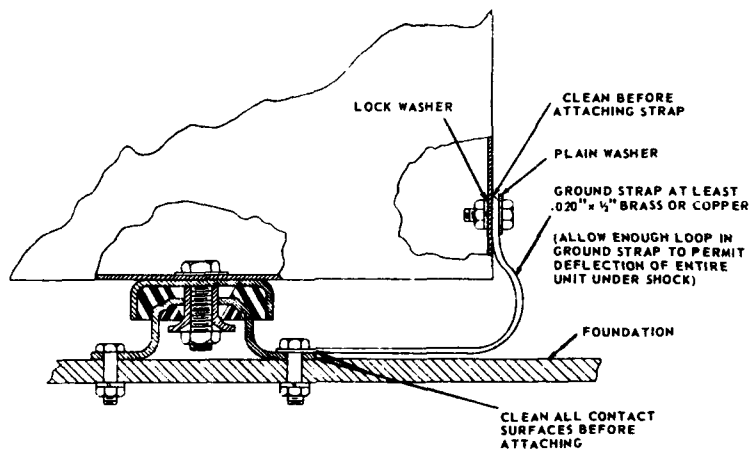


Figure 5-16.—Shock mount and method of grounding the equipment.

All units of electronic equipment whose d-c resistance from case to ground exceeds 0.01 ohm must be grounded by the use of straps as prescribed. A method of grounding the equipment is illustrated in figure 5-16.

Electronic Equipment

A RADAR installation usually includes a transmitter-receiver unit, radar modulator, master indicator, antenna, radar set control, power supply, and associated cables and waveguides. One or more repeaters may be

added to this installation; switching systems are also a part of the over-all installation.

A typical radar installation is treated in chapter 14 of this training course (fig. 14-1).

RADIO RECEIVERS and TRANSMITTERS may be widely separated throughout the ship. The greater number, however, will be concentrated in Radio 1 (Radio Central). Some idea of the arrangement of radio equipment (including teletype) in Radio 2 and Radio 3 may be obtained from figure 9-19 in chapter 9 of this training course; and from figure 5-22, included later in this chapter under antenna distribution systems. Chapter 12 includes a description of typical radio transmitters and receivers (see for example, figures 12-1 and 12-13).

SONAR installations usually consist of a transducer, transmitter-receiver, video and audio scanning switch assembly, indicator control, indicators, and possibly loudspeakers. The relationship of the various components is given in chapter 14 of this training course (fig. 14-7).

Most RADIAC EQUIPMENT (survey meters and dosimeters) are portable and are therefore not installed as other electronic equipments are installed. Certain monitoring equipment (for example, water and air monitors) may be installed at strategic locations.

Radiac equipment is discussed in chapter 11 of this training course.

The Grounding of Electronic Equipment

The proper grounding of electronic equipment is one of the most important steps in the installation procedure. Even during routine checks, tests should be made to ensure that all equipment is properly grounded. The following information is quoted from NavShips 900,171.

"All units of electronic equipment whose d-c resistance from case to ground exceeds 0.01 ohm (10 milliohms) shall be grounded by the use of straps as follows:

1. On units requiring sound isolation, the straps shall be copper braid, not less than $\frac{1}{2}$ of an inch wide.

2. On other units, the strap shall be not less than 0.020 inch thick by $\frac{1}{2}$ of an inch wide, sheet copper or brass.

3. The surface at the point of attachment of the straps shall be thoroughly cleaned to ensure metal-to-metal contact.

4. The straps shall be as short as possible with only enough loop allowed to permit satisfactory deflection of shock or isolation mounts.

5. The strap connections shall be locked to prevent loosening from vibration.

6. Only one strap wire is required for each unit unless tests indicate more are needed."

The proper grounding procedure is equally as important for shielded cables and other components as it is for electronic equipment.

RIGID R-F TRANSMISSION LINES

Construction

Rigid r-f transmission lines include waveguides (rigid and flexible), bead-supported coax (teflon and steatite), stub-supported coax, and pyrotenax cable.

Rigid waveguides may be round or rectangular in shape; however, the use of round waveguides is limited to special applications, such as rotating joints. Rectangular waveguides are widely used in radar applications.

Waveguides are generally designated by size; and table 11 lists some of the more common sizes.

Flexible waveguides have greater power loss than rigid waveguides, and therefore the flexible type is seldom used except where there is considerable vibration.

Bead-supported coax was used on early radar equipment installations and is still necessary in certain types of installations.

Stub supported coax was more widely used on early radar equipment installations; and short runs are still

TABLE 11
COMMONLY USED SIZES OF RIGID WAVEGUIDE

Size (inches)	Radar Band	Frequency Band
6½ x 3¼	L	UHF
3 x 1½	S	UHF/SHF
1¼ x ⅝	X	SHF
1 x ½	X (small)	SHF
⅝ x ⅝ ₁₆	K	SHF/EHF

found in late equipments, usually within the antenna pedestal.

Pyrotenax coax r-f cables have a solid copper inner conductor, a seamless copper outer conductor, and a tightly packed powdered magnesium oxide dielectric. They are fireproof and pressure proof, and are designed for installations where these properties are important.

The proper type and size of waveguide is determined by the equipment designer, and no change is made without the approval of the Bureau of Ships.

Installation

Many factors are considered when a waveguide is installed. However, two of the most important considerations are: (1) the range of the equipment depends on the height of the antenna and (2) a great deal of energy is lost when the length of the waveguide is increased by a small amount (over one-half of the power may be lost in a 50-ft run).

The method of installation is equally important. For example, sharp bends, dents, and foreign materials in the guide will cause serious attenuation of the signal (see chapter 11 of NavShips 900,171).

From these considerations it may be seen that there is an optimum height beyond which additional waveguide length will defeat its own purpose.

Figure 5-17 shows the r-f transmission line used with Radar Set AN/SPS-8A.

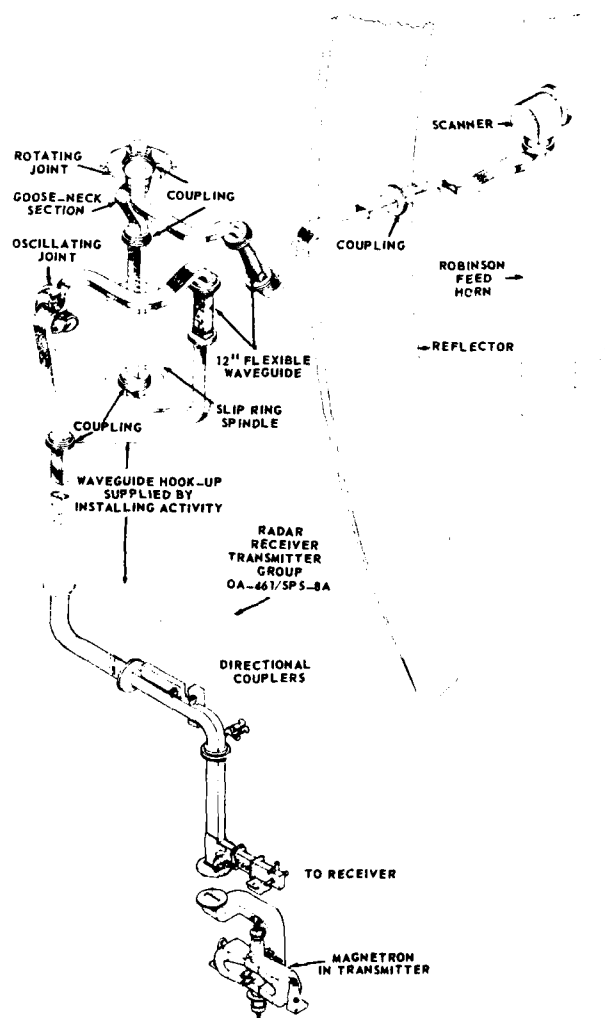


Figure 5-17.—R-f transmission line.

FLEXIBLE R-F TRANSMISSION LINES

Construction

Flexible radio-frequency transmission lines (coax) are two conductor cables, one conductor of which is concentrically contained within the other, as illustrated in figure 5-18. Both conductors are essential for efficient operation of the transmission line. Of course, the proper connectors and terminations are also necessary for efficient operation of the line.

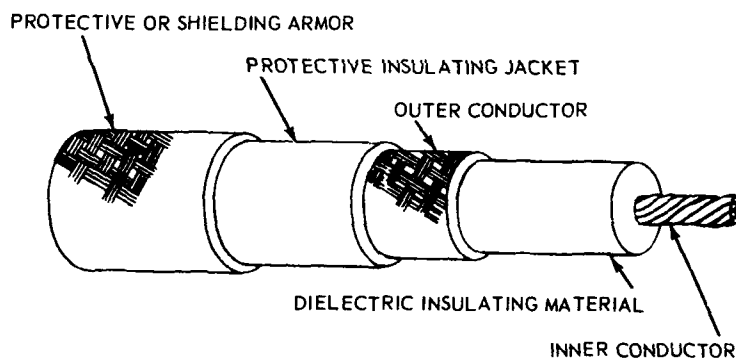


Figure 5-18.—Construction of flexible r-f transmission line.

The inner conductor may be either solid or stranded and may be made of unplated copper, tinned copper, or silver-plated copper. Special alloys may be used for special cables.

The dielectric insulating material is usually polyethylene or teflon, although neoprene or other rubber-like materials are occasionally used for pulse cables. (Pulse cables carry d-c pulses that may have relatively high voltages during a relatively short pulse time).

Braided copper is usually used for the outer conductor; it may be tinned, silver plated or bare. The outer conductor is chosen to give the best electrical qualities consistent with maximum flexibility.

The protective insulating jacket is usually a synthetic plastic material (vinyl resin). Neoprene rubber is generally used on pulse cable; silicone rubber jackets are being used for high-temperature applications.

A armor is needed for protection. It may be braided aluminum or sometimes galvanized steel, similar to that used on power cables.

R-f cables may look like power cables, but they require special handling and careful installation. These cables are vital to the proper operation of all electronic equipment and therefore must be installed and maintained with the greatest care.

Classification by Dielectric

The three common types of dielectric are polyethylene, teflon, and synthetic rubber.

Polyethylene is a gray, translucent material. Although it is tough under general usage, it will flow when sub-

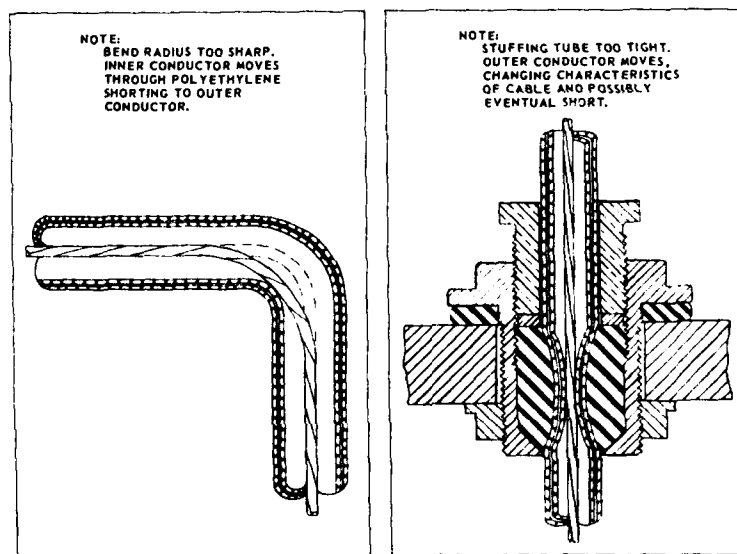


Figure 5-19.—Effects of bad installations.

jected to heavy pressure for a period of time. Two possible effects of bad installations are illustrated in figure 5-19.

Teflon is a white opaque plastic material. This material will withstand high temperatures and will remain flexible at relatively low temperatures. It has a peculiar quality in that nothing will stick to it and it is unaffected by the usual solvents.

Synthetic rubber (neoprene) is black and very flexible. It has high power loss at high frequencies and therefore is not used in cables carrying r-f energy. However, it is used for transmitting high-voltage d-c pulses. Because of its flexibility and ability to "stick" to metals, it forms very tightly around the conductors and minimizes corona (high-voltage breakdown of the air surrounding a conductor).

Location and Length of Cable Runs

When possible, cables are run along different well separated paths to reduce the probability of battle damage to several cables simultaneously. Wherever possible, high-temperature locations are avoided. Pulse cables are run separately, when possible, to reduce coupling and interference.

Because attenuation (power loss) in a line increases with its length, cables are kept as short as practicable, consistent with avoiding high-temperature locations, sharp bends, and strain on the cable. (See chapter 10 of NavShips 900,171 for additional information.)

If the equipment is shock mounted, enough slack in the cable is allowed to permit unrestricted motion of the equipment. The cable may be wrapped with friction tape for a distance of three or four inches from a point under the last cable clamp in the direction of the equipment. This eases the bending of the cable at that point and reduces the possibility of cable deformation because of constant vibration.

When cables are connected to equipment that slides out for maintenance, extra slack is provided.

Installing the Cables

Flexible cables are flexible only in the sense that they will assume a relatively long bend radius. They are not intended to be stretched, compressed, or twisted; and they are installed with this in mind. Bends are made as large as practicable, the radius of the bend being greater than 10 times the diameter of the cable.

The number of connectors are generally kept to a minimum to reduce line losses and maintenance problems.

Fabricated straps are used for holding the cables. They are snug, but not too tight. Back straps (which keep the cable away from a surface) are used in making cable runs along masts or in compartments that are subject to sweating. In more recent installations semicon-tour straps and cable bands are used for certain applications.

The exact methods of installing cables are included in Chapter 9 of the *Electronics Installation Practices Manual*, NavShips 900,171.

Although the installation of r-f cables is not the primary duty of an ET, he nevertheless has to live with and depend on them all of the time. Therefore he should have some knowledge of good installation practices. Some important points to remember are: (1) do not change the physical dimensions of a cable because this will change the electrical property; (2) remember that a damaged insulating jacket may allow water into the cable and cause a short at the connector; (3) avoid putting a strain on a cable (for example, pull on the plug, not on the cable), and (4) avoid exposing the cable to abrasion by the use of the necessary grommets, sleeving, tape, etc.

Splicing cables and installing fittings require special skill. Instructions are given in Chapter 10 of *Electronic Installation Practices Manual*, NavShips 900,171.

MOTOR-GENERATORS AND AMPLIDYNES

Motor-Generator Sets

Motor-generator sets are used to change an available type of power to a desired type of power. The change may be from d-c to a-c, a-c to d-c, from one frequency to another, one voltage to another, or a combination of these.

Each motor-generator set consists of a driving motor and one, or sometimes two, generators. A coupling is provided to connect the motor and the generator mechanically together. In most motor-generator sets the stationary components of all the machines are rigidly coupled together on a mounting bed to maintain proper alignment.

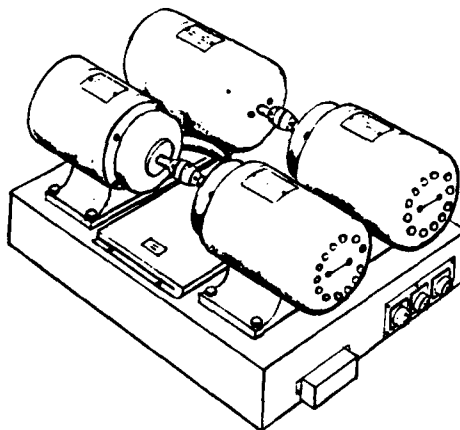


Figure 5-20.—A typical motor-generator set for electronic equipment.

In electronic applications, the motor-generator sets (when used) are usually designed to supply power to one particular equipment. A typical motor-generator set is shown in figure 5-20.

The Amplidyne

The theory of operation and the practical applications of amplidyne generators are treated in Chapter 17 of *Basic Electronics*, NavPers 10087.

One example of the installation of amplidyne generators (motor-generators) is shown in figure 5-21. This set of motor-generators is used with Radar Set AN/SPS-8.

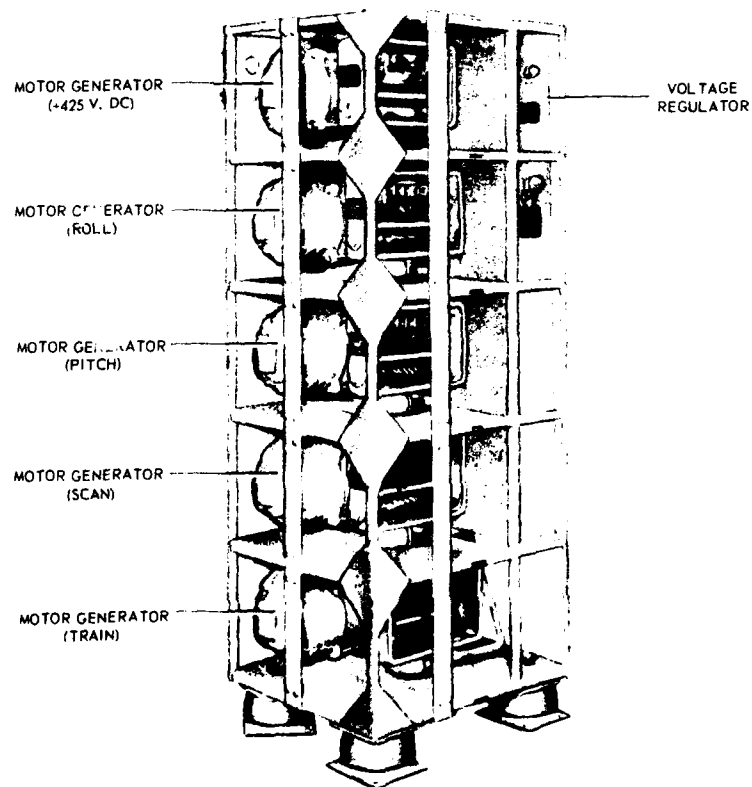


Figure 5-21.—Motor-generator (amplidyne) group used with the AN/SPS-8 radar.

Each of the five amplidyne motor generators weighs about 160 pounds. They are supplied with 450-volt, three-phase current. The top generator produces the 425-volt, d-c (B+) needed by the equipment; the others provide 250-volt, d-c power for the roll, pitch, scan, and train motors.

POWER SYSTEM FOR ELECTRONIC EQUIPMENT

The power distribution system connects the generators of electric power to the equipments that use it. Built into the system are devices that protect the generators, the equipments that use the power, and the system itself from certain types of damage.

A comprehensive distribution system includes the following:

1. SHIP'S SERVICE DISTRIBUTION SYSTEM includes the ship's service generators and the ship's service distribution system. It is the normal source of electric power.
2. EMERGENCY DISTRIBUTION SYSTEM includes at least one emergency generator and the emergency distribution system. An emergency system is installed on most vessels to supply a limited amount of power for the operation of vital equipment when the ship's service system is incapacitated.
3. CASUALTY POWER DISTRIBUTION SYSTEM is installed on many vessels to make temporary electrical connections if both the ship's service and the emergency distribution systems are damaged.

At least two independent sources of power are provided for selected vital loads (for example, steering, I. C. and F. C. switchboards, and turrets). This is done by means of a normal and an alternate ship's service feeder; or a normal ship's service feeder and an emergency feeder; or, in some cases, both normal and alternate ship's service feeders plus an emergency feeder.

Normal and alternate feeders run from different ship's service switchboards and are spaced as far apart as

feasible to minimize the possibility that both will be damaged by a single hit.

ANTENNA SYSTEMS

One of the most important functions performed aboard ship is that of communicating with other ships or stations; and one of the most important links in a communication chain is the antenna system. The following paragraphs are included to give the prospective ET 3 information about shipboard antennas and antenna transmission lines.

Wire Antennas

The whip and dipole antenna assemblies are displacing the wire antenna for shipboard installations. However, the wire antenna is still used on some installations and is often used as an emergency antenna.

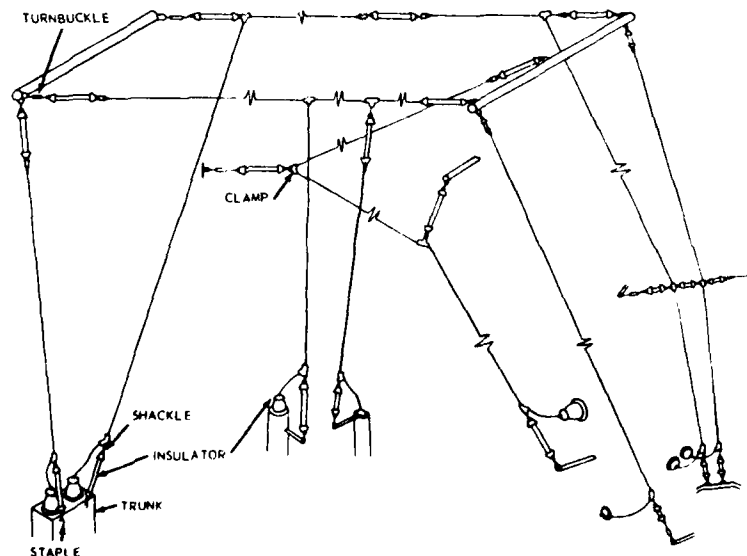


Figure 5-22.—Typical wire antenna installation.

Antenna wire is usually a stranded, bare, phosphor or silicon-bronze wire. For transmitting, a $\frac{5}{16}$ -inch diameter wire is commonly used; and a $\frac{1}{8}$ -inch diameter wire is commonly used for receiving. The wire is continuous from the entrance insulator to the far end. Good installation practice requires that it be free from splices, kinks, sharp bends, deformed spots, and broken strands. The length, of course, depends on the frequency that is being transmitted, the space that is available, and other considerations.

In addition to the necessary wire, an antenna installation requires such items as supporting insulators, turnbuckles, clamps, shackles, safety links, staples, and pad eyes.

A typical wire antenna installation is illustrated in figure 5-22. The methods of installing antennas are included in Chapter 2 of *Shipboard Antenna Details*, NavShips 900121(A).

Whip Antennas

Whip antennas give a neater topside appearance to naval vessels, and on carriers they are a practical necessity. Because whip antennas are essentially self-supporting, they may be installed in many locations aboard ship. They may be deck mounted or mounted on brackets on the stacks, superstructure, etc. If the stack is used, the outer casing will usually have to be reinforced to support the added weight and stress. When the whip antenna is installed on a stack, it is usually mounted near the top and approximately 24 inches away from the stack. In all installations of whip antennas, allowance is made for swaying of the whip. The whip is mounted in a clear space where it cannot strike other objects.

Whip antennas that are used for receiving only are mounted away from the transmitting antennas so that a minimum of energy from the transmitter will be picked up.

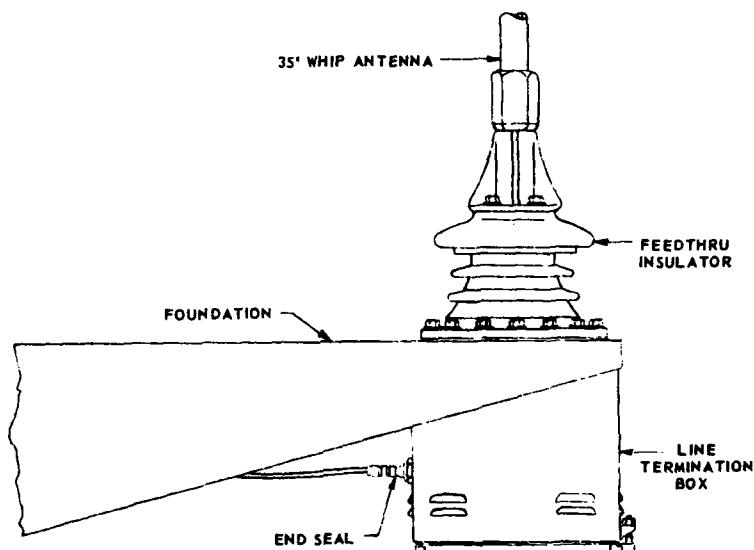


Figure 5-23.—Method of mounting a whip antenna.

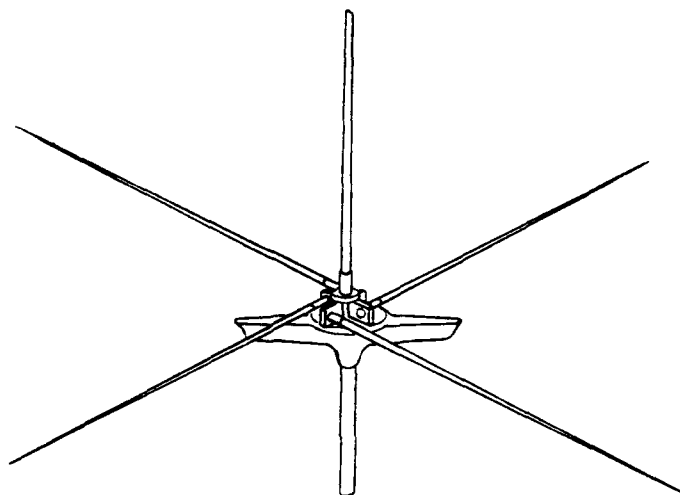
The preferred method of mounting whip antennas on shipboard is shown in figure 5-23.

VHF and UHF Antennas

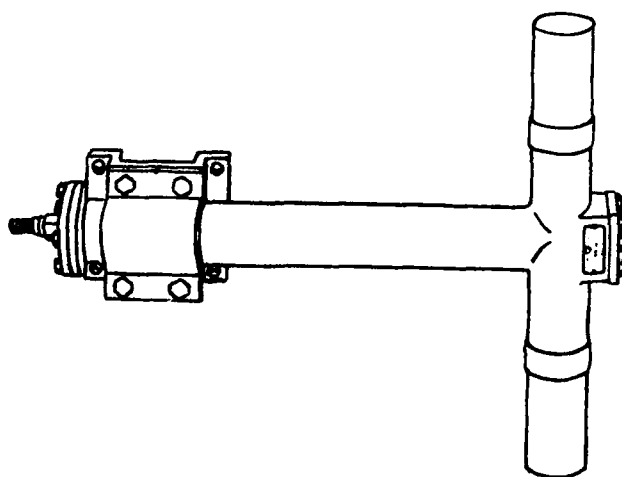
The physical size of antenna elements becomes smaller as the frequency increases. Antennas that operate in the VHF (30-300 mc) and UHF (300-3000 mc) frequency ranges are relatively small in size. Because line-of-sight communication is used in the VHF-UHF ranges, high power is not necessary. Receiver signal strength then depends upon antenna height and the distance from the transmitter.

In these frequency ranges, it is important that both the transmitting and receiving antennas have the same polarization. The Navy employs vertical polarization in the VHF-UHF ranges.

Vertical conductors such as masts, rigging, and cables in the vicinity of UHF antennas will cause unwanted



A VHF ANTENNA



B UHF ANTENNA

Figure 5-24.—Types of VHF and UHF shipboard antennas.

directivity. For this reason, these antennas are mounted as high and as much in the clear as possible.

Figure 5-24 shows two types of shipboard antennas operating in the VHF-UHF frequency range. Usually, either a vertical quarter-wave stub with a ground plane (part A) or a vertical half-wave dipole (part B) is used. The ground plane prevents the metallic support mast from acting as a radiating portion of the antenna. It establishes the ground level at the base of the antenna.

Microwave Antennas

Parabolic-shaped reflectors are generally used to direct microwaves in the desired direction and in the required pattern.

Figure 5-25 illustrates that the energy from a radiating element placed at the focal point of a parabolic reflecting surface will be reflected into a narrow beam.

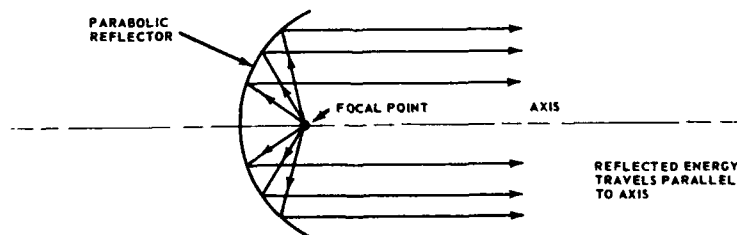


Figure 5-25.—Principle of parabolic reflection.

Two types of parabolic reflectors used for microwave operation are shown in figures 5-26 and 5-27. (Other types—for example, the parabolic cylinder and the paraboloid—are used in aircraft; the paraboloid is also used aboard ship in fire-control radars.) These reflectors are usually fabricated from solid metal plate or metal screening. In many instances (practically always aboard ship) these reflectors are placed on rotatable mounts.

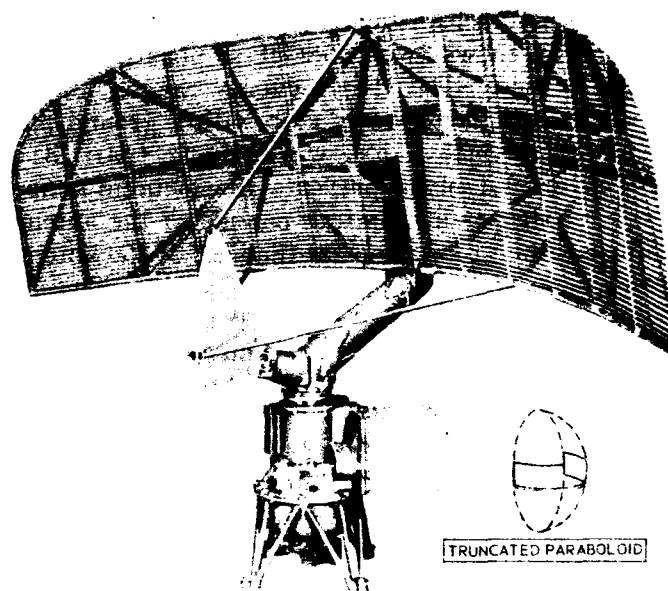


Figure 5-26.—Typical antenna installation utilizing the truncated paraboloid.

The transmission lines used at microwave frequencies are coaxial lines or waveguides, and either a front- or a rear-feed system is used. In a front-feed system the waveguide or coaxial line approaches the reflector from the front and directs the spray of r-f energy into the reflector. In a rear-feed system the coaxial line or waveguide projects through the reflector from the rear, and an additional parasitic reflector is placed in front of the radiating element to direct the energy back toward the parabolic reflector.

Receiving Antenna Distribution System

One type of receiving antenna distribution system for small vessels is shown in figure 5-28. However, the use of standard antenna transfer panels (or, more recently, antenna filter assemblies) is preferred. An antenna

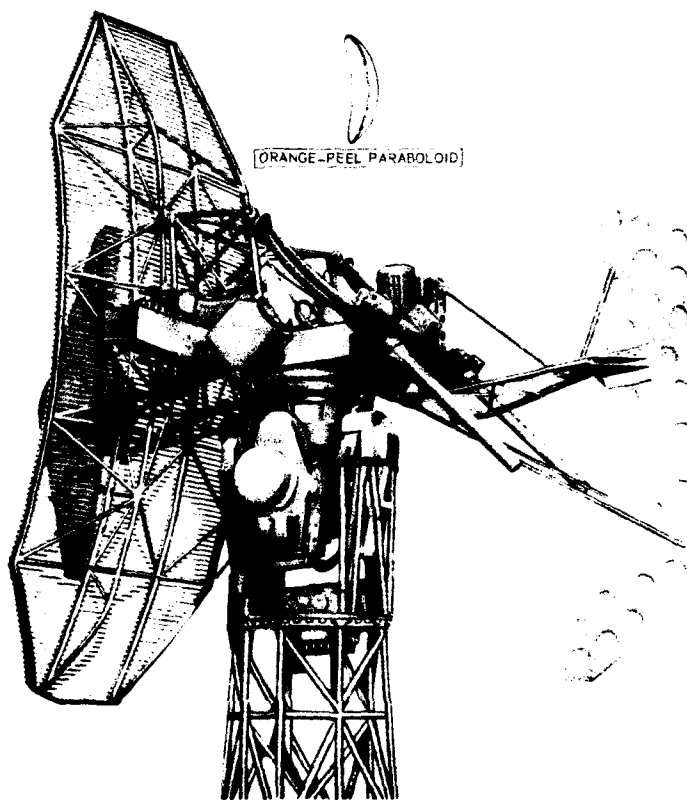


Figure 5-27.—Typical antenna installation utilizing the orange-peel paraboloid.

transfer panel is shown in figure 5-29, A; a filter system is shown in part B of the same figure.

All terminal boxes comprising the antenna transfer assembly (fig. 5-28) are mounted within a 30-inch diameter circle to permit the use of standard 36-inch patch cords. The assembly is mounted on a vertical bulkhead and in a position convenient to operating and servicing personnel.

The lines running to the individual receivers connect directly to the input connector on the receiver. In older

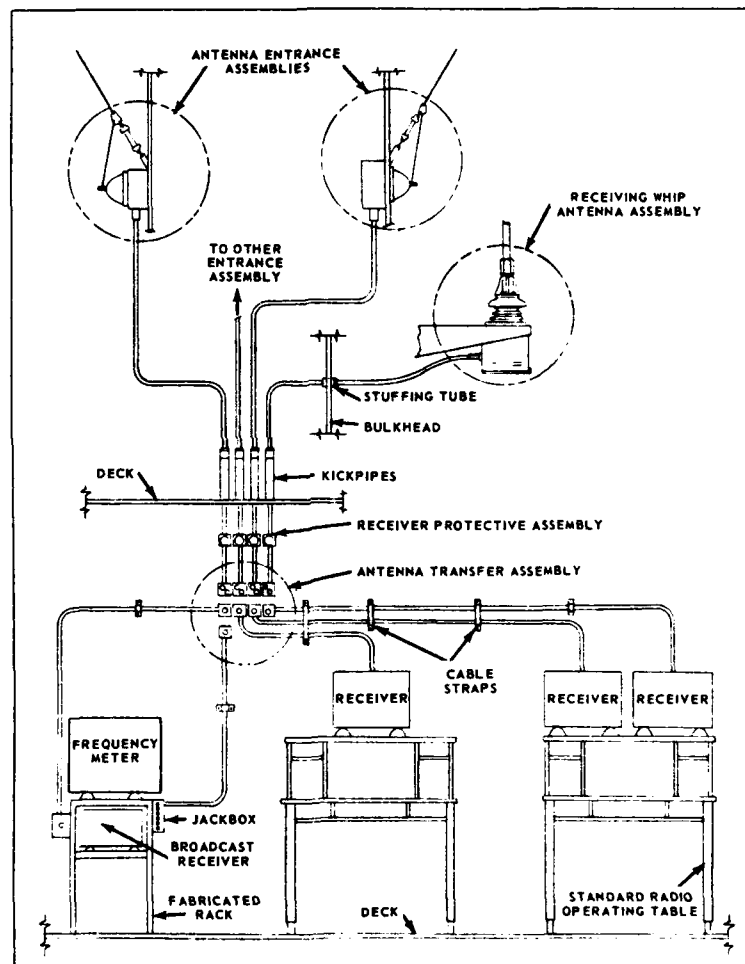


Figure 5-28.—Receiving antenna distribution system (using terminal boxes).

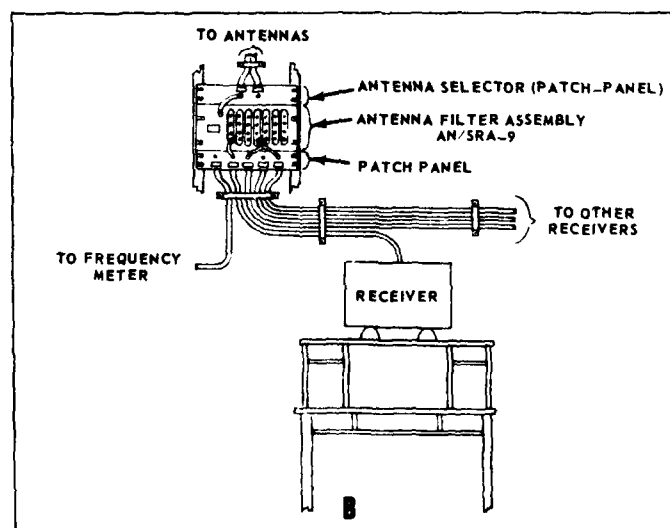
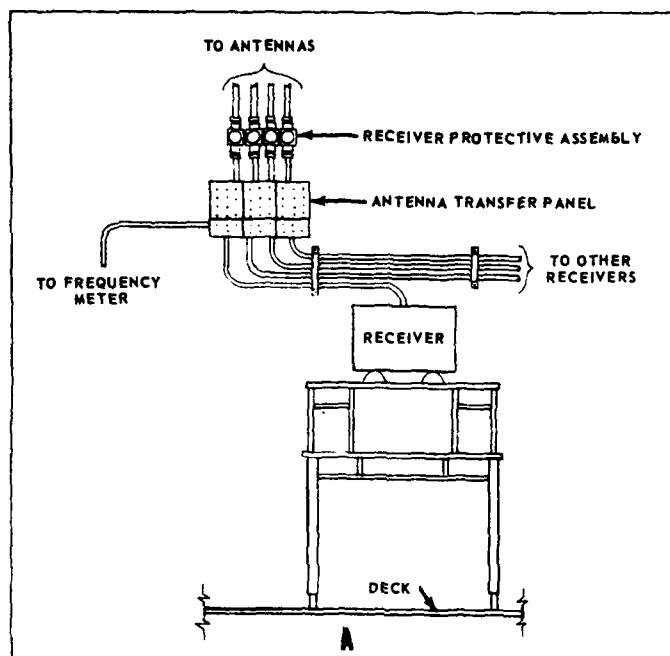


Fig 5-29.—Receiving antenna distribution systems (using transfer panel and filter assembly).

systems the lines terminated in jack boxes behind each receiver, and a patch cord was used to complete the connection to the receiver.

Receiving antenna transmission lines aboard ship are usually terminated in antenna transfer panels in the respective radio spaces. These transfer panels are interconnected so that a receiver in any radio space may be connected to any receiving antenna, regardless of its topside location.

There are five standard receiving antenna transfer panel used in shipboard installations. They are Navy types 23404, 23405, 23406, 23407 and SB 346/S. These transfer panels are the same structurally; they differ in the number of antennas and receivers that they can accommodate.

These transfer panels provide means for operating as many as four radio receivers simultaneously into one antenna. At the transfer panel, each antenna is connected to a row of four jacks. One jack is connected directly to the antenna; the other three jacks are connected in parallel through 600-ohm decoupling resistors. The receivers connected to the three decoupled jacks will operate at a reduced efficiency. More details about these panels are given in chapter 9 of this training course.

Transmitting Antennas and Trunkline Assemblies

In general, radio transmitting and receiving antennas are similar (fig. 5-22) except that in the case of transmitting antennas much larger amounts of r-f power are handled. Because transmitting antennas present a hazard to personnel, the transmitting antenna installation is planned with the safety of the personnel in mind. For the proper safety precautions to be taken when work is done on antennas or transmission lines, see chapter 2 of this training course. See also *United States Navy Safety Precautions*, OpNav 34P1, and chapter 67 of *Bureau of Ship's Manual*. For additional information,

see *general Installation Specifications For Shipboard Radio Transmitting Antenna Systems*, RE 66A430.

In shipboard radio transmitting systems, both open-wire and whip antennas are used. The transmission line for the antenna consists of a copper bus enclosed in an antenna trunk. Trunks are used with high-power transmitters. Coaxial cable may also be used for the transmission line between the transmitter and its antenna.

It is necessary to minimize the power losses in the transmission line if most of the power from the transmitter is to be radiated from the antenna. Matched impedances are maintained as closely as practicable in the antenna system to avoid high voltage-standing-wave ratios. In general, all r-f transmission lines should be as short as possible.

A transmitting wire antenna trunkline assembly is illustrated in figure 5-30. The purpose of the trunk is to carry energy from the transmitter to the wire antenna with minimum loss, minimum interference, and maximum safety.

The disconnect switch (fig. 5-31) has three positions: GROUND, CLOSED, and OPEN. The switch has a shield, or blanking-off plate, which is inserted into the trunk section of the switch between the switch mechanism and the bus leading to the transmitter. An interlock prevents the shield from being inserted into the slide except when the switch is in the GROUND position. This prevents closing the switch again before the shield has been removed.

In the OPEN position, the antenna is disconnected from the transmitter; in the CLOSED position, the antenna is connected to the transmitter; and in the GROUNDED position, the antenna is grounded through the antenna bus at the disconnect switch.

Other antenna switches (for example, the NT-2406 and the NT-24223) have only two positions: CLOSED and GROUNDED. In the CLOSED position, the antenna is

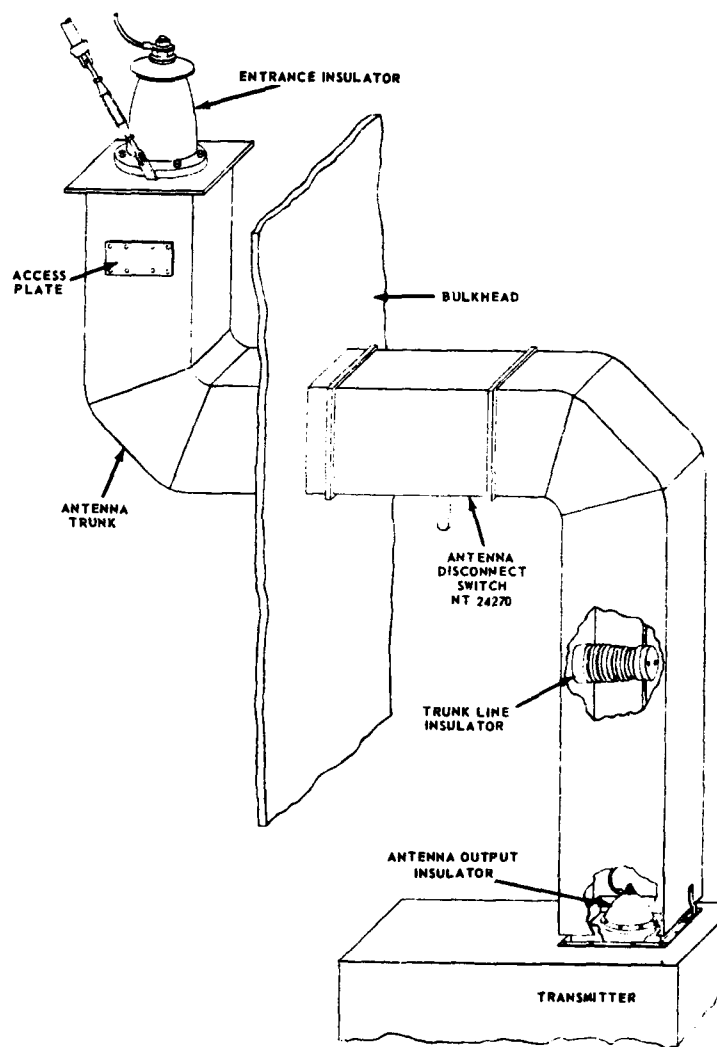


Figure 5-30.—Transmitting wire antenna trunkline assembly.

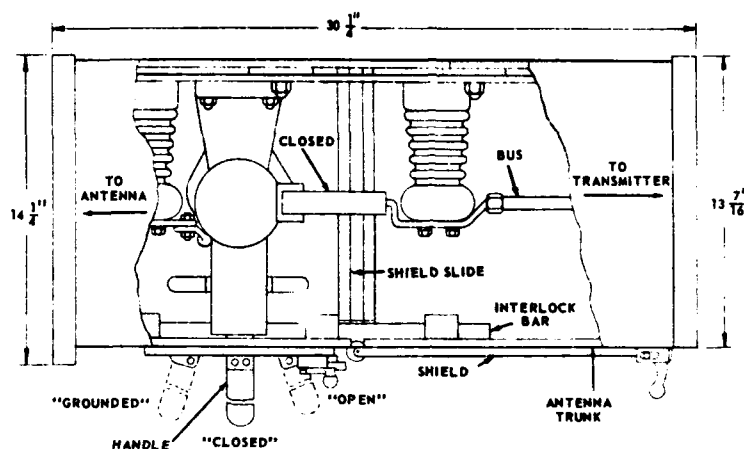


Figure 5-31.—NT-24270 antenna disconnect switch.

connected to the transmitter; in the OPEN position, the antenna is grounded.

MULTICOUPLERS

Because of the increasing number of communications equipments required aboard naval vessels, it has become difficult to find suitable locations for the necessary additional antennas. One approach to the problem has been the use of multicouplers. These devices permit the simultaneous operation of a number of transmitters and/or receivers into a single antenna. Thus, the number of antennas can be reduced without sacrificing any of the required communications channels. This arrangement permits maximum use of the best available antenna locations and reduces the intercoupling between antennas.

Much research and development is being done on multicouplers, and various types have been designed to cover different frequency ranges and to operate with either receivers or transmitters or both. Filter-type multicouplers are described in detail in chapter 9 of this training course. The information on multicouplers given

in this section is of a general nature. Improvements are continually being made by the Bureau of Ships, and the equipments described will eventually become obsolete. This is essentially true of all electronic equipment.

VHF-UHF Multicouplers

One type of VHF-UHF multicoupler (the CU-255/UR) is shown in figure 5-32. When six units are used (as shown), a system is provided for operating six transmitters (and/or receivers) into a single antenna. One coupler is required for each transmitter or receiver, or transmitter-receiver combination. The frequency range of this particular equipment is 230 to 390 mc.

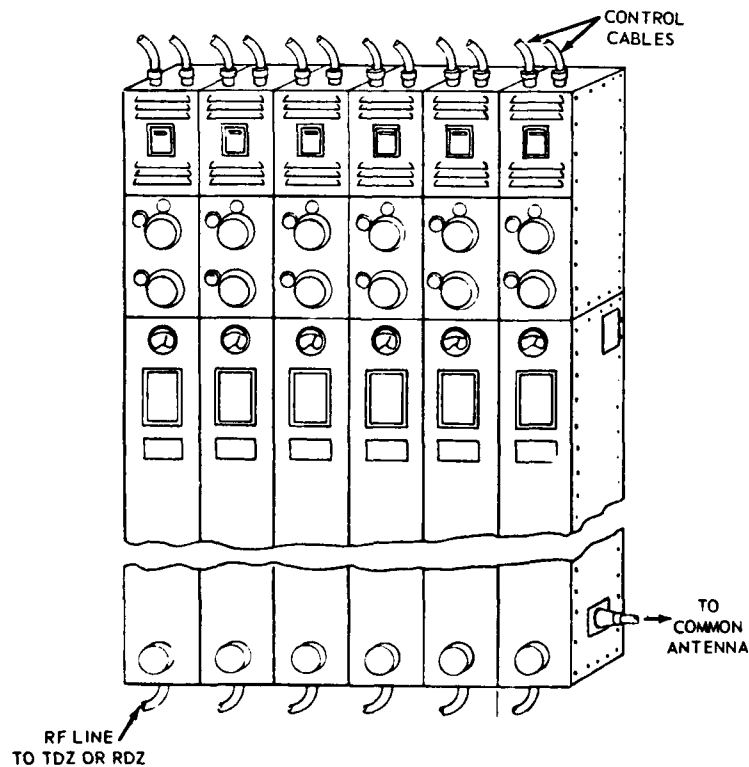


Figure 5-32.—VHF-UHF multicoupler (the CU-255/UR).

These couplers can be tuned manually to any frequency in this range. When used with the TDZ/RDZ equipment (which in many cases have been replaced by other equipment), they may be tuned automatically to any one of 10 preset channels in this band by dialing the desired channel locally on the TDZ or on a remote channel selector.

This coupler consists of two major components: the coupling cavity, or r-f section, and the automatic-drive mechanism.

The r-f section is essentially an impedance-matching device. It is capable of transforming antenna loads ranging from 50 to 125 ohms into 50 ohms at the r-f feedline terminal. This results in maximum power transfer to or from the antenna system. (The theory of operation of these devices is included in the training course, *Electronics Technician 1 and C*, NavPers 10192.)

Correct adjustment of the tuning controls is indicated by the meter on the front panel of the unit. This meter indicates the output from the reflectometer, which is a device for indicating the magnitude of the power reflected back from the coupling circuit. When the controls are adjusted so that the tuning indicator reads zero, the system impedances are properly matched and there is minimum reflected power in the system.

This multicoupler is designed to be mounted vertically on a bulkhead or other solid support on small ships. Space limitations, however, may dictate other arrangements. In some cases, the couplers may be mounted horizontally overhead. However, this position is inconvenient from the point of view of tuning.

A typical TED-AN/URR-13 installation employing multicouplers (CU-332A/UR) is illustrated in figure 5-33. One coupler unit is required for each transmitter or receiver, or transmitter-receiver combination.

The CU-332A/UR multicoupler is identical to the CU-255/UR multicoupler previously described except for the drive mechanism. The CU-332A/UR provides for

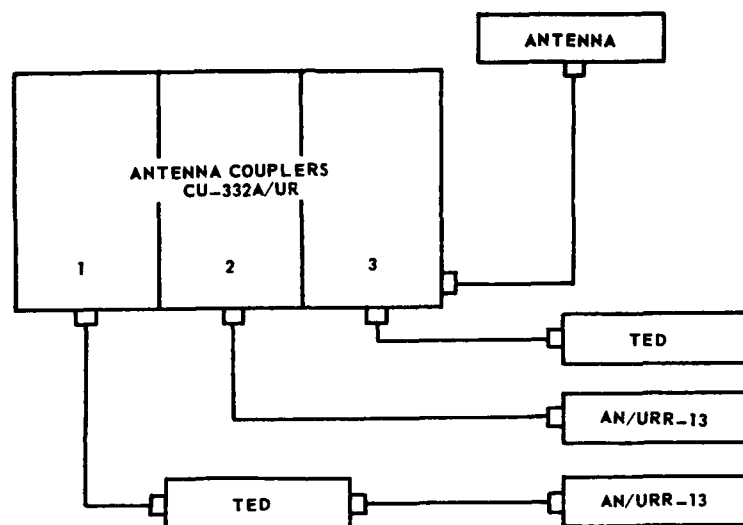


Figure 5-33.—TED-AN/URR-13 installation employing a multicoupler.

manual tuning only; whereas, the other has both automatic and manual tuning.

The CU-332A/UR coupler is used with manually tuned UHF equipment, such as the Model TED transmitter and the AN/URR-13 receiver, or any other manually tuned equipment operating in the 230- to 390-mc frequency range.

HF Multicouplers

A system of h-f antenna couplers has been developed for simultaneously operating up to four transmitters into the same antenna in the frequency range of 2 to 26 mc. These antenna couplers are made up into four channel groups, each group operating in one of the following bands: 2-6 mc, 4-12 mc, 6-18 mc, and 9-26 mc. To obtain complete coverage from 2 to 26 mc, four coupler groups and four broad-band antennas are required. These experimental equipments were designed for installation on the USS Northampton (CLC-1). They are

included here only to illustrate the trend toward multicouplers in the h-f region.

The four types of h-f couplers are the AN/SRA-13, 14, 15 and 16. The AN/SRA-15 coupler, which is typical of this group of couplers, provides for the simultaneous operation of four transmitting equipments (each with 500 watts output) into a single broad-band antenna.

The AN/SRA-15 antenna multicoupler is illustrated in figure 5-34. It covers the frequency range from 6

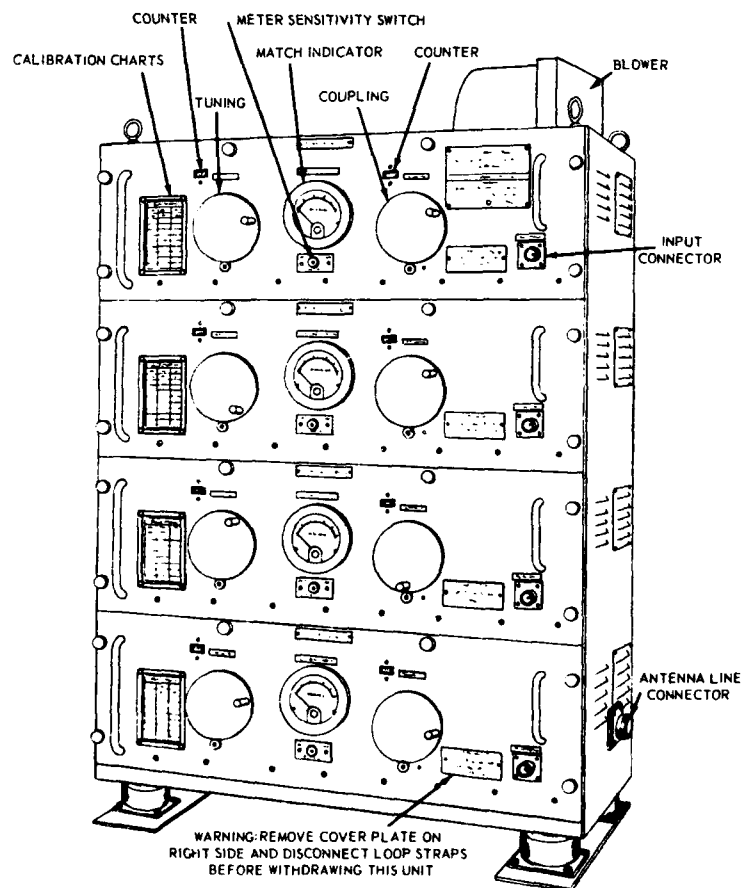


Figure 5-34.—Antenna multicoupler AN/SRA-15.

to 18 mc and will operate into any antenna having a standing wave ratio (relative to 50 ohms) of 3 to 1 or better. The four transmitters connected to this coupler may be operated anywhere in the frequency range from 6 to 18 mc, as long as there is sufficient separation between the operating frequencies.

INSULATION

Electrical insulation isolates current-carrying conductors from personnel, the ship's structure, and from other conductors. For reasons of safety and efficiency the insulation chosen for a particular application must have certain desirable properties. Insulation properties include resistance, dielectric strength, dielectric loss, tensile strength, flexibility, and abrasion resistance.

Insulation RESISTANCE is the resistance to the flow of an electric current through and over the surface of insulation. This resistance should be high and is usually measured in megohms. However, the insulation may be damaged and still exhibit a high resistance to ground. Therefore, insulation resistance furnishes a useful but not a final test in determining the condition of the insulation.

The DIELECTRIC STRENGTH of insulation is a measure of the voltage that can be applied to insulation without breaking it down. It may be expressed as volts per mil of thickness. For practical purposes, it is the value obtained by dividing the breakdown voltage by the thickness of the material. When breakdown occurs, the insulation is changed abruptly from a nonconductor to a conductor.

The DIELECTRIC LOSSES in insulation result from stresses set up in the insulation when an a-c voltage is applied across it. Charges are alternately stored and released. The action is similar to that of a capacitor. The voltage causes a physical stress, and heat is produced. The heat generated in the insulation is known as dielectric loss and varies directly with the frequency.

The product of the dielectric constant and the power factor is called the loss factor of the dielectric. The loss factor is a measure of the effectiveness of a dielectric to insulate high r-f voltages.

TENSILE STRENGTH is a measure of the physical force required to break a material when it is subjected to a stretch, or pull, and is expressed in pounds per square inch.

FLEXIBILITY is the ability of insulating material to withstand forming and bending without breaking. Some insulators, such as glass and porcelain, are hard and brittle and have no flexibility.

ABRASION RESISTANCE is a measure of the ability of an insulating material to withstand damage caused by handling.

The properties of shipboard electronic insulation are affected by temperature, moisture, atmospheric action, and mechanical damage.

As a rule, high temperatures cause a decrease in dielectric strength and insulation resistance. For high operating temperatures, teflon, silicone rubber, asbestos, and glass are the best insulators.

Moisture as well as high temperature lowers insulation resistance and dielectric strength of an insulating material.

SILICA GEL

Silica gel is a hard, glassy compound in the form of small crystals that can absorb moisture. It is also called a desiccant, and normally has a white or milky color. It may be mixed with a small amount of cobalt chloride or similar moisture-indicating material. With this material added, the color changes from blue to pink to red as more and more moisture is absorbed.

A typical use of silica gel is keeping coaxial lines and joints free of moisture on earlier air search radar equipments, such as the SA, SK, and SR radars.

The line is kept air-tight, and an opening allows breathing during temperature changes. A protex plug containing silica gel is placed in the opening to dry all air entering the transmission line. This method requires the replacement of the protex plug when the silica gel crystals turn pink. If the replacement of the plug is neglected, air with moisture is breathed into the coaxial line as if no protex plug were there.

QUIZ

1. A cable designated DSGA contains how many conductors?
2. What two quantities determine the cable size for a particular application?
3. What information is contained in the cable marking, 2R-ER3?
4. What is the purpose of stuffing tubes?
5. What problem has been increased by the use of electronic receiving equipments of greater sensitivities?
6. Background noise is due largely to what three causes?
7. How may conductive coupling be eliminated?
8. To what type or class of filter do power-lead filters belong?
9. What three main circuits leading into or out of the rear of the AN/URR-35 radio receiver are filtered?
10. What are the two most important considerations when a waveguide is installed?
11. What are three common types of dielectric used with flexible r-f transmission lines?
12. What type of dielectric is used on cables for transmitting high-voltage d-c pulses?
13. When possible, why are pulse cables run separately?
14. What are four good points to remember in working with flexible r-f transmission lines?
15. A comprehensive power distribution system aboard ship includes what three distribution systems?
16. Good installation practice requires that wire antennas be free from what defects?

17. Why are whip antennas that are used for receiving only mounted at a distance from the transmitting antennas?
18. Why are UHF antennas mounted as high and as much in the clear as possible?
19. What is the purpose of the ground plane often used on VHF antennas?
20. What is the purpose of interconnecting antenna transfer panels?
21. Why are matched impedances maintained as closely as practicable in a transmitting antenna system?
22. What is the purpose of an antenna trunk?
23. What is the purpose of antenna multicouplers?
24. What is the function of the r-f section of the CU-255/UR VHF-UHF multicoupler?
25. The loss factor of a dielectric is the product of what two quantities?
26. What is the result of failure to replace protex plug filled with silica gel when the silica gel turns pink?

CHAPTER

6

MAINTENANCE PROCEDURES

INTRODUCTION

An indication of the scope of the work done by the ET is contained in a policy statement on page 1-1 of the EMB (change 9 January 1956), which lists the following as items normally done by the ship's force (of course, not all of the jobs listed are performed by the ET 3):

1. Antennas—cleaning and painting; replacement of wire antennas.
2. Bearings—replacement in small motors and generators.
3. Cabling—replacement of short lengths not critical in nature.
4. Direction finders—cleaning, routine maintenance, loop checks, and calibration.
5. Field changes—all field changes of a minor nature and those designated as being accomplished by ship's force.
6. Generators—routine cleaning, maintenance, and minor repairs.
7. Insulators—cleaning and replacement as required.
8. Jacks (phone)—replacement and repair.
9. Keys (telegraph)—installation, replacement, adjustment, and repair.
10. Loran—repair and adjustment.

11. Meters—minor repairs only; replacement of meters that are integral parts of equipment.

12. Oscilloscopes—repair and adjustment.

13. Receivers (all types)—all tests and repairs except alignment.

14. Transmitters (all types)—all tests, repairs, and alterations except major changes and repairs to sealed oscillator compartments.

15. Test instruments—all repairs except where special instruments or techniques are required.

OPERATIONAL MAINTENANCE consists normally of inspection, cleaning, servicing, preservation, lubrication, and adjustment, as required, and may also consist of minor parts replacement not requiring high technical skill or internal alignment.

TECHNICAL MAINTENANCE (corrective maintenance) will normally be limited to maintenance consisting of replacement of unserviceable parts, subassemblies, or assemblies and the alignment, testing, and adjustment (internal) of equipment. (This work, in general, requires skill and detailed knowledge of equipment.)

PREVENTIVE MAINTENANCE is the systematic accomplishment of items deemed necessary to reduce or eliminate failures and prolong the useful life of the equipment. (These items are more specifically defined and outlined in the instruction books furnished with each equipment. This work, in general, requires skill and a detailed knowledge of the equipment.)

TENDER/YARD MAINTENANCE requires a major overhaul or complete rebuilding of parts, subassemblies, or the end items, as required.

REPAIR is the correction of damage incurred through long use, accident, or other causes.

MAINTENANCE BEYOND THE CAPACITY OF SHIP OR STATION FORCES is performed by tender or naval shipyards and industrial managers or by contractors or other agencies responsible to the maintenance yard.

Although there may be certain exceptions, operational

maintenance is done by the operational ratings and technical maintenance (corrective maintenance) is done by the technical ratings. The duties of the two ratings are summarized as follows:

1. Operational ratings—operational use, manipulation, and operational maintenance of electronic equipment associated with the technical specialties of the ratings and such portions of preventive maintenance as do not require realignment after accomplishment.

2. Technical ratings—manipulation, technical and tender/yard maintenance, repair of electronic equipment and preventive maintenance, which requires realignment after accomplishment.

Essentially all electronic equipment can be subdivided into one or more of the following categories: (1) transmitter, (2) receiver, (3) amplifier, or (4) indicator.

The function of any transmitter (radio, radar, or sonar) is to generate the carrier frequency and then to amplify, modulate, and finally to radiate it from a suitable antenna. Every transmitter must have the required ability to stay on the assigned frequency (frequency stability), to transmit faithfully the desired intelligence (fidelity), and to produce the required output power.

The function of any receiver (radio, radar, or sonar) is to receive, amplify, and deliver the desired intelligence in a useful form. Every receiver must have the required ability to pick up weak signals (receiver sensitivity), to pick up a signal at the desired frequency while rejecting signals on adjacent frequencies (receiver selectivity), and to amplify an incoming signal and deliver it to an indicator without distortion (receiver fidelity).

The function of any amplifier is to increase the strength of the signal fed to it without adding anything to the signal or removing anything from it.

The function of any type of indicator is to present information in the desired manner, without distortion.

When an electronic equipment deviates appreciably from normal operation, it will generally be noted by the operator. If the trouble cannot be corrected by operational maintenance procedures, technical maintenance (as outlined in the appropriate instruction book or technical manual) will be necessary. Technical (or corrective) maintenance procedures differ widely among the various electronic equipments, and therefore the appropriate instruction book must be used.

Besides the major units, you will be concerned also with the various accessories, such as transmission lines, antenna systems, motors, motor-generators, synchros and servomechanisms, switching systems, and others.

As has been stated, the operational maintenance and much of the preventive maintenance should be done by the operating personnel. This includes daily checks on the operating controls to note binding, excessive play, or other defects. Meter readings should be checked daily to determine if they are normal (the exact procedures are outlined in the appropriate Maintenance Check-off Book described later). Equipments should also be checked daily for loose knobs, burned out pilot lights, loose cable couplings or bonding straps, missing spare fuses, and broken meter glasses.

Also, external surfaces should be dusted periodically. Interiors of equipments should be cleaned carefully at weekly intervals with a soft brush and, if available, a vacuum cleaner.

Periodic cleaning of the interior of radio transmitters or other equipments employing high voltage is particularly important. Potentials in excess of 3000 volts are often present in these equipments, and dust on insulators or other high-voltage components forms a convenient path for arc-overs and consequent damage. In addition, a mixture of dust and lubricant forms an excellent abrasive, which can do considerable damage to moving parts.

PREVENTIVE MAINTENANCE PROCEDURES

In this portion of the chapter some of the more common preventive maintenance procedures are discussed briefly. It is obvious that the way the operator or the technician goes about his preventive maintenance duties depends upon the type of equipment (or equipments) to which he is assigned. If the Maintenance Check-Off Book is available, the task is made easier. In any case, the steps to be followed in performing preventive maintenance is spelled out in detail in the equipment instruction book. Generally, one section (Section 6) of the instruction book is devoted entirely to preventive maintenance. However, in the new specifications, preventive maintenance will be included in the operator's volume or in the POMSEE books.

Certain items like cleaning and lubricating electronic equipment, maintaining air filters, caring for motors and motor-generators, and testing electron tubes and crystal diodes are sufficiently general to be treated under separate headings. However, preventive maintenance, as applied to specific equipments, must conform to the specific routine spelled out in the Maintenance Check-Off Book or the equipment instruction book. To illustrate the methods commonly used in maintaining the various types of electronic equipments, a brief summary of the preventive maintenance procedure for certain typical equipments is included. For the detailed procedure, the equipment instruction book must be consulted in each case.

The POMSEE Program

The Bureau of Ships is supplementing existing instruction books or technical manuals with two separate publications which together make up the POMSEE program. The expression, POMSEE, means "Performance, Operational, and Maintenance Standards for Electronic

Equipment." The POMSEE publications are described as follows:

1. Performance Standards Sheets provide the operational performance data and basic technical measurements indicative of the minimum acceptable level of performance for electronic equipment. A binder, titled "Binder for Electronic Equipment Performance Standard Sheets (NavShips 93000)," for incorporating all sheets required on a ship under one cover, has been distributed.

2. Maintenance Standards Books provide standard methods for determining measurements affecting the performance of a specific equipment, space to record such measurements, and a preventive maintenance schedule for the equipment. The Maintenance Standards Book includes Part I, Test Procedures and Maintenance References (formerly Performance Standards Book, and referred to as such in this training course) and Part II, Preventive Maintenance Check-Off (formerly Maintenance Check-Off Book, and referred to as such in this training course).

According to Bureau of Ships Instruction 9670.86A, all holders of POMSEE publications are required to change the title of all "Performance Standards Books" to "Maintenance Standards Books, Part I, Test Procedures and Maintenance References" and to change the title of all "Maintenance Check-Off Books" to "Maintenance Standards Books, Part II, Preventive Maintenance Check-Off."

The "Performance Standards Book" (Maintenance Standards Book, Part I, Test Procedures and Maintenance References) provides an itemized step-by-step procedure, which enables the engineer or other person making the standard tests to set down critical or significant operating values (dial readings, etc.) representative of optimum operating conditions. Upper and lower limits or tolerances for dial readings, voltages, or currents are given so that an indication is readily avail-

able if performance is below the allowable limits. No attempt is made in the Performance Standards Book to show how to locate the trouble; however, a comparison with established critical circuit readings will help the ET to isolate the trouble.

Reference to the instruction book for the particular equipment is still required for troubleshooting or corrective maintenance.

The Maintenance Check-Off Book (Maintenance Standards Book, Part II, Preventive Maintenance Check-Off) requires that standard tests be performed at regular intervals on circuits and components and specifies what and when other routine maintenance, such as lubrication, is to be accomplished. By the proper use of this book, routine checks and routine preventive maintenance may be accomplished in a systematic manner.

In general, the same steps required for determining Performance Standards must be repeated later by the ship's force in making routine checks for entry in the Maintenance Check-Off Books. The daily and some of the weekly tests prescribed should be done by operators, not technicians, so that the ET's can concentrate on corrective maintenance. The individual vessel's electronics material officer will determine who should undertake the routine tests.

Cleaning Electronic Equipment

The following information was obtained from Chapter 67 of the *Bureau of Ships Manual*.

1. All electronic equipment must be cleaned to assure good performance and not for appearance only.
2. Steel wool or emery in any form must not be used on or near electronic equipment.
3. Sandpaper and files will be used only with competent advice or not at all.
4. The use of a vacuum cleaner with NONMETALLIC hose and adequate dust receiver is to be resorted to wherever practicable.

5. The use of solvents is to be resorted to only where absolutely necessary and where the proper safety precautions are taken (see Chapter 15, Section 8 of *BuShips Manual*).

Alcohol or other flammable solvents must not be used on energized equipment or on equipment near other electronic equipment from which a spark is possible. They are to be exposed in the smallest possible quantity and may be used only in well-ventilated compartments. Except in locations wholly in the open, alcohol will be limited in quantity to one pint.

For additional safety precautions that the ET must observe in cleaning electronic equipment, see *United States Navy Safety Precautions*, OpNav 34P1.

Lubricating Electronic Equipment

In electronic gear, lubrication is as important as it is anywhere else, and the carrying out of the lubrication procedure is no more complicated than in other equipments. There are actually only a few types of parts that have to be lubricated. They are summarized in a general way as follows:

1. Drive motors and motor-generator sets run at high speeds and, if not lubricated properly at regular intervals, will quickly deteriorate and fail. Determine where the motor-generators (as well as the drive motor) are located so that they will not be overlooked during routine lubrication.

2. Sonar hoists are quite simple to lubricate. Generally, only one of these is installed in a ship, but they are often neglected. This is fairly slow-moving machinery and will stand a lot of abuse, but nevertheless it needs lubrication.

3. A radar antenna is rather slow-moving too, but a great deal of trouble and expense has resulted from a lack of proper lubrication. In one instance the failure to use thirty cents worth of grease resulted in a \$30,000 repair bill. Several factors combine to cause antenna

trouble. First, the antenna is a long way up in the air, and it is a nuisance to climb all the way up the mast to lubricate it. Second, the ship spends much of its time at sea, and the mast is no place to be when the ship is heaving around underneath. Third, the rolling and pitching of the ship throws a heavy strain on the moving parts of the pedestal, and even though the antenna moves slowly, the great pressure on the moving parts causes rapid wear unless they are kept well lubricated. Fourth, the pedestal is constantly exposed to the action of salt air and salt water, which attacks the lubricant and tends to make it less slippery.

If the antenna is neglected and the pedestal freezes, the drive motor will burn up, and the radar will be out of commission. This condition involves lifting the antenna off with a crane and results in an expensive repair job. This waste of money and time, and the possible placing of the ship in jeopardy, can be prevented if the correct lubrication procedure (as outlined in the instruction book, the lubrication charts, or POMSEE books) is followed.

There are three common methods of lubricating electronic equipment.

The first is the use of the oil can. A drop of oil from the spout of the can into the oil hole on the machinery is all that is necessary. However, there are many types of oil and you must be sure that you are using the correct one. In many cases, the mixing of dissimilar oils will form a gummy substance that has little or no lubrication properties. The result may be a frozen bearing.

The second is the use of a grease gun on a pressure-type fitting. The main thing to remember is that the fitting must be clear of dirt or paint obstructions, otherwise the grease cannot enter. Even if the grease should be forced in, dirt will be taken along and eventually the bearing will be damaged. Grease fittings should always be kept as clean as bright work; and the hole should be cleaned out with a pin before the grease gun is applied.

The third is the use of the grease cup. Grease cups are generally found on the heavier motors and motor-generators, and must be used properly if damage to the machinery is to be prevented. Information on the use of grease cups is included in the section on the care of motors and motor-generators.

For certain types of electronic equipment, special lubrication charts are provided. For example, a set of twelve plastic lubrication charts (NavShips 250-970-40) are provided for the personnel who lubricate the antenna of Radar Set AN/SPS-8. Pictures and instructions are given to ensure adequate lubrication instructions.

Care of Motors and Motor-Generators

The following information on the care of motors and generators (or motor-generators) is condensed largely from Chapter 60 of the *Bureau of Ships Manual*. The essential points to remember are: (1) keep the insulation clean and dry and of high resistance, (2) keep the electrical connections tight, and (3) keep the machines in good mechanical condition by proper cleaning, lubrication, and replacement of defective parts.

The ET 3 is expected to be able to inspect and clean commutators and collector ring (slip ring) assemblies and inspect and replace brushes on motors and motor-generators that are used with or are a part of electronic equipment. It is therefore important that he follow the approved procedures.

The four acceptable methods of cleaning motors and generators are wiping, use of suction, use of compressed air, and use of a solvent.

LUBRICATING MOTORS AND MOTOR-GENERATORS.—The ET 3 should be familiar with and be able to distinguish between grease-lubricated and permanently lubricated ball bearings.

The grease-lubricated type requires periodic lubrication with grease. The permanently lubricated type con-

tains two seals, has been lubricated by the manufacturer, and requires no additional lubrication throughout its life. Equipment furnished with these bearings can be recognized by the absence of grease fittings or provision for attaching grease fittings. When permanently lubricated bearings become inoperative they should be replaced with new bearings of the same type.

Cleanliness is of prime importance in avoiding ball bearing failure. Due to the extremely high pressures and close fit between balls and races, even minute particles of dust may cause bearing failure. Dirt may be introduced into the bearing housing by careless handling, or by inclusion with the lubricant, or it may work its way into the housing along the shaft.

Extreme care must be exercised in the handling of bearings, grease fittings, housing parts, and tools used in maintaining the bearings to ensure the exclusion of all foreign matter, particularly when reassembling grease fittings, etc.

Improper greasing procedures are a frequent cause of trouble in rotating electrical machinery provided with grease-lubricated ball bearings. The trouble is generally caused by an excessive quantity of grease being forced into the bearing housing. When grease is forced through the bearing seals and into the windings (or onto the commutator), deterioration of the insulation is a likely result. Excessive grease in the bearing housing itself results in churning, increased temperatures, rapid deterioration of the grease, and ultimate destruction of the bearing.

The stock numbers of grease to be used for lubricating ball bearings that operate in two broad temperature ranges are given in Chapter 60, Article 60-287 of the *Bureau of Ships Manual*. Machines that require the special high-temperature silicone grease have a plate with the words, USE HIGH TEMPERATURE GREASE, attached near the grease fitting.

Motors and generators provided with bearings that

should be lubricated with grease are normally delivered with the grease cups removed from the bearing housings and replaced with pipe plugs. The grease cups are delivered with the onboard repair parts or special tools. It is recommended that grease cups be attached to electric motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole that remains should be plugged with a suitable pipe plug. When this procedure is used, the grease cups should remain in the custody of responsible maintenance personnel.

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

To avoid the difficulties caused by an excessive amount of grease, grease should be added only when necessary; and, when grease is added, it should be done as follows:

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

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

3. Remove pipe plug at top of grease pipe. Select the proper grease cup and clean it (top and bottom parts) thoroughly. Install the bottom portion of the grease cup on the grease pipe.

4. Fill the bottom part (receptacle) of the grease cup with clean grease.

5. Put into the top part (the part that is to be screwed down) of the grease cup no more grease than will half fill it.

6. Screw the top part of the grease cup down as far as it will go. The purpose of screwing the grease cup down is to protect the machine from being overgreased because of accidental or unauthorized turning of the top part of the grease cup.

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

8. Do not use a grease gun to lubricate bearings unless there are no other means available. If a grease gun must be used, the drain plug must be removed while greasing is being done and extreme care must be used to avoid inserting too much grease.

BRUSHES.—The correct grade of brushes and correct brush adjustment are necessary to avoid commutation trouble. For good commutation:

1. Use the grade of brushes recommended by the manufacturer.

2. The brush shunts or "pigtails" should be securely connected to the brushes and the brush holder.

3. Brushes should move freely (for example, $\frac{1}{32}$ inch), but should not be loose enough to vibrate in the holders.

4. Brushes that are half worn, or that have chipped corners or edges, should be replaced after all dirt is cleaned from the brush holders.

5. The spring tension on the brushes should be maintained according to the manufacturers' instructions (see *BuShips Manual*, section 60-293, for details).

6. All brush holders should be the same distance from the commutator—not more than one eighth of an inch, or less than one sixteenth of an inch.

7. The toes (forward edge in the direction of rotation) of all brushes on each brush stud should line up with each other and with the edge of one commutator segment.

8. The brushes should be evenly spaced around the commutator.

9. Brushes should be staggered in pairs (see Article 60-293 in *BuShips Manual*) to prevent grooving of the commutator.

10. The brush surface in contact with the commutator should be an accurate fit.

When new brushes are installed, or old brushes do not fit, they should be fitted and seated. For this purpose, sandpaper and/or a brush seater should be used. Sandpaper is probably more familiar to everyone, but the use of a brush seater has certain advantages. (Never use emery paper or any other kind of paper or cloth containing a metallic abrasive.)

When using sandpaper to fit brushes, disconnect all power and make sure the machine cannot be started while the work is being done. Lift the brushes to be sanded and insert a strip of fine sandpaper (No. 1) sand side up, between the brushes and the commutator. With the sandpaper held tightly against the commutator surface (to conform to the curvature), and the brushes held down by normal spring pressure, the sandpaper is pulled in the direction of normal rotation of the machine (see fig. 6-1). When the sandpaper is reinserted for another pull, the brushes must be lifted. This operation is re-

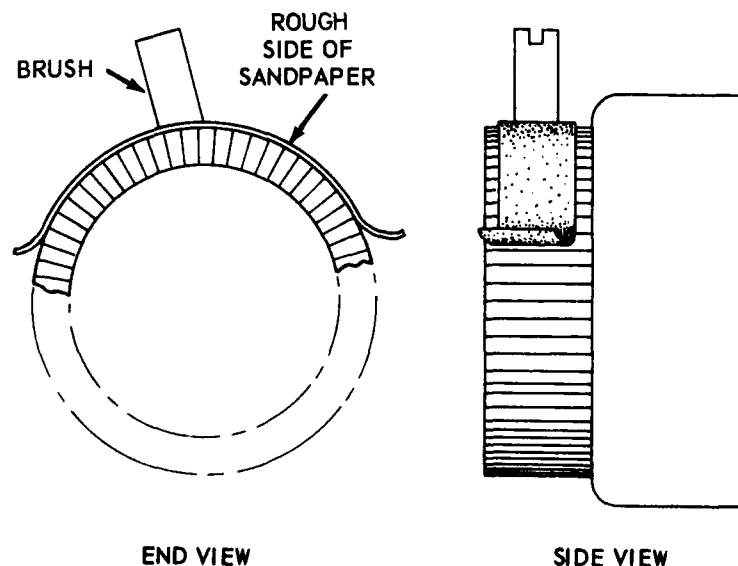


Figure 6-1.—Method of sanding brushes.

peated until the fit of the brush is accurate. Always finish with a finer grade (No. 0) sandpaper. Use a vacuum to remove the dust during the sanding operation; afterwards, the commutator and windings must be thoroughly cleaned to remove all carbon dust.

The brush seater consists of a mildly abrasive material loosely bonded and formed in the shape of a stick about five inches in length. The brush seater is applied to the commutator while the machine is running, and therefore every precaution must be taken to prevent injury to the person applying it. The brush seater is applied lightly, for a second or two, exactly at the heel of each brush (fig. 6-2). If the seater is placed even one-fourth inch away from the heel of the brush, only a small part of the abrasive will pass under the brush. Pressure is applied to the brush by setting the brush spring tension at maximum (during the seating operation) or by pressing a stick of insulating material against the brush. Dust is removed during the operation, and the machine

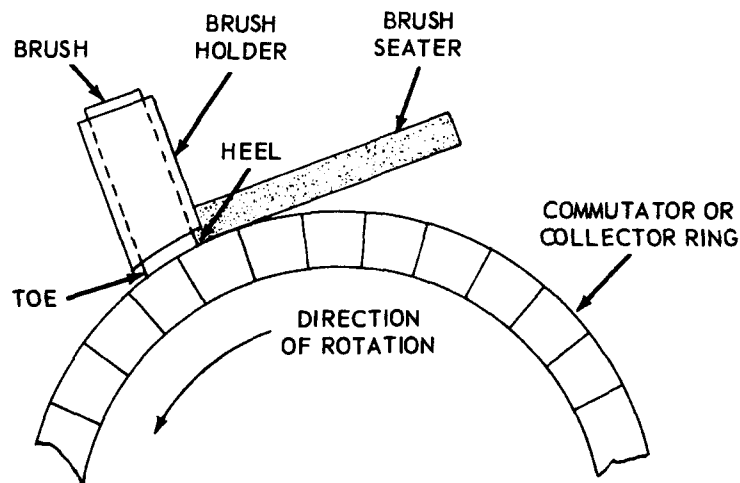


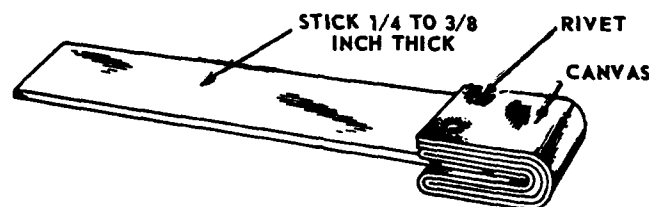
Figure 6-2.—Using the brush seater.

is thoroughly cleaned afterwards the same way as when sandpaper is used.

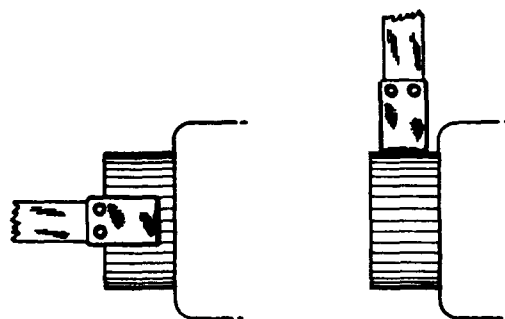
COMMUTATORS AND COLLECTOR RINGS.—In a properly operating machine, the commutator will develop (within about two weeks of use) a uniform, glazed, dark brown polish where the brushes ride on it. A nonuniform color or surface or a bluish color indicates improper commutation conditions. If the commutator retains a smooth, uniform finish of the proper color and shows no evidence of poor commutation, it may be cleaned with a canvas wiper, as described in the following paragraph. If however, the commutator cannot be sufficiently cleaned with the canvas wiper, or if the surface is slightly rough, a fine grade of sandpaper may be needed. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum.

One of the most effective ways of cleaning commutators or collector rings is to apply a canvas wiper while the machine is running. The wiper can be made by wrapping several layers of closely woven canvas over the end of a strong, pliable wood strip and securing the canvas with rivets, as shown in figure 6-3, A. The strip should be long enough so that the user can hold it securely in both hands, about one-fourth inch to three-eighths inch thick, and of a width appropriate to the size of the machine on which it will be used. Linen tape should be wrapped around the canvas wiper over the rivets to prevent all possibility of their coming in contact with the commutator. The canvas wiper is applied to the commutator in either of the ways illustrated in figure 6-3, B. When the outer layer of canvas becomes worn or dirty, it is cut off to expose the next layer.

When the machine is secured, use a toothbrush to clean out the commutator slots, and wipe the commutator and adjacent parts with clean canvas or cheesecloth. Take care not to leave threads lodged between the commutator bars or on the brushes. Do not use cotton waste or any cloth that leaves lint.



A CANVAS WIPER



B USING THE CANVAS WIPER
ON A COMMUTATOR

Figure 6-3.—(A) Canvas wiper. (B) Using the canvas wiper on a commutator.

Do not use solvents for routine cleaning of commutators, and do not use any lubricant on the commutator.

If the commutator is only slightly (blackened, scratched, or dirty) but not out of true (flat, grooved, or eccentric), a fine grade of sandpaper (No. 00) may be used. Sandpapering is also used to reduce high mica, or to finish a commutator that has been ground or turned. The machine is run under a light load at approximately rated speed. The sandpaper is attached to a wooden block that has a face shaped to the same curvature as the commutator. Move the sandpaper very slowly back and forth in a direction parallel to the axis of the machine. Rapid motion of the sandpaper will cause diagonal scratches. Do not use coarse sandpaper because this will make deep scratches. Do not use emery paper,

emery cloth, or emery stone on a commutator as these materials contain carbon, which will become embedded in the commutator slots and short-circuit the armature coils.

Maintaining Air Filters

The maintenance of air filters is EXCEEDINGLY important for the proper operation of electronic equipment. The lack of proper servicing (cleaning or replacing) of air filters will cause an enormous amount of trouble. For some reason (perhaps they are difficult to locate or their importance is not fully recognized) it appears that air filters are often neglected or disregarded until excessive heating causes a breakdown of the equipment.

Equipments that use a great deal of power and/or have high ambient temperature must be cooled. Air cooling is commonly employed, and this means moving a large volume of air over the hot portions of the equipment. The air is filtered to keep dust and other foreign particles out of the equipment. If the filters are efficient, they will remove most of this foreign material from the air that passes through them. This foreign material will tend to clog the filter and prevent the air from moving through. The result is that the equipment gets too hot and may be ruined. AIR FILTERS MUST BE SERVICED OFTEN.

An analysis of the failures of parts in electronic equipment indicates that the MAJORITY OF FAILURES CAN BE TRACED TO EXCESSIVE HEAT CAUSED BY DIRTY AIR FILTERS. This fact cannot be overemphasized; and on the basis of this alone, it would appear that the technician can reduce his workload substantially by ensuring that air filters are properly serviced.

Maintaining Antennas and Transmission Lines

Specific instructions for maintaining VHF/UHF and microwave antennas are given in the instruction book for a particular equipment or a particular antenna.

Good practical information on testing antenna systems is included in Chapter 4 (Testing Antenna Systems) of *Shipboard Antenna Details*, NavShips 900,121A. Equally helpful is the information on transmission lines contained in *Installation and Maintenance of Transmission Lines, Waveguides, and Fittings*, NavShips 900,081. Another useful publication is *Armed Services Index of R-F Transmission Lines and Fittings*, NavShips 900,102B.

This portion of the chapter treats in a general way the use of meggers in testing antenna systems and the cleaning of antenna and transmission line insulators. However, before the subject of testing antenna systems is treated it is perhaps best to review what is said about the ohmmeter and the megger in Chapter 9 of *Basic Electronics*, NavPers 10087.

Basically, an ohmmeter (or the ohmmeter section of a multimeter) is used to determine if a circuit is open, shorted, or grounded; it is likewise used to determine the resistance of a circuit or component. It is simple to use. The test leads are connected to the instrument, and the range switch and the meter adjustments are made. The probes are then placed across the circuit or component to be tested. If no reading is obtained (infinite resistance), the circuit is open (or the resistance is so high that the meter will not give an indication); if a reading is obtained, the circuit is not open. If no resistance is indicated, the circuit or component is short-circuited. If the ohmmeter indicates essentially no resistance between a point in a circuit and ground, that point is grounded. The value of the resistance of a circuit or component is indicated on the meter dial.

In general, ohmmeters are used for low or medium values of resistance; meggers and insulation test sets are used for high values of resistance (perhaps hundreds of megohms).

USE OF INSULATION TESTERS IN TESTING ANTENNA SYSTEMS.—The theory of operation of the megger is discussed in Chapter 9 of *Basic Electricity*, NavPers 10086.

Essentially, it consists of a d-c generator supplying a 2-branch circuit, which contains an indicating meter calibrated to read in megohms the unknown resistance inserted in one of the branches.

The megger is used to check the insulation resistance of antennas, transmission lines, cables, generators, motors, transformers, and so forth. Occasional checks over a period of time with a megger will show the condition of insulating material used on antennas, transmissions, etc, and in this manner indicated likely faults. It is also widely used to detect, or track down, insulation faults after they have occurred.

Another type of insulation test set (closely related to the 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 6-4. It is designed to measure insulation resistance from 0 to 1000 megohms. The testing voltage is 500 volts d-c.

The meter pointer should read infinite resistance when there are no external connections to the output binding posts, L, and GND. If the pointer does not stand over the infinity mark, it is necessary to adjust the meter adjustment screw until the pointer stands over the infinity mark. When the meter terminals are short-circuited and the crank is turned at normal operating speed (indicator buttons glowing steadily), the meter pointer should be over the zero mark.

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.

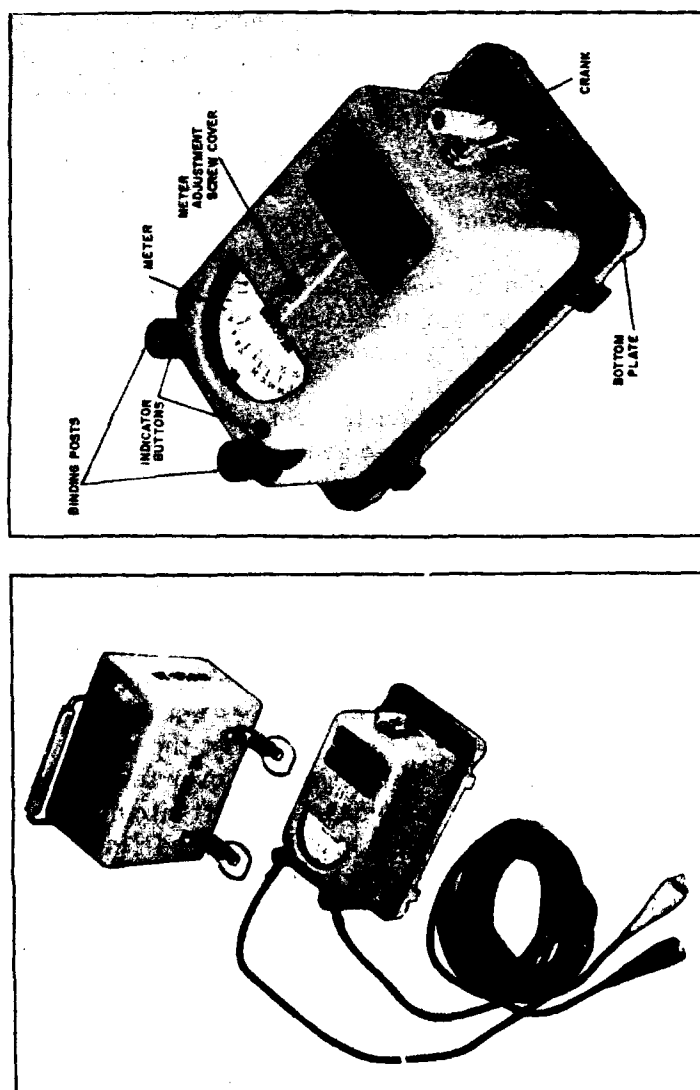


Figure 6-4.—Insulation Test Set AN/PSM-2A.

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.

Measuring the insulation resistance of lines and antennas is a very important and effective means of determining the condition of the antenna and its transmission line. Readings taken in these tests should be 100 megohms or greater, although lower readings will be registered on wet or humid days. Of course, megger tests are more meaningful if made during good weather. Some antennas have a d-c short circuit and therefore the insulation resistance cannot be measured directly; among those that are short-circuited with respect to direct current are the AT-150/SRC, the AS-390/SRC, the NT-66015, and the NT-66016.

Before performing any tests, the megger should be checked to determine if it is in good working order, as explained previously. Make good, positive, clean connections to antenna and ground, otherwise the contact resistance will be an appreciable part of the total megger reading.

For most antenna installations the test procedure is as follows:

1. Disconnect the transmission line at the equipment and test the line at this point. (NOTE: Do not connect the megger to the equipment at any time.)

2. If the reading registers below 100 megohms, disconnect the transmission line at the antenna and test individually both the transmission line and the antenna at this point. This will indicate that the trouble lies either in the transmission line or the antenna or both.

3. If the trouble (low-resistance indication) is shown to be in the transmission line, disconnect the line at the various coaxial connectors and test the individual sections of the line to further localize the trouble.

4. If the trouble (low-resistance indication) is shown to be in the antenna, the antenna will have to be repaired.

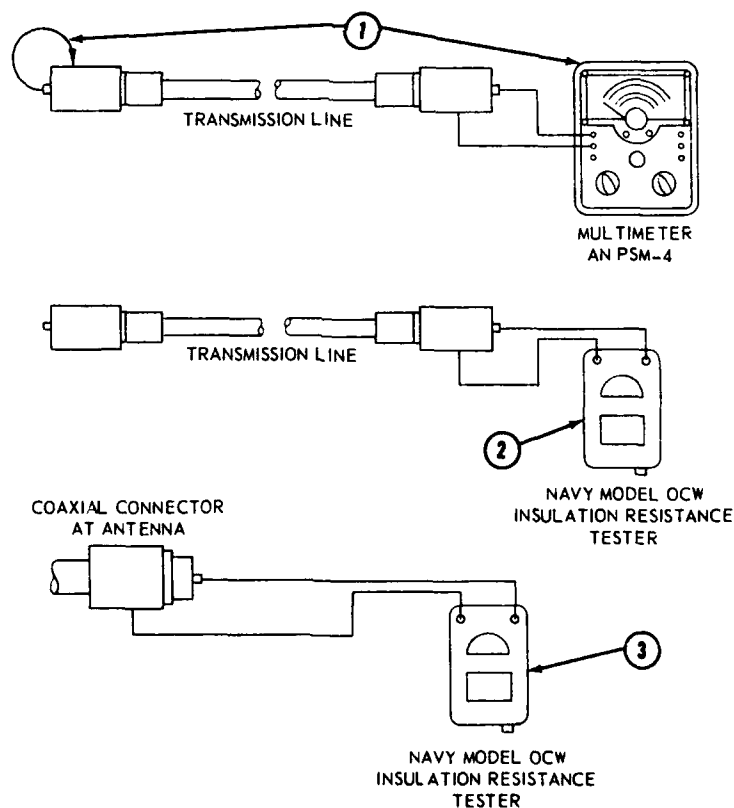


Figure 6-5.—Meter connections for making antenna and transmission-line measurements (receiver).

(However, it should be recalled that certain antennas normally contain a d-c short circuit. The resistance of these antennas should be approximately zero ohms, as indicated on a low-reading ohmmeter.)

These tests are made at prescribed intervals, and the readings are recorded on the proper forms (the Main-

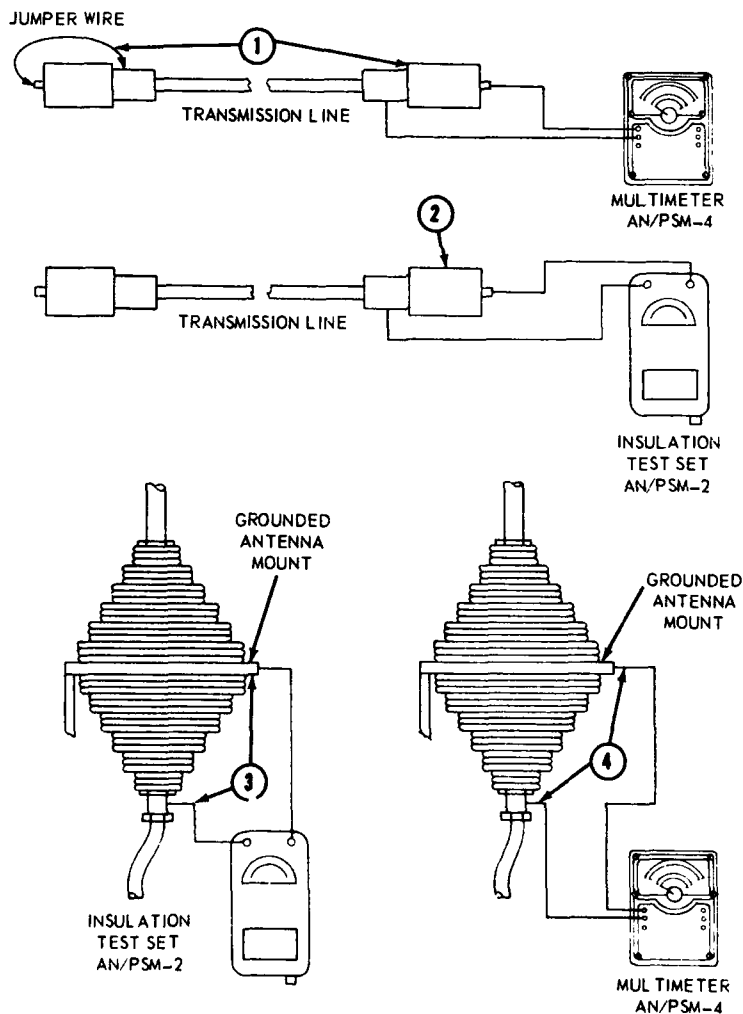


Figure 6-6.—Meter connections for making antenna and transmission-line measurements (transmitter).

tenance Check-Off Books, Resistance Test Record Card, etc).

Continuity checks are also made with the megger or a multimeter. In performing these tests, the transmission line is disconnected at both ends. At one end, the inner conductor is shorted to the outer shield. At the other end, the resistance between the inner conductor and the outer conductor is measured.

The following three steps, taken from the *Maintenance Check-Off Book for Radio Receiving Sets AN/SRR-11, 12, 13*, NavShips 91875.41, will illustrate the routine measurements made on the antenna and transmission line. The steps are indicated in table 12, and the connections are illustrated in figure 6-5.

Four of the steps used in testing the antenna and transmission line of Radio Transmitting Sets AN/SRT-14, 15, 16 are illustrated in figure 6-6 and table 13. These steps are taken from the Maintenance Check-Off Book, NavShips 92121.41, for these transmitting sets.

NOTE 1: The jumper wire must be connected from the inner conductor to the outer conductor. The jumper wire should be as short as possible and the connections must be good. The resistance indicated is that of the inner conductor in series with the outer conductor and should be low (a fraction of an ohm).

NOTE 2: With the switches in the positions indicated, continuity is provided from the antenna through the antenna cable, and through the antenna coupler loading switches to a loading capacitor that blocks the d-c path to ground through the tuning coils. The resistance indication should be very high.

NOTE 3: With the switches in the positions indicated, continuity is provided from the meter, through the antenna cable, the antenna coupler, the cable from antenna coupler to the r-f tuner, the r-f tuner coils to ground, and back to the meter. The resistance indicated should be a small fraction of one ohm.

TABLE 12—ANTENNA AND TRANSMISSION LINE
Operating Conditions and Control Settings:
 Antenna and transmission line disconnected from Radio
 Receiving Set AN/SRR-11, -12, or -13

Test Equipment Required:
 Multimeter AN/PSM-4
 Navy Model OCW Insulation Resistance
 Test Equipment

Step		Preliminary Action	Read Indication On	Perf. Std.
No.	Action Required			
1	Record resistance of transmission line.	Connect equipment as shown in fig. 6-5. Set Multimeter AN/PSM-4 function switch: Rx1.*	Multimeter AN/PSM-4	—ohms (See note at bottom of chart.)
2	Record insulation resistance of transmission line.	Connect equipment as shown in fig. 6-5.	Insulation Resistance Navy Model OCW Test Equipment.	—meg (50 or higher.)
3	Record insulation resistance of antenna.	Connect equipment as shown in fig. 6-5.	Insulation Resistance Navy Model OCW Test Equipment.	—meg (50 or higher.)

* When recording resistance of transmission line, the jumper wire must be connected from inner conductor to outer conductor. This method of connection provides continuity from meter, through inner conductor, jumper wire, and outer conductor, back to meter. Resistance reading will therefore be resistance of outer conductor plus resistance of inner conductor. To avoid error due to jumper wire connection, jumper wire must be kept as short as possible, and connections must be good. The resistance reading obtained in this step depends upon length and type of transmission line. For all normal installations, resistance is a small fraction of one ohm.

TABLE 13

OPERATING CONDITIONS AND CONTROL SETTINGS

Operating Conditions and Control Settings:

All transmitter Primary Power switches set to OFF position;
Antenna and Transmission lines disconnected.

Steps 1 through 4

Test Equipment Required:

Multimeter AN/PSM-4

Insulation Test Set AN/PSM-2

Step		Preliminary Action	Read Indication On	Perf. Std.
No.	Action Required			
1	Record transmission line resistance. (See Note 1.)	Connect Multimeter AN/PSM-4, using R x 1 ohm-meter scale, from inner conductor to output conductor of transmission line. Connect jumper wire from inner to outer conductor at opposite end of transmission line. Record resistance (a) of line from transmitter to Antenna Coupler, and (b) from Antenna Coupler to Radio Frequency Tuner.	Multimeter AN/PSM-4.	(a)—ohm (b)—ohm

2	Record transmission line insulation resistance.	Connect Insulation Test Set AN/PSM-2 from inner to outer conductor of (a) transmission line from transmitter to Antenna Coupler, and (b) transmission line from Antenna Coupler to Radio Frequency Tuner.	Insulation Test Set AN/PSM-2.	(a)—meg (b)—meg (50 or over.)
3	Record antenna insulation resistance. (See Note 2.)	Reconnect all transmission lines. Set Antenna Transfer switch to TUNER IN, ANTENNA COUPLER LOADING switch to A, and TRANSFORMER switch to DIRECT. Connect Insulation Test Set AN/PSM-2 as shown on opposite page, and record insulation resistance.	Insulation Test Set AN/PSM-2.	—meg (50 or over.)
4	Record antenna cable resistance. (See Note 3.)	With all antenna cables connected, set ANTENNA TRANSFER switch to TUNER IN, ANTENNA COUPLER LOADING switch to DIRECT, and TRANSFORMER switch to DIRECT. Connect multimeter AN/PSM-4, using R x 1 ohmmeter scale, as shown on opposite page.	Multimeter AN/PSM-4.	—ohm

Time Schedule: Record and initial.

Approx. Time Req'd. for Quarterly Steps—3 hrs.

Quarter		1st Quarter 19—	2nd Quarter 19—	3rd Quarter 19—	4th Quarter 19—
Step 1	a				
	b				
Step 2	a				
	b				
Step 3					
Step 4					
Initial					

CLEANING INSULATORS.—Leakage current over the surface of an insulator is usually due to moisture and impurities on the surface such as salt spray, soot, or dust.

All standoff insulators, end seals of transmission lines, and waveguide windows should be cleaned at least once a month, and more often if conditions warrant.

The smaller the insulator, end seal, or waveguide window, the more important is this maintenance procedure. The cleaning must be thorough with nothing left to chance.

Paint, varnish, shellac, or grease must not be applied to any portion of ceramic or phenolic insulating materials forming a part of the antenna system.

Testing Electron Tubes

The leading cause of failure or poor operation of electronic equipment (transmitters as well as receivers) is the electron tube. If all tube failures could be eliminated, the maintenance load would be reduced considerably. Tubes do not always collapse completely. Their performance may gradually deteriorate but not to the extent that it will be apparent in a tube checker. One reason for the failure of the average tube checker to

give a full indication of the capabilities of a tube is the 60-cycle sine wave that is applied to the grid of the tube under test. In electronic equipment, all kinds of wave shapes may be applied at frequencies varying from a few cycles to several billion cycles per second. The usual shipboard tube tester cannot determine accurately the ability of a tube to act as an oscillator or as an ultra high frequency amplifier.

Because of the importance of the method of using the tube checker, the Bureau of Ships has issued an instruction (BuShips Inst. 9670.89) establishing the general policy for testing electron tubes. Additional information is included in the June 1956 issue of the *Bureau of Ships Journal*. A portion of BuShips Inst. 9670.89 is contained in EIB No. 455, and is repeated as follows:

The practice of wholesale removal and test of electron tubes on a periodic basis is to be discontinued immediately. Action is being taken to revise instruction books that specify such routine. If routine test of an electron tube in a designated application is necessary, the instruction book will specify an exception to the rule.

The following maintenance routine is strongly recommended:

1. When a performance deficiency is detected, make an all-out attempt to isolate the specific cause.
2. When the trouble has been localized and a tube is suspected, remove and test that tube. If found good, replace in the same socket. Interchange of tubes between sockets should be avoided.
3. If repair by tube substitution is necessary as a last resort, test the new tube (within the capability of the tube tester) before placing it in service.
4. If a new tube tests good but will not work in a particular socket, make a note of this fact and save the tube for use in another application where it will work. The Bureau of Ships is particularly interested in receiving information on cases where extensive selection of tubes for a particular socket is necessary for proper

operation. Failure Report Forms (DD787) and Performance and Operating Reports (NavShips 3878) are convenient ways to do this.

Testing Crystal Diodes

Navy electronics technicians usually will be working with three types of crystal diodes: General-purpose germanium and silicon diodes, power silicon diodes, and forward and reverse high-frequency silicon diodes (commonly called mixer crystals).

A sectional view of a typical germanium crystal diode is illustrated in figure 6-7, A. A number of different

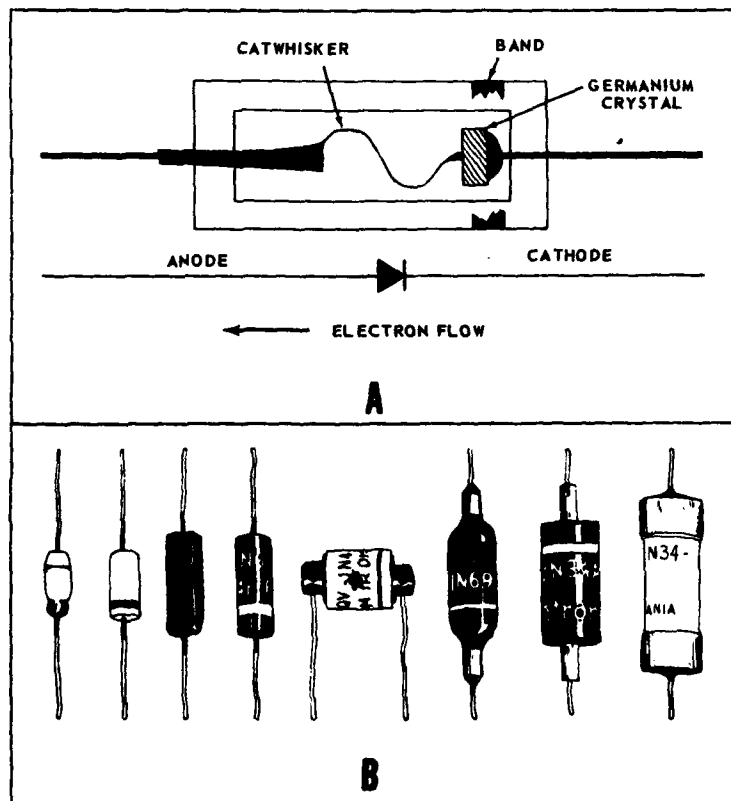


Figure 6-7.—Typical germanium crystal diodes.

types of crystal diodes are illustrated in part B. Germanium diodes are usually enclosed in a plastic or glass cylindrical case with pigtail connections.

The cathode end, usually marked with a painted band or other distinctive marking, contains a small crystal of N-type germanium. A thin catwhisker wire makes a point contact with the crystal. Electrons will flow easily from the germanium into the catwhisker; this makes the catwhisker the anode and the crystal the cathode. Some diodes of this design are being made with silicon crystals in place of the germanium. Silicon power diodes are just beginning to be produced. Their outputs and operating temperature are considerably above those of germanium.

Germanium diodes, such as the 1N34A or 1N69, are used for a wide range of applications, such as video, audio, and pulse circuits. Many are used as detectors in radio and television equipment, and as mixers at frequencies up to 900 megacycles.

Mixer crystals, such as the 1N21 or 1N23, are designed for microwave detection and mixing. These are very carefully made diodes, with low-loss ceramic barrels and

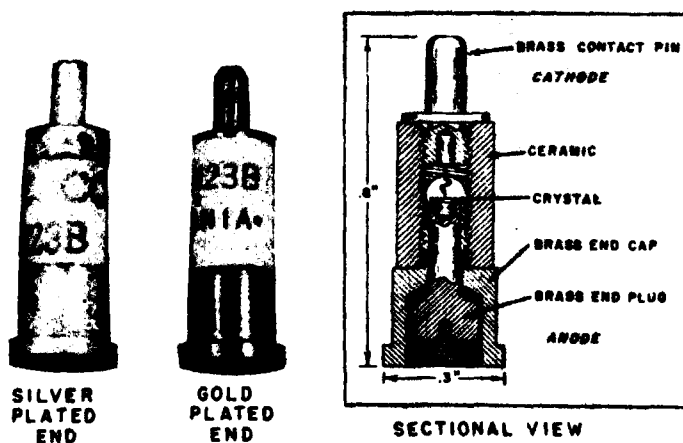


Figure 6-8.—Cartridge-type silicon crystal diodes.

machined and gold-plated brass tips and bases for close fits in waveguides and coaxial fittings. Two 1N23B silicon crystal diodes are shown in figure 6-8; a sectional view is also shown.

A small crystal of almost pure silicon acts as a P-type semiconductor. Electrons will pass easily from the cath-whisker to the silicon, making, in effect, the base the anode and the tip the cathode. Mixer crystals of this type are available for use with frequencies from 1000 to 10,000 megacycles.

Diodes for 10,000 megacycles and above are usually of the coaxial type, as shown in figure 6-9.

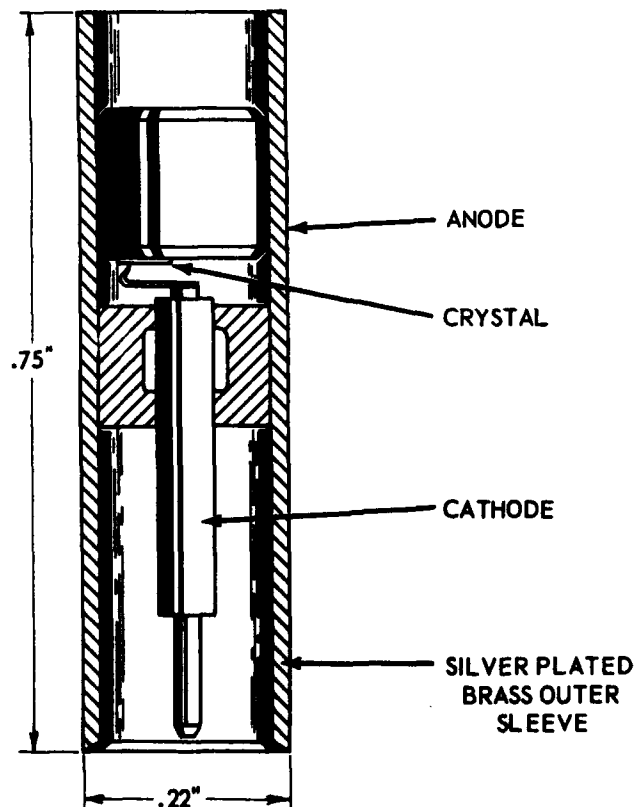


Figure 6-9.—Sectional view of coaxial silicon crystal diode.

Reverse crystal mixers (for example, the 1N23CR) cause considerable confusion. Reverse polarity crystals (fig. 6-10, A) are identical in characteristics to the ordinary type (fig. 6-10, B) whose number they carry. Thus, a 1N23CR is identical electrically to a 1N23C except for

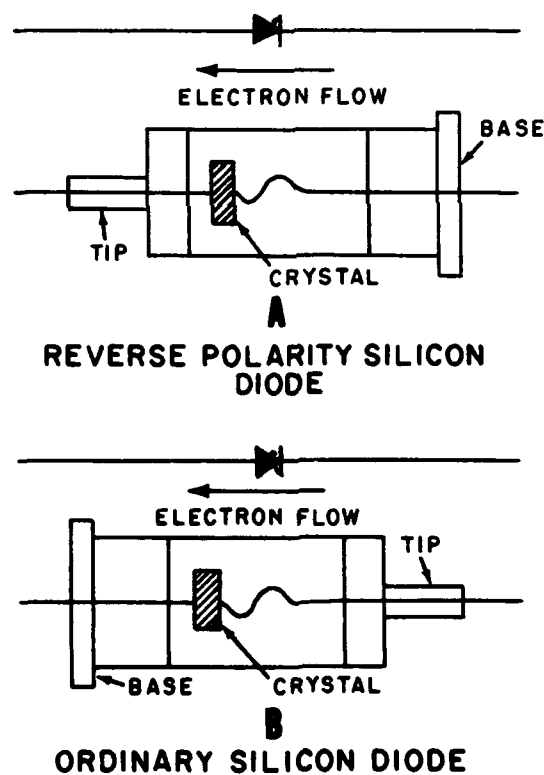


Figure 6-10.—Ordinary and reverse-polarity silicon diodes.

the reversal of polarity. The crystal in the reverse type (1N23CR) is fastened to the tip, making the tip the anode and the base the cathode. In the ordinary type the crystal is fastened to the base, making the base the anode and the tip the cathode.

The properties of the crystal rectifier depend on the pressure, the contact area, the place of contact, etc. This has been carefully adjusted at the factory and should not be upset by tampering with the set screw.

The area of the contact is very small, and if too much power is passed through the cartridge, the resulting heat will damage it, and the crystal rectifier will be impaired. The crystal rectifier may be damaged, for example, by a static discharge through it. If the ET holds one end of the crystal and touches the equipment with the other end, any static charge on his body will discharge through the crystal mixer. He should first touch his finger to the mixer chassis and then insert the crystal rectifier in its holder, as illustrated in figure 6-11.

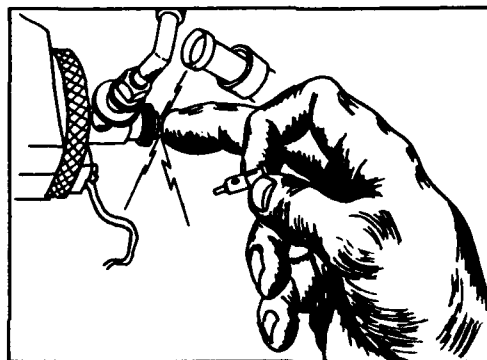


Figure 6-11.—Reinserting crystal rectifier in mixer.

A crystal may also be damaged by exposure to a strong r-f field. Therefore crystal rectifiers must be kept in a metal box or wrapped in metal foil except when in use or being tested.

In the equipment in which the crystal rectifier is used, it is normally protected by a TR tube. The purpose of the TR tube is to place a short across the line leading

to the crystal rectifier by means of gas breakdown in the tube during the firing of the main transmitter pulse. The returning signal, or echo, is much smaller than the transmitter pulse and does not cause a breakdown. It therefore comes through to the crystal rectifier. During the main pulse, some power does leak through the TR tube because it is not a perfect short. However, this power is normally small enough not to damage the crystal.

It is obvious that if the TR tube does not function properly, the crystal rectifier may be damaged. Improper functioning may be due either to the fact that the TR tube is defective or there is incorrect TR tuning (if tuning adjustments are provided).

Another possible cause of crystal damage is a distortion of the pulse shape of the modulator. If the pulse has a sharp peak at the beginning (instead of the usual square shape), much more power will come through the TR tube than for a square pulse of equal energy (because of insufficient time for the blocking action to occur) although the TR tube may be operating normally. Faulty TR operation and distorted modulator pulses are the two main causes of crystal rectifier impairment. Continued impairment of good crystal rectifiers is an indication that the TR tube and the modulator should be checked.

The deterioration of the crystal rectifier in a receiver produces an increase in noise or a decrease in signal, or both, assuming that other factors (for example, receiver gain, transmitter strength, and target distance) remain the same. Such a change results in a decrease in the signal-to-noise ratio; and it is the signal-to-noise ratio that determines the over-all merit of a receiver. Other possible causes of a low signal-to-noise ratio are improper functioning of the first IF stage (pre-IF), or excessive losses between crystal and first IF stage (such as in the cable or connectors), or improper tuning of the local oscillator.

If produced gradually, the impairment of a crystal rectifier is quite difficult to notice. One method of detecting the impairment is to compare the operation of the crystal rectifier with that of a new one. If, under the same operating conditions, the noise is less or the signal is greater with the new crystal, the old crystal is probably impaired. However, if the crystal rectifier current remains unchanged, it does not necessarily mean that the crystal rectifier is unimpaired.

To test a crystal rectifier properly and completely is an elaborate matter and requires precision test equipment. However, the crystal rectifier tests sets (for example, Model TS-268/U) supplied to the Navy ET's are sufficiently accurate for field use.

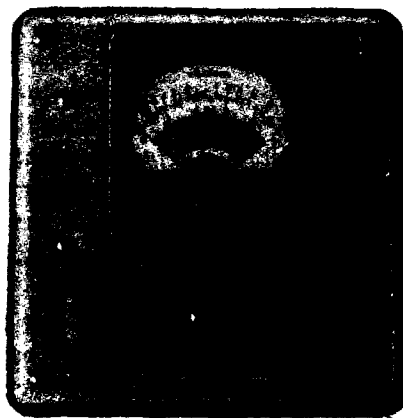


Figure 6-12.—Front view of Model TS-268/U Crystal Rectifier Test Set.

A front view of Model TS-268/U Crystal Rectifier Test Set is shown in figure 6-12. The limits (minimum forward-to-reverse resistance ratio and maximum reverse (back) current) established by laboratory tests are shown in table 14.

TABLE 14
CRYSTAL RECTIFIER LIMITS

Crystal Rectifier Types	Backward-to-Forward Resistance Ratio (minimum)	Back Current in ma (maximum)
1N21	10/1	0.40
1N21A	10/1	0.175
1N21B	10/1	0.125
1N23	10/1	0.4
1N23A	10/1	0.3
1N23B	10/1	0.175

Maintaining Earphones and Microphones

The best way to maintain earphones and microphones is to ensure that they are handled properly. Proper handling includes, for example, hanging up earphones by the straps, not by the cord; removing a plug from a jack by grasping the plug, not the cord; avoiding kinks or other strains in the cord; avoiding rough handling of microphones and earphones, and avoiding exposure to moisture. Heat lamps may be used to protect or to dry out carbon microphones.

Repair consists largely of replacing or repairing plugs, jacks, and cords. In any case, do not place defective equipment with the ready spares. It should be repaired first.

General Precautions for Handling Magnetrons

Specific instructions for handling magnetrons are prepared by the manufacturer and shipped with the magnetron. Study these instructions before removing the magnetron from the packing container.

The magnetron is the heart of most radar sets; and, although it is capable of generating high-pulse power, it can be damaged easily by careless handling. A damaged magnetron can be costly both in safety and in money, and therefore proper handling must be emphasized.

The magnetron shipping container is necessarily bulky in order to protect the tube during shipment and storage. There are two principal reasons why the magnetron must be carefully protected. Excessive vibration or shock can damage the tube, particularly the cathode portion, which is relatively long and suspended only at one end. Also, the magnetic properties of these tubes must be protected during shipment and storage as well as during the time they are in use. If these tubes are not properly spaced in storage (by means of one container within another) the magnetic fields may interact to the detriment of both permanent magnets.

When it becomes necessary to transfer a magnetron from its container to a radar transmitter, care must be exercised to make certain that the parts that are normally protected by the shipping container are not injured in handling. Some of the larger magnetrons (tube and magnet) may weigh as much as 70 lb; therefore handling them may be a real chore.

The size and weight of some magnetrons may lead one to assume that they are rugged; however, this is not the case. For example, if the heater terminal is struck during handling, it is possible that the cathode may be moved sufficiently (a few thousandths of an inch) to cause permanent damage.

Magnetrons (the integral magnet type) must be kept away from iron or steel (tools, decks, tables, etc). Read and follow the instructions on the caution label.

Additional precautions may be summarized as follows:

1. DO NOT USE STEEL WOOL for cleaning a magnetron because the strong magnetic field may cause the steel particles to stick to the insulated portions of the tube.
2. Do not write on the ceramic parts of a magnetron; for example, a pencil mark could cause arcing and a permanently damaged tube.
3. When water is used as a coolant, be certain that all water is drained before the tube is stored in a compartment that will be subject to freezing temperatures.

If water freezes in the tube, it will very likely be ruined. (Be sure to wipe the moisture from the insulated portions of any magnetron that has been stored in such a compartment before it is put into use.)

4. The oil required in the cathode bushing of some magnetrons must be kept free from dirt and moisture. Use only the oil specified in the instructions.

5. Tubes to be returned to the manufacturer should be handled carefully and packed according to instructions; consult the latest ESO publications for information on the disposal of magnetrons.

Radio Transmitters

The correct preventive maintenance procedure for any type of transmitter is included in the instruction book that accompanies the equipment. It is the purpose of this portion of the chapter to list some of the general procedures used in maintaining one type of transmitter (Radio Transmitting Sets AN/SRT-14, 15, 16). The operation of this transmitter is covered more in detail in chapter 12 of this training course.

GENERAL MAINTENANCE.—The ET should make every effort to become familiar with the equipment in order that he may be able to recognize and anticipate avoidable defects. Table 15 will be of assistance in making these observations.

The radio frequency amplifier meter readings (power amplifier current, intermediate power amplifier current, and voltmeter) should be taken under the same conditions and with the same antenna or dummy load. Weekly readings are to be made and compared with those of the previous week so as to check the various conditions existing. It should be borne in mind that production-line tubes will vary considerably in their current output readings. However, definite trend or fluctuation in the readings is to be interpreted as an indication of trouble. By charting these fluctuations, a reliable record of tube performance is available for ready reference and trou-

TABLE 15
INITIAL CHECKS

Item	Check
1. Primary Power-----	The ship power supply must be available at all times.
2. Control Equipment-----	Radiophones, teletype, facsimile, hand keys and other control equipment must be in good working order and connected properly.
3. Insulators-----	Antenna and line insulators must be kept clean and free of unwanted grounds.
4. Cables-----	All internal and external cables must be firmly and properly connected.
5. Dirt and Moisture-----	Leakage paths are often provided by dirt and moisture, resulting in arc-overs and loss of efficiency.
6. Loose Parts-----	In operation, some mountings or fittings may work loose or become damaged. Correct this condition as quickly as possible.
7. Visual Check-----	Check for broken, damaged, or loose hardware; meters; knobs; dials; or lamps. Replace damaged parts without delay.

ble may be avoided by changing tubes before a critical stage is reached.

Complete instructions for taking and recording the meter readings are given in eleven weekly steps in the *Maintenance Check-Off Book* (NavShips 92121.41) for this equipment. The meters to be read in performing steps 3, 4, and 5 are illustrated in figure 6-13. Page five of the *Maintenance Check-Off Book* (which lists the operating conditions and control settings for steps 3, 4, and 5) is reproduced as table 16. Following page five in the *Maintenance Check-Off Book* are charts for recording the weekly meter readings associated with steps 3, 4, and 5.

STEPS 3 THRU 5

TABLE 16
OPERATING CONDITIONS AND CONTROL SETTINGS

Operating Conditions and Control Settings:
Transmitter adjusted for 100-watt, CW operation.
TEST KEY: locked ON position.

Step		Preliminary Action	Read Indication On	Perf. Std.			
No.	Action Required			I _{o1}	I _{o2}	I _k	
3 **	Record IPA METER readings.	Set IPA METER SELECTOR switch (S1386) to I _{o1} , I _{o2} , and I _k , in turn. Record meter indication for each position and with transmitter adjusted for each of the frequencies indicated in PERF. STD. column.	IPA CURRENT meter (M1304).	mc			
				.35	—	—	ma
				2.5	—	—	ma
				5.5	—	—	ma
				6.5	—	—	ma
				11.0	—	—	ma
				15.5	—	—	ma
				16.5	—	—	ma
				21.0	—	—	ma
				25.5	—	—	ma
				(0.1 to 2)	(4 to 8)	(50 to 85)	

STEPS 3 THRU 5

TABLE 16—Continued
OPERATING CONDITIONS AND CONTROL SETTINGS

Operating Conditions and Control Settings:
Transmitter adjusted for 100-watt, CW operation.
TEST KEY: locked ON position.

Step		Preliminary Action	Read Indication On	Perf. Std.																																												
No.	Action Required																																															
4 **	Record PA METER readings (100-watt operation).	Set PA METER SELECTOR switch (S1386) to I_{c1} , I_{c2} , and I_t , in turn. Record meter indication for each position and with transmitter adjusted for each of the frequencies indicated in PERF. STD. column.	PA CURRENT meter (M1303).	<table><tr><td>mc</td><td>I_{c1}</td><td>I_{c2}</td><td>I_t</td></tr><tr><td>.35</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>2.5</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>5.5</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>6.5</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>11.0</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>15.5</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>16.5</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>21.0</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>25.5</td><td>—</td><td>—</td><td>ma</td></tr><tr><td>(10 to 20)</td><td>(20 to 80)</td><td>(150 to 300)</td><td></td></tr></table>	mc	I_{c1}	I_{c2}	I_t	.35	—	—	ma	2.5	—	—	ma	5.5	—	—	ma	6.5	—	—	ma	11.0	—	—	ma	15.5	—	—	ma	16.5	—	—	ma	21.0	—	—	ma	25.5	—	—	ma	(10 to 20)	(20 to 80)	(150 to 300)	
mc	I_{c1}	I_{c2}	I_t																																													
.35	—	—	ma																																													
2.5	—	—	ma																																													
5.5	—	—	ma																																													
6.5	—	—	ma																																													
11.0	—	—	ma																																													
15.5	—	—	ma																																													
16.5	—	—	ma																																													
21.0	—	—	ma																																													
25.5	—	—	ma																																													
(10 to 20)	(20 to 80)	(150 to 300)																																														

5 **	Record VOLT-METER indications.	Set VOLT-METER switch (S1384) to BIAS, LV, MV, PA E-2, and PA E- in turn. Record meter indication for each position and with transmit- ter adjusted for each of the fre- quencies indicated in PERF. STD. column. Set SERVICE SELECTOR switch (S1101): PHONE. Set VOLT- METER switch (S1384): PA E-.	VOLT-METER (M1301).	mc BIAS LV MV .35 ——— VDC 2.5 ——— VDC 5.5 ——— VDC 6.5 ——— VDC 11.0 ——— VDC 15.5 ——— VDC 16.5 ——— VDC 21.0 ——— VDC 25.5 ——— VDC (-210 to (270 to (450 to -230) 330) 550) mc E-2 E- E- PH .35 ——— VDC 2.5 ——— VDC 5.5 ——— VDC 6.5 ——— VDC 11.0 ——— VDC 15.5 ——— VDC 16.5 ——— VDC 21.0 ——— VDC 25.5 ——— VDC (950 (1200 to (270 to 1150) 1400) to 330)
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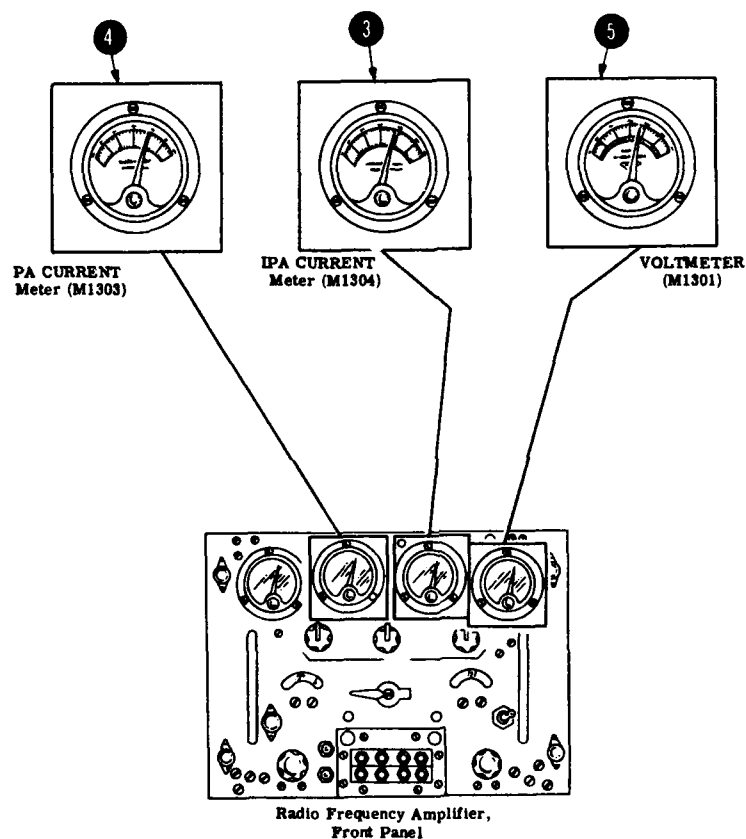


Figure 6-13.—Meters to be read in performing steps 3, 4, and 5 in the Maintenance Check-Off Book.

Some general maintenance procedures may be listed as follows:

1. Check for unusual odors, such as that of hot potting compound, which might indicate an overloaded transformer; burning paint, due to overheated resistors; and burning rubber, due to excessive current through a rubber-covered conductor.

2. Use an air hose to remove dust, dirt, and foreign particles. Extreme care must be exercised when the air hose is used around delicate parts such as tuning capaci-

tors. As a precautionary measure, the air line should be purged of moisture by directing the nozzle toward the floor and releasing the air in the line before directing it toward the equipment.

3. Avoid, if possible, disturbing the layout of the wiring. If wiring must be removed, be sure to return it to its original position after the cleaning procedure to prevent oscillation, feedback, and other circuit disturbances. Check all sockets, and remove any dirt or corrosion with solvent or with fine sandpaper or crocus cloth.

4. After cleaning, inspect the equipment for faulty or damaged parts. Some of these parts include tube sockets and contacts, springs, gears, tuning capacitors, potentiometers, bandswitches, insulators, terminal strips, jacks, plugs, and hinges. Check for and replace or secure loose or damaged hardware.

5. The operating controls should be given a careful visual inspection and then checked for correct operation and setting. Turn each control slowly to its maximum clockwise limit, then to its maximum counterclockwise limit. Binding or scraping should be noted and corrective measures taken.

6. In gear assemblies and in tuning mechanisms backlash must be held to a minimum. Hence, trouble of this sort should be noted and corrected or reported as soon as possible.

7. Replace damaged parts, such as shorted or leaky capacitors or burned out resistors. However, before actual replacement of the damaged part, the circuit should be carefully inspected to find the cause of the trouble. Only in extreme emergencies should replacement be made without a checkup.

8. It is important to remove dirt or corrosion on the prongs of plug-in parts, such as tubes, jacks, and plugs, to avoid a high-resistance connection between the prong and its socket. Use crocus cloth or fine sandpaper.

9. Cables and cords and their jacks and plugs must be checked for damage to their inserts and insulation. Look for opens, shorts, and intermittent contacts. The latter may often be found by wiggling the plugs in their sockets. If damage is found, or if trouble is suspected, use an ohmmeter to check for continuity in the cords and cables.

LUBRICATION.—The lubrication procedure is spelled out in the instruction book. However, the following information is generally applicable to radio transmitters.

When dispensing a lubricant, wipe all dirt, dust, or moisture from around the opening of the container. The containers must be kept closed when not in use to prevent moisture condensation on the surface of the lubricant and to keep dust and dirt out of the container. It is extremely important that lubricants be kept free of foreign matter.

Many of the bearings used in this particular equipment are made of oil impregnated bronze and require no lubrication.

The effects of overlubrication are almost as serious as those of under lubrication. Too much lubricant in ball and roller bearings prevents efficient operation and may cause a good deal of harm from the pressure that is built up in the bearings as they become warm. An excess will cause an overflow of the lubricant onto the machine. The overflow not only collects harmful dirt and grit, but necessitates more cleaning time. In some equipments, breakdowns have been traced to overlubrication. The oil tends to destroy electric insulation; careless handling of the lubricant can result in dirt being carried into bearings with the lubricant.

SPECIAL MAINTENANCE.—Shafts should be checked for dirt and corrosion. Dirt may be removed with an approved solvent. The shafts may also be cleaned with fine crocus cloth to remove obstinate dirt marks. Use a fine file or fine sandpaper to remove burrs. After

cleaning, the shafts should be relubricated according to instructions.

Noise, loss of sensitivity, and improper tuning may be caused by faulty or dirty tuning capacitors. (Serious losses may also occur in certain other tuned circuits.)

Rotor contacts, bearings, and plates may be cleaned with an approved solvent. Pipe cleaners (if available) are especially useful for cleaning between capacitor plates. A small brush, dipped in solvent, may also be used for this purpose. Be careful not to damage or bend any of the plates.

Some relay contacts are plated with thin coats of silver. In cleaning this type of contact, avoid the use of abrasives, which may damage the contact surfaces. These surfaces are cleaned with solvent.

Pitted contacts on heavier relays, such as those used for power contact circuits, are cleaned with a fine grade of crocus cloth. Badly pitted contacts should be replaced singly, if possible; if not, a complete new relay may have to be installed. After being cleaned, the contacts of relays are finished with a burnishing tool.

The moving parts of relays are checked as follows:

1. Check the armature pivot points. They should be free of burrs, rust, corrosion, or any other defect that may prevent free movement. Remove burrs or corrosion with a fine file or fine sandpaper. However, be sure that the shape and location of the pivot points have not been changed.

2. The return spring should be inspected for correct tension. Replace the spring if rusted or damaged.

3. Examine the relay winding for damage to the insulation. Damaged wires or insulation may be repaired with tape or insulated tubing (spaghetti).

4. Check the relay core for corrosion. If corroded, the relay should be replaced to avoid possible future failure.

5. Check the frame; repair or replace if damaged.

Particular care should be used in checking the mating threads when examining jacks and plugs. Any damage

to the threads will make it difficult, if not impossible, to mate the connectors. Clean off grease and dirt with solvent, using a firm, bristle brush. After cleaning and checking the plug or jack, only the threaded part should be relubricated with a thin film of grease. Avoid over-lubrication.

Gears and racks must be checked for dirt and other foreign particles in the gear teeth. Clean off dirt or caked lubricant with a small brush dipped in solvent. The gear shafts may also be cleaned with the solvent. Polish the shaft with a piece of fine crocus cloth, if necessary. After cleaning, the gears and racks are relubricated according to the procedures described in the instruction book.

Wafer switches and detents should be examined carefully to ensure firm spring tension. Weak spots require restoration of spring tension. However, long telephone-type switch or relay contacts should never be bent. These contacts should be replaced, if possible. If the contacts cannot be replaced singly, the entire switch may have to be replaced, because poor contact pressure leads to trouble and eventual failure.

Check the detent actions and the switch shaft. These parts, as well as the switch contacts, may be cleaned with solvent. The various detent assemblies, especially those in the various subunits of the RFO, need careful attention. After a switch or detent has been cleaned, the part should be relubricated as directed in the instruction book.

When inspecting the miniature sprocket-type chains, be sure to check the adjustment of the sprocket idlers. Proper tension on the chains must be maintained at all times. To achieve correct tension, a balance must be found which is a compromise between ease of operation and minimum backlash. In case of severe damage to the chain, it should be replaced. Remove dirt and grease with solvent.

Radio Receivers

INSPECTION, CLEANING, AND ADJUSTMENTS.—The instruction book for each radio receiver lists certain preventive maintenance procedures that must be followed if the equipment is to be maintained in peak operating condition. Of course the instructions will vary, depending on the particular type of receiver, but the preventive maintenance instructions for Radio Receiving Sets AN/SRR 11, 12, 13 is probably typical.

The MONTHLY checks include the following: (1) Inspect to determine if the mounting bolts in the cabinet are tight, and tighten mounting bolts and all external fasteners when loose; and (2) inspect cords and plugs for wear and broken parts. Replace any cord that causes clicking sounds in the earphones when shaken during operation.

The QUARTERLY checks include the following: (1) Remove and replace the chassis in the cabinet. (If the chassis binds on the rails, adjust the chassis tilting fulcrum accordingly and lubricate according to the instruction book.); (2) check each plug-in unit for loose connections and appearance of the component. If the components show signs of overheating, apply corrective maintenance, as given in the instruction book; (3) inspect the chassis for loose interstage connectors (multi-sockets) on the chassis, and tighten as required; (4) inspect the band selector and reception control for loose crank pins that connect to the wafer shafts. If pins are loose they should be tightened according to the instructions given in the instruction book; and (5) remove dust from the chassis and assemblies by the use of a small blower. Remove excess lubricant from the band switch and reception control racks, miter gears, and dial gears. After the cleaning is accomplished, the equipment is lubricated according to instructions.

The SEMIANNUAL checks include the following: (1) Inspect spare assemblies for evidence of physical damage; (2) check alignment of tuning dial and the opera-

tion of the dial light, check the mirror assembly (mirror used for reflecting the frequency scale onto the ground-glass screen), and align the tuning dial and clean the mirror according to instructions. Another semiannual check is that of receiver sensitivity. This is somewhat involved and is treated separately in the following section.

SENSITIVITY CHECK.—The setup for checking the sensitivity of the AN/SRR-11, 12, 13 receiving sets is shown in figure 6-14. Sensitivity checks (in microvolts) are made at various frequencies in the five bands covered by the receiver and under various operating conditions—for example, A1 broad and FSK, A1 sharp, A2, A3 broad, and A3 sharp.

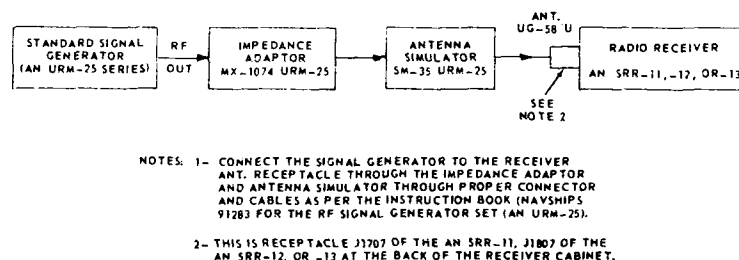


Figure 6-14.—Test setup for receiver sensitivity measurements.

Details for making the sensitivity checks are included in the instruction book and the Maintenance Check-Off Book; and a general treatment of sensitivity measurements is included in chapter 7 of this training course. However, the following brief description of the procedure for making one check (band 1, 14 kc, A1 broad) on the AN/SRR-11 is sufficient to give the general idea.

1. Set the reception control (fig. 12-15) to A1 BROAD, the output control to maximum (10), and the tuning dial to 14 kc.
2. Disconnect the antenna simulator (dummy antenna) from the signal generator and connect a short across the input of the antenna simulator.

3. With the add decibels switch in the -10 db position, adjust the gain control for a noise level of -10 db, as read on the output meter. (This is a total of -20 db with respect to 6 milliwatts, or the equivalent of an output level of 60 microwatts, or 0.19 volt across 600 ohms.)

4. Remove the short across the input of the antenna simulator and reconnect the dummy antenna to the signal generator.

5. With the signal generator set for an unmodulated output, tune the signal generator for a maximum indication on the receiver tuning meter.

6. Set the reception control to A1 SHARP, and adjust the receiver freq vernier to produce a beat note of 1000 cycles per second. This condition produces a maximum reading on the output meter.

7. Set the reception control to A1 BROAD.

8. With the add decibels switch in the 0 db position, adjust the signal generator for 0 db reading on the receiver output meter. (This is the equivalent of an output level of 6 milliwatts, or 1.9 volts across 600 ohms.)

9. Under this condition, the signal generator output level (in microvolts) is a quantitative measure of the receiver sensitivity. This value should be checked against the corresponding value given in the tables in the instruction book. For the particular check discussed (band 1, 14 kc, A1 BROAD) the sensitivity should be 4.7 microvolts.

Radar Equipment

Preventive maintenance (normally done by operators of radar equipment) includes the periodic inspection, cleaning, lubrication, checking of brushes, cleaning and tightening of contacts, calibration, and checking of system performance.

The routine maintenance schedule includes daily, weekly, monthly, quarterly, semiannual, and annual checks. In each case the necessary safety precautions must be taken.

The detailed steps to be taken in the preventive maintenance of radar equipment depend, of course, on the particular equipment being maintained. The following preventive maintenance procedures apply to Radar Set AN/SPS-4, which is described in chapter 12, Common Operating Adjustments.

DAILY CHECKS include checking the calibration of the range step on the range indicator and the echo box ringing time of the transmitter.

WEEKLY CHECKS include cleaning out dust, wiping parts (especially insulators), wiping tubes and checking their seating (including tube clamps), testing spare fuses and replacing any missing spares, and cleaning plastic windows. Other weekly checks include CHECKING AIR FILTERS (a most important check) and making sure that the blowers are running, checking for any arcing in the r-f system, and checking to ensure that the crystal currents are within the correct range (0.4 to 0.6 ma).

MONTHLY CHECKS include such items as checking electrical contacts and the action of interlocks; checking the oil level in the antenna assembly and making sure that the nozzle is clean; lubricating gears, and washer stop assembly on the range indicator; replacing TR and ATR tubes every 500 hours if necessitated because of poor signals or poor recovery time; and listening along the waveguide, r-f system, and antenna for arcing.

QUARTERLY CHECKS are largely of a mechanical nature. Stuffing tubes are checked and repacked if necessary, terminal strips and cables are checked, ferrule resistors and fuses are cleaned, and blown-fuse indicators and dial lights are checked to ensure that they are operative. Other monthly maintenance procedures include such items as replacing tubes missing from tested emergency spares, checking tube pins and sockets for corrosion, checking for corrosion in other places and applying touch-up paint as needed, lubrication, checking brushes on the antenna main drive motor and the slip rings, and cleaning the r-f system and tubes as needed.

The SEMIANNUAL CHECKS include greasing certain points in the antenna well, checking the brushes on the antenna selector switch motor, checking the brushes on the pulse-length switch motor, and oiling hinges and rotors.

ANNUAL CHECKS include a visual inspection of resistors for evidence of overheating, antenna overhaul, synchro and slip ring check, tightening of flange bolts, and certain greasing operations.

The chassis and cabinets are best cleaned with a vacuum cleaner or with clean cloths. A cloth moistened with an approved solvent may be used to clean high-voltage insulators and metal surfaces; the surfaces are finally polished with a dry cloth. Oil and dust must be cleaned out thoroughly, both inside and outside the cabinets. Oil inside a cabinet will usually be caused by a leaky oil-filled capacitor, which should be found and replaced. Oil inside the antenna assembly may be caused by leakage, carelessness in lubrication, or excessive lubrication.

Compressed air or portable blowers may blow dust into relay contacts and into open switches, and should be used cautiously, if at all.

Plastic windows and color filters should be cleaned on both sides with lens tissue or a soft cloth free from abrasive. An approved solvent may be used when needed. Care should be taken to avoid scratching because the plastic is relatively soft.

Air filters are used in the cabinet, modulator, and transmitter. The filters must be cleaned periodically (at least monthly). The accumulated dust is removed by hosing the cleaner with hot water or allowing water to float through the cell from the clean side. The cell is then washed in a solution of hot water and washing compound, rinsed, and allowed to drain. The cell is then recharged by immersion in light machine oil and allowed to drain for at least twelve hours. An alternative method of recharging is to spray the cleaner with a hand-oper-

ated spray gun until the cleaner has received as much oil as it will take without dripping.

Ceramic insulators should be kept clean to prevent leakage and possible arc overs. If wiping with a clean cloth is not sufficient, a cloth moistened with an approved solvent may be used. The insulator is then polished dry with another clean cloth.

Ferrule resistors and fuses should be removed from their clips, and corrosion and dirt removed from the components and the clips. To ensure correct replacement they should be removed and replaced one at a time, FIRST TURNING OFF ALL POWER. A clean cloth moistened with an approved solvent will usually be sufficient, but in some cases crocus cloth or fine sandpaper may be required.

A clean dry cloth (which will not leave any lint) will usually suffice to remove dust from tubes. Great care must be exercised in cleaning tubes that operate at high temperature because a layer of dust interferes with heat radiation and raises the operation temperature of the envelope. When cleaning is completed, the tubes must be inspected to see that they are properly seated and all clamps locked.

Both sections of the TRANSMITTER INTERLOCK SWITCH should be inspected. These ordinarily will not require attention unless a switch is opened under load, such as during conditions of extreme shock or when the unit is opened when the power is on. Contacts should be cleaned with crocus cloth or fine sandpaper. A burned switch should be replaced.

The CABINET INTERLOCKS are of the microswitch type and require no servicing except replacement in case of failure.

The GROUNDING SWITCH in the modulator power supply is a safety switch and normally will receive very little use. When necessary its contacts may be cleaned with crocus cloth.

RELAYS and RELAY CONTACTS should be cleaned peri-

odically. Any dirt found should be removed and the contacts inspected. If the contacts are clean and bright and the relay is functioning normally, it should be left alone; but if the contacts are dirty or pitted, they should be cleaned. The use of carbon tetrachloride or alcohol for cleaning contacts is not satisfactory because it leaves an insulating film. Other unsatisfactory methods include the use of a file (it leaves a rough surface that impairs the wiping action), crocus cloth (it leaves a rough surface and a coating of rouge), emery cloth (it leaves emery embedded and causes arcing), and sandpaper (it leaves sand particles and causes arcing). The use of a burnishing tool is the accepted method.

It is extremely important to maintain electrical contacts in good condition because faulty electrical contacts can cause equipment failure at a critical time.

ANTENNA SLIP RINGS should be inspected once a year during overhaul. If dirty, they should be cleaned with a cloth pad on a stick; if extremely dirty or oxidized, they may be burnished with crocus cloth or very fine sandpaper sufficiently worn to remove loose sand particles. Do NOT use emery cloth on slip rings.

In general, all R-F CONTACT SURFACES and the interiors of resonant cavities should be kept as clean as possible to ensure maximum performance. A vacuum cleaner may be used to remove loose (dust) particles. Where the surfaces can be reached, as in TR and ART cavities, they should be cleaned with lens tissue moistened with an approved solvent and then dried carefully with clean tissue.

CORROSION SPOTS on metal surfaces should be cleaned and touched up with suitable paint. The cause of the corrosion should be carefully investigated and steps taken to prevent its recurrence. Possible causes may be open heater resistors or defective thermal switches.

LUBRICATION is an extremely important part of preventive maintenance. Insufficient lubricant in the antenna will eventually cause failure of the equipment.

Insufficient lubricant in the range indicator will cause damage to the stop assembly for the range step crank, but system operation will not be affected otherwise. Routine lubrication at these points as well as at other less vital points is indicated in the lubrication chart in the instruction book.

BRUSHES are used only in the modulator and antenna. The two modulator brushes are in the pulse-length switch motor; they should last almost indefinitely because of their light service. The antenna brushes receive moderate service and must be checked more frequently; there are two brushes in the main drive motor, and a brush lock assembly inside the antenna pedestal which contacts the seven slip rings on the motor.

In general, frequent checking of brushes is a simple way to prevent possible equipment failure. Brushes should always be replaced before they are worn to the minimum length specified in the instruction book. Spare antenna brushes are contained in equipment spares; spare modulator brushes are secured to the chassis of the pulse-length switch.

Certain ROUTINE MECHANICAL CHECKS are necessary. Terminal strips should be cleaned and terminal screws checked for tightness at regular intervals. It is important not to overtighten terminal screws, but because they sometimes work loose, they should be checked.

Cables should be inspected for looseness or damage at unit entrances, and at any other point in a run where the cable is subject to damage from heat or other abuse. Cables showing signs of damage should either be rerouted or suitably protected. Particular attention should be given to coaxial cables, which are easily damaged by dents or sharp bends.

Certain ROUTINE ELECTRICAL CHECKS are also necessary. Blown-fuse indicators are checked by removing and replacing the fuses, one at a time, with the power on. INSULATED FUSE PULLERS MUST BE USED for all fuses held by fuse clips, and care must be taken to avoid

injury from shock. With the circuit energized, the indicator lamp should not glow when a good fuse is in place but it should glow when the fuse is removed. If the operation is abnormal, corrective maintenance will be required.

When a dial lamp burns out, it must be replaced.

The calibration of the range step should be checked only after the range indicator has been running for at least one-half hour. Unless extensive experience indicates otherwise, this check should be made daily. An approximate check of the calibration can be made by ranging on targets of known or measured ranges, using either optical or electronic fire-control radar equipment.

The echo-box ringing time is very important, and a check should be made during each day of operation. The check will be made during each operator's watch if so prescribed. This check will ensure peak performance of the system, and minimize system failure by indicating faulty operation in its early stages.

Sonar Equipment

The following information is condensed from Section 6 (the preventive maintenance section) of the instruction book for Sonar Sets AN/SQS-10, 10A, 11, 11A. As is true of all electronic equipment, the instruction book (or the appropriate POMSEE book or both) must be consulted before preventive maintenance is undertaken.

Maximum performance can be expected from this equipment only when it is constantly maintained in first class operating condition. Constant vigilance is therefore necessary on the part of maintenance personnel who are charged with maintaining this equipment in peak condition. To aid them, a complete set of performance tests and adjustments is provided. The tests are thorough and should be performed only by competent personnel.

Because the equipment operates on 117-volt, 60-cycle power, the voltage regulator must be adjusted (if neces-

sary) to meet the 117-volt requirement before any tests or adjustments are made.

To perform the required tests the following test equipments are needed: (1) a d-c microammeter, (2) a capacitance-inductance-resistance bridge, (3) a signal generator, (4) a r-f signal generator, (5) a tube tester, (6) a sonar portable testing equipment, (7) an audio oscillator, (8) an oscilloscope, and (9) three types of multimeters.

Monthly performance tests and adjustments are made by the operators as follows: (1) cathode-ray tube adjustments, (2) training control system checks, (3) a-f r-f amplifier checks, (4) scanning switch circuits check, (5) receiver circuit tests and adjustments, (6) video azimuth alignment, (7) keying control circuits check, (8) transmitter operation checks and adjustments, (9) maintenance of close contact circuit checks, and (10) transducer leak detector check.

Careful attention should be paid to the instructions for lubricating this particular equipment. All bearing surfaces in the equipment are lubricated at the time of manufacture, and no provision is made in the equipment for periodic lubrication of assemblies and parts without complete disassembly. It is recommended that when assemblies and parts require lubrication they be returned to a competent repair facility such as on board tenders and at Navy yards where correct lubrication procedures have been established.

Radiac Equipment

Station personnel may perform limited maintenance of radiac equipment, but such work is restricted to repairs that **DO NOT AFFECT CALIBRATION**. Radiac repair is accomplished by technicians at a radiac repair facility.

Currently, most of the difficulty with shipboard radiac equipment seems to be caused by dead batteries, electronic circuit failure, corroded battery compartments and physical damage, of which corrosion appears most frequently and proves most serious.

The battery (BA-401) used in the AN/PDR-27 equipments (see chapter 11 of this training course) is not leak proof and the outer can is of thinner material than many other batteries; as a result, it is subject to rupture by internal chemical action. The BA-30 battery used in the AN/PDR-18 equipments is leak proof; however, instances have been noted in which substitute nonleak-proof batteries have caused corrosion difficulties.

The following points from EIB 469 should be kept in mind:

1. Radiac equipments are extremely sensitive and should be checked when brought aboard ship. If not immediately stowed, they should be checked before stowage.
2. The location of stowage should be readily accessible for frequent inspections, and these inspections should be made frequently.
3. Strict adherence to the regulation of *BuShips Manual*, article 67-120 is mandatory.

The routine maintenance checks for a typical radiac equipment (Radiac Set AN/PDR-27G) include the following:

Weekly

1. Check the battery condition by turning the range switch to BATT COND (meter pointer should rest at right of black line marked BATT).
2. Clean exterior surfaces with clean dry cloth.
3. Tighten front panel screws as needed.
4. Check range-switch knob and tighten as needed.
5. Clean and tighten radiac calibration port plug as needed.
6. Check and tighten packing nut at both ends of radiac detector tube as needed.

Monthly

1. Check radiacmeter with radioactive test sample. (This check is made only to determine if the equipment is working; it is NOT a calibration check.)

2. Check headset for dirt and loose screws and connections.

CORRECTIVE MAINTENANCE PROCEDURES

To perform effective corrective maintenance the ET must have a good working knowledge of the basic principles of electricity and electronics. The only way to acquire this knowledge is by diligent study. The ET must also be thoroughly familiar with the theory of operation of the equipments that he must service. A knowledge of the theory of operation can be acquired through a study of the "Theory of Operation" section (generally, section 2 of current instruction books) of the equipment instruction book. In the new technical manuals, a different procedure will be followed. This knowledge should be broadened to include other equipments at the earliest opportunity. As a matter of fact, ET's are generally rotated on the various electronic equipments so that their knowledge will be broadened and they will therefore be more valuable to the fleet.

Skill in the use of test equipment (and hand tools) is also necessary for effective corrective maintenance. Skill in the use of test equipment comes with practice and with careful study of the instruction book that comes with each piece of test equipment. The ET should take advantage of every opportunity to learn more about every type of electronic test equipment used aboard ship. The ability to use test equipment effectively is an absolute must for every well trained ET.

Chapters 7 and 8 of this training course will introduce the prospective ET to some of the more common test equipments. Additional valuable information (both on test equipment and methods of troubleshooting) is contained in *Handbook of Test Methods and Practices*, NavShips 91828(A). A list of the various electronic test equipments (also troubleshooting methods) is included in the *Electronics Maintenance Book*, NavShips 900,000.

This portion of the chapter treats, in a general way, some of the corrective maintenance procedures used for the various types of electronic equipment. Detailed procedures for troubleshooting each piece of electronic equipment are contained in the instruction book for that particular piece of equipment. One of the most valuable items in the instruction book is the troubleshooting chart. These charts will be discussed under the various types of electronic equipment.

Importance of Tests and Measurements

Tests (for example, for opens, grounds, and shorts) and measurements (for example, current, voltage, resistance, frequency, power, etc) enable the technician to diagnose troubles so that repairs may be made. In many instances tests and measurements will indicate conditions that may be corrected before an actual breakdown occurs. Thus, tests and measurements (particularly measurements) are important both in preventive and corrective maintenance.

The purpose of any type of electronic test equipment is to measure accurately certain circuit values or to indicate certain circuit conditions. Each of these measurements or indications is used to determine the operating condition of electronic or electrical equipment. The accuracy with which measurements are made depends on the type of instrument used, its sensitivity, its rated accuracy, its useful range, and the care that the technician uses in making the measurement.

The exact procedure for making tests and measurements is given in the technical manuals (instruction books) that accompany the various electronic equipments.

Utilizing Results of Measurements

It should be emphasized that the mere taking of measurements means little unless they can be properly interpreted. For example, the presence of a direct potential across a grid resistor in an audio amplifier would mean

little to an ET unless he could interpret this in terms of a possible leaky coupling capacitor. In this connection, the necessity for a knowledge of basic circuit operation must be emphasized.

Before any attempt is made to interpret the results of measurements, an understanding of how the equipment operates should be acquired by a careful study of the applicable technical manual or instruction book.

The actual voltage, resistance, and current measurements that should be obtained are indicated in the circuit diagrams, charts, or in the performance standards or check-off books. The same is true of waveform measurements. Any deviation from the standard values (beyond the tolerance limits) means that some component is not doing the job that it should. By applying effect-to-cause reasoning, the defective component may be located. This is, of course, a job for a skilled technician.

Isolating the Fault

According to the "quals," the prospective ET 3 must be able to localize equipment casualties to components of a system of electronic equipment; he must be able to localize electronic equipment casualties to parts or sub-assemblies and to make the repair by replacement of subassemblies or parts. However, it is conceivable that under certain circumstances, especially on smaller vessels, the ET 3 may have to effect the entire repair. In any case, the "quals" spell out only the minimum qualifications for advancement in rating, and the prospective ET 3 should in no way restrict his knowledge or his ability to make repairs.

There are numerous ways to isolate a fault to a component of a system, depending on the type of equipment. The technician must, first of all, know what each component does before he can know that it is not functioning properly.

Assume, for example, that the display on a certain radar repeater is faulty. The trouble could be in the

repeater or it could be in one of the circuits that feeds into the repeater. If the other repeaters are working properly, it is probable that the trouble is in the repeater having the faulty display or in its power supply or in the transmission lines or switching system.

The best way (the most economical in time and effort) to isolate a fault is by the use of the troubleshooting chart in the instruction book. Troubleshooting charts are included in the discussion of corrective maintenance of the various types of electronic equipment in the remaining portions of this chapter.

Radio Receivers

By far, the largest section of the average instruction book is the one devoted to corrective maintenance. This is the section written especially for the ET; and for him it will very likely be the most valuable part of the book. However, the section on theory of operation is also important and should be studied with care.

The following information, condensed from the corrective maintenance section of the instruction book for Radio Receiving Sets AN/SRR-11, 12, 13, will give a general idea of the procedures used in performing corrective maintenance on radio receivers. Of course, the instruction book for the particular receiver being serviced must be used in every instance.

The following test equipment is needed:

1. Multimeter (AN/PSM-4, TS-352/U series).
2. Electronic Multimeter (ME-25/U series).
3. R-f Signal Generator (AN/URM-25), with the necessary impedance adapter, antenna simulator, and test lead having isolating capacitor.
4. Audio Oscillator (TS-382A/U or higher, Navy Model LAJ series).
5. Heterodyne Frequency Meter (Navy Model LR series).
6. Oscilloscope (OS-8/U Model OBL or OBT series).
7. Tube Tester (TV-3/U series).

When trouble occurs, the first step is to establish in which assembly the fault exists. The faulty assembly can then be replaced if a spare one is available, or repaired if there is no spare assembly.

Most of the assemblies are divided into subassemblies, many of which plug into the assembly. Each plug-in subassembly contains a subminiature electron tube and associated parts.

Plug-in subassemblies are of two types: plug-in boards and plug-in units. The plug-in boards are located in the antenna, r-f, mixer and oscillator assemblies; the plug-in units are in the first i-f, second i-f, audio, BFO, and crystal-calibrator assemblies. The tuning dial and filter assemblies do not contain electron tubes.

The procedure given in the troubleshooting chart in the instruction book will permit the ET to quickly and systematically check the functioning of the radio receiver by observation of the indicators that are built into the equipment.

Two of the indicators (the tuning meter and the output meter) check the signal circuits; the other two indicators (the pilot light and the dial light) check the power circuits. If the technician follows the exact procedure given in the troubleshooting chart, he can localize the trouble to an assembly or system. After the trouble has been localized to an assembly or system the detailed troubleshooting procedure (also given in the instruction book) may be used to locate the defective component (tube, resistor, capacitor, etc).

The troubleshooting chart from the instruction book is reproduced in figure 6-15. When trouble occurs, the chassis should be inspected for charred insulation, discoloration of parts, leakage of potting compound, or other indications of abnormal operation. If the parts appear normal, the ET then proceeds to track down the trouble by the use of the trouble shooting chart, as follows:

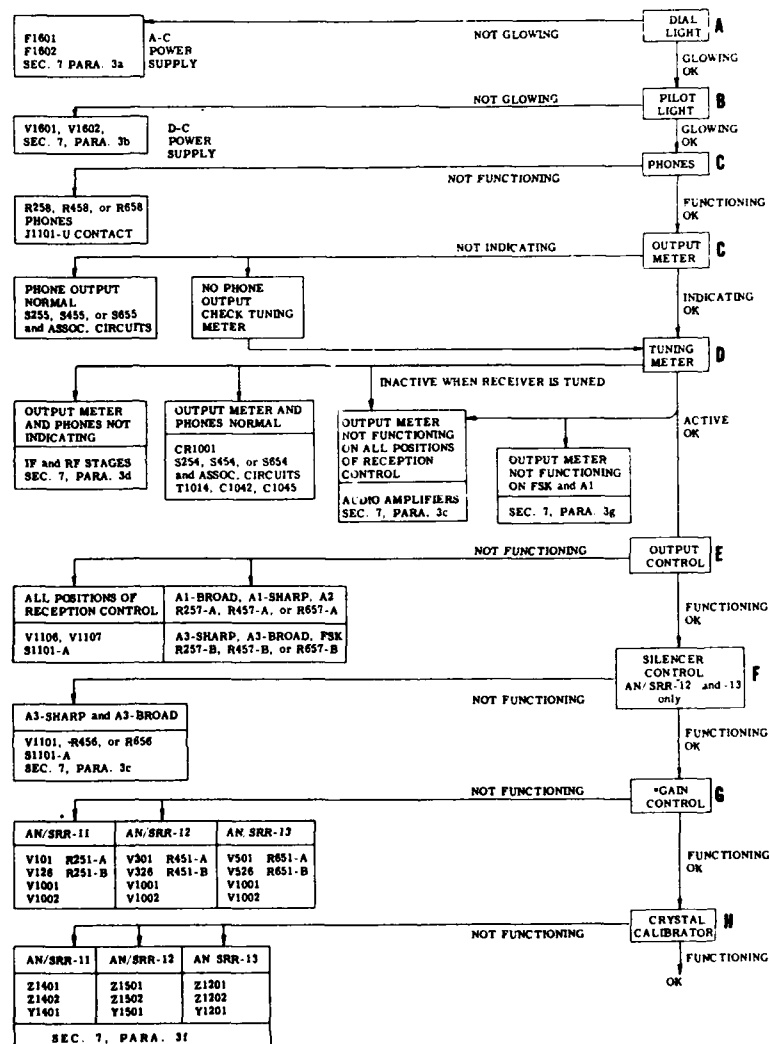


Figure 6-15.—Troubleshooting chart for Radio Receiving Sets AN/SRR 11, 12, 13.

1. Turn the power switch ON and check the dial light. If the light glows, the power input and power transformer primary circuits are operating. In this case, move on to the next step, B. If the dial light does not

glow, switch the lamps control to the SPARE position; if the dial light still does not glow and the receiver is dead, then replace the fuses (F1601 and F1602) located in the bottom of the power supply assembly. If this does not cure the trouble, the ET should then consult the detailed troubleshooting procedure included in the instruction book.

2. Check the pilot light. If the light glows, the d-c power supply is operating. In this case move on to the next step, C. If the pilot light does not glow, replace it if it is burned out. If the light still fails to glow, replace V1601 and V1602 in the power-supply assembly. If these measures fail, consult the detailed troubleshooting procedure.

3. Check the output meter and phones while attempting to tune in a signal. If the output meter and phones BOTH give an indication of signal, then the receiver is operating, but other associated devices such as the crystal calibrator or tuning meter may not be operating. For a more thorough check, move on to the next step, D. If only one of the indicators (the output meter OR the phones) gives an indication of signal, then the trouble lies within the immediate circuits of the other. This trouble can be localized by taking resistance measurements of the faulty circuit. Refer to the appropriate schematic diagram. If the output meter AND the phones BOTH do not give an indication of signal then move on to the next step, D.

The same general procedure is followed for six more steps, as indicated in the troubleshooting chart.

Radio Transmitters

Corrective maintenance in radio transmitters follows much the same pattern as in radio receivers, except that more indicators are likely to be involved in the use of the system troubleshooting chart. Consider for example, the Radio Transmitting Sets, AN/SRT 14, 15, 16.

The following test equipment is required:

1. Multimeter (ME-25A/U).
2. Oscilloscope (OS-8A/U).
3. Frequency Meter (AN/USM-29 or AN/FRM-3).
4. Receiver (RBA, RBB, RBC, or equivalent).
5. Audio oscillator (TS-382A/U).
6. Dummy Load (DA-91/U).
7. R-f Signal Generator (AN/URM-25).
8. D-c Ammeter (Navy type 60,107 or Multimeter AN/PSM-4).
9. Resistance Bridge (ZM-4/U).
10. Radio-Frequency Bridge (Navy type 60094).
11. One-megohm, linear taper potentiometer.

Like most transmitters, this equipment operates at high voltages that are dangerous to life. Therefore, safety regulations must be observed at all times. Do not change tubes or make adjustments inside the equipment when the high voltage is on; do not use the "battle short" for bypassing interlocks. Never measure potentials in excess of 1000 volts by means of flexible test leads or probes.

The manner in which this equipment operates or fails to operate often indicates the source of trouble. A knowledge of the control circuits (see chapter 12 of this training course) is most important for the localization of faults. It is, of course, necessary for the ET to become familiar with the simplified power and control schematic diagrams in the instruction book. The sequence of operations that result in the establishment of a carrier frequency is accomplished by visual panel indications.

The order in which the visual indications appear is shown in the system troubleshooting chart (in the instruction book), a small portion of which is included in figure 6-16. If the proper sequence of events does not take place, trouble is indicated.

The heavy blocks tell what is to be observed, and the heavy arrows between these blocks point in the direction

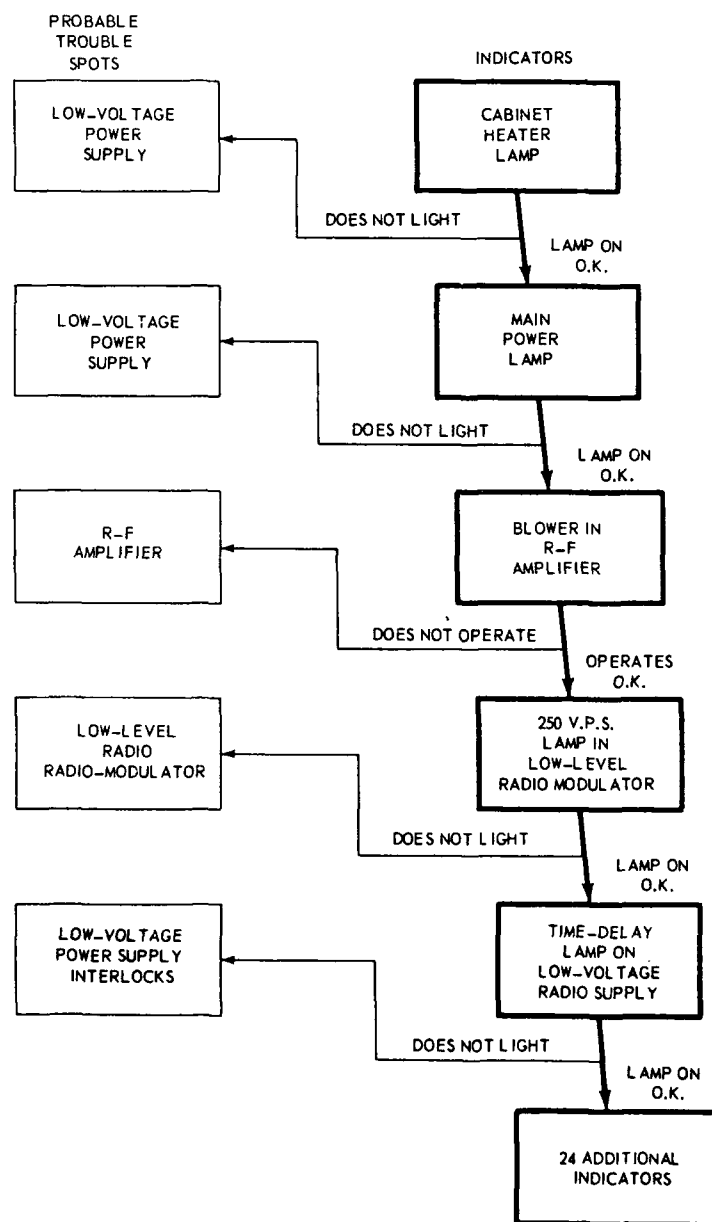


Figure 6-16.—First five indicators in the AN/SRT 14, 15, 16 troubleshooting chart.

of the sequence of indications that should be obtained (when the transmitter bay is operating properly) from the time that main power is applied to the time that the carrier is keyed on the air. Indications of proper operation are listed in the general order in which they occur. Each indication along the heavy path is evidence of proper operation only if all preceding indications have been obtained. However, some of the indications may occur simultaneously.

If the proper indication is not obtained, the lighter blocks (to the left) name the unit (or units) in which trouble may exist. The ET should then refer to the portion of the instruction book that gives troubleshooting information for that particular unit. If the proper indication fails to occur, the ET should first check the indicating component.

A dummy load (type DA-91/U) may be used during tests and maintenance procedures to avoid radiating an r-f carrier from the antenna.

Radar Equipment

The localization of trouble in an equipment as complex as a radar set (for example, Radar Set AN/SPS-8A) demands an orderly and systematic approach if the trouble is to be located and corrected as quickly as possible. To this end, the first step in the troubleshooting procedure should be an attempt to localize the trouble to a particular unit or circuit. This is usually accomplished by a process of elimination. The ET must take time to analyze the trouble and consider the possible sources before beginning to make any actual physical or electrical checks on the equipment.

Use should be made of the equipment oscilloscope to help localize troubles. There are also test points throughout the equipment that afford readily accessible voltage and waveform checks. The corrective maintenance section of the instruction book includes voltage tables, troubleshooting charts, pictures, and circuit diagrams,

all designed to make troubleshooting as easy as possible for the ET. The use of the instruction book is a must.

In the case of Radar Set AN/SPS-8A, a large number of troubleshooting charts are included in the instruction book. The first chart covers system troubleshooting. Following this, there are charts on the power systems, the synchronizer, the trigger amplifier, the modulator, and so forth; actually, there are 17 troubleshooting charts in all.

The following test equipments are needed:

1. Multimeter (AN/PSM-4 or TS-352/U series)—used for general-purpose testing.
2. Synchroscope (AN/USM-24 or TS-34AP)—used to check waveforms.
3. Electronic Multimeter (ME-25/U series)—used for general-purpose testing.
4. 30-mc Signal Generator (AN/URM-25 or 26 series)—used for checking receivers.
5. 39- and 60-mc Sweep Signal Generator (TS-452/U series)—used for checking receivers.
6. 3400-3600-mc Signal Generator (TS-403/U series)—used for checking AFC and minimum discernible signal.
7. Crystal Checker (TS-268/U)—used for checking receiver crystals.
8. Dummy Director (Mark 1 Mod 3)—used for checking servo systems.
9. Ammeter (SNSN G17-A-5900)—used for measuring amplidyne outputs.
10. Gunner's Quadrant (Mark 6 Mod 1)—used for checking antenna level.
11. Resistance Bridge (ZM-4/U)—used for checking sine and cosine potentiometers.
12. Power Bridge (TS-295/UP)—used for transmitter power measurements.

The system troubleshooting chart for Radar Set AN/SPS-8A is shown in figure 6-17. This chart is much

the same as those discussed under radio receivers and transmitters. However, it is a SYSTEM troubleshooting chart. If a system defect is indicated the ET must then use the tables (actually, individual troubleshooting charts) indicated on the left of the figure. As has been

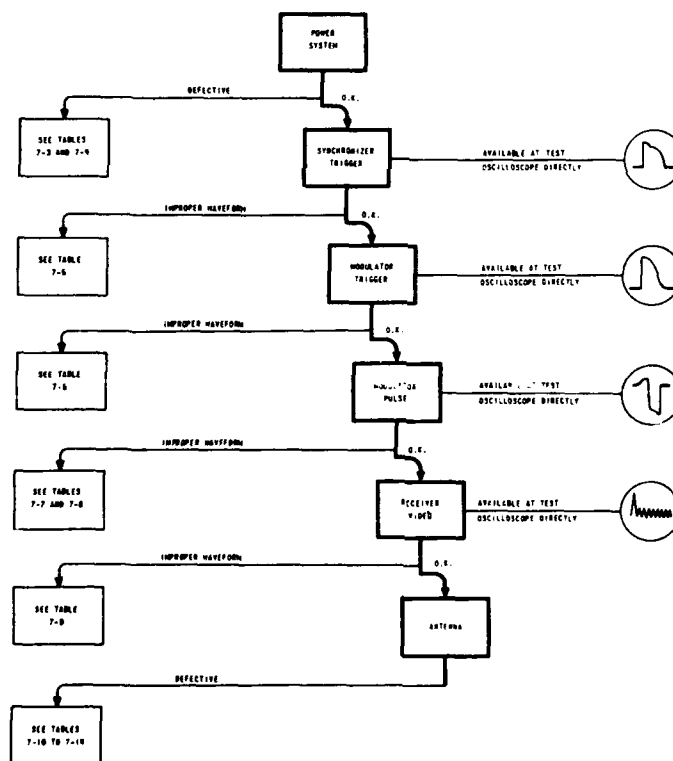


Figure 6-17.—System troubleshooting chart for Radar Set AN/SPS-8A.

mentioned, there are 17 troubleshooting charts in all. The ET will find the over-all servicing block diagram (in section 7 of the instruction book) a great help when he uses the system troubleshooting chart.

Sonar Equipment

The need for corrective maintenance of sonar equipment (or any other electronic equipment) becomes apparent when the equipment is unable to perform one or more of its functions properly. The corrective maintenance portion of the instruction book is therefore generally arranged according to functions of the equipment. This is especially true of the instruction book for Sonar Sets AN/SQS-10, 10A, 11, 11A.

Basic technical information and schematic diagrams of the seven fundamental circuits of the equipment are included in the instruction book. The seven basic circuits are (1) primary power, (2) keying, (3) indicator, (4) transmission, (5) directional sensitivity, (6) synchro system, and (7) three-channel receiver.

The location of trouble in a complicated system (such as in Sonar Sets AN/SQS-10, 10A, 11, 11A) is always accomplished most quickly and simply by checking the various functions of the equipment. If only one function is inoperative, the circuits concerned solely with that function should be investigated first. If two or more functions are inoperative, it is likely that the fault lies in a circuit common to both circuits. For this reason, whenever trouble is observed in one function of an equipment, a quick check of other functions should be made first before an attempt is made to localize the fault.

In the instruction book for this particular sonar set several quick checks are suggested to help the service personnel trace the trouble to a particular circuit. After these checks are made, the suspected circuits should be investigated by the use of the appropriate schematic diagram.

A troubleshooting chart for the over-all equipment is included in the instruction book. In the various blocks of the chart are numbers, which are keyed to paragraphs in the corrective maintenance section of the instruction book. These paragraphs give detailed corrective maintenance procedures that are to be followed.

Although repairs can be effected by following the procedures specified, it is nevertheless obvious that intelligent maintenance requires a thorough familiarity with the theory of operation of the equipment on a functional basis. This may be obtained from section 2 (Theory of Operation) of the instruction book.

QUIZ

1. Operational maintenance is usually done by what ratings?
2. Technical (corrective) maintenance is usually done by what types of ratings?
3. Essentially all electronic equipment can be subdivided into what four categories?
4. Why is the periodic cleaning of the interior of equipments employing high voltage particularly important?
5. What is the derivation of the term, POMSEE?
6. Briefly, what are four factors that combine to cause radar antenna lubrication troubles?
7. (a) Why should pressure-type fittings be kept as clean as bright work and (b) the hole cleaned out with a pin before the grease gun is applied?
8. (a) What is a likely result of over-lubrication, for example, when grease is forced through the bearing housing seals and into the windings?
(b) Excessive grease in the bearing housing results in what four effects?
9. Why must the brush seater be applied exactly at the heel of each brush during the seating operation?
10. Why should emery cloth, emery paper, or emery stone NEVER be used on a commutator?
11. With respect to air filters, (a) what is their function; (b) why must they be cleaned or replaced often?
12. Why is it not possible to measure the insulation resistance of some antennas?
13. What usually causes leakage current over the surface of an insulator?
14. What is the leading cause of failure or poor operation of electronic equipment?

15. Is the practice of wholesale removal and test of electron tubes on a periodic basis permitted?
16. How does the 1N23CR crystal differ from the 1N23C crystal?
17. Why should crystal rectifiers be stored in a metal box or wrapped in metal foil when not in use?
18. What are three possible operating conditions that might cause crystal rectifier impairment?
19. What is the best way to maintain earphones and microphones?
20. When a wiring layout is disturbed during maintenance, why is it necessary to return it to its original position?
21. Why should relay contacts that are plated with a thin coat of silver be cleaned with a solvent rather than with abrasives?
22. What is the quantitative meaning of the sensitivity of a radio receiver?
23. What is included in the daily checks for Radar Set AN SPS-4?
24. How often should the air cleaners of Radar Set AN SPS-4 be checked?
25. What is the usual cause of oil inside the cabinet of Radar Set AN/SPS-4?
26. Why is it especially important to clean electron tubes that operate at high temperatures?
27. What instrument must be used for changing all fuses held by fuse clips?
28. Maintenance of radiac equipment by station personnel is restricted to what type of repairs?
29. What is the only way to acquire a good working knowledge of the basic principles of electricity and electronics?
30. What is the purpose of any type of electronic test equipment?
31. What two sections of the average instruction book are of most value to the ET?
32. In Radio Receiving Sets AN/SRR-11, 12, 13, (a) which two indicators check the signal circuits; (b) which two indicators check the power circuits?
33. What is the maximum potential that may be measured by means of flexible test leads?
34. What should be the first step in troubleshooting Radar Set AN SPS-8A?

CHAPTER

7

PRACTICAL APPLICATIONS OF TEST EQUIPMENT

INTRODUCTION

One of the most important parts of the ET training program is learning to use test equipment in all types of maintenance work. To be effective in his work, the ET must become familiar not only with the common types of measuring instruments (like the ammeter, voltmeter, and ohmmeter) but also with the more specialized equipment like oscilloscopes, synchrosopes, power and frequency meters, impedance bridges, echo boxes, and so on.

The purpose of this chapter and the next is to better acquaint the technician with the practical use of test equipment. A cabinet or room full of test equipment is of little value if the technicians are not familiar with its use. Also, outdated or specialized equipment for testing or servicing electronic equipment that is no longer aboard ship is of no value and takes up valuable space.

In the POMSEE books the necessary instruments for testing the electronic equipments are listed near the front, and the technician will do well to become familiar with these instruments.

The next most important thing, after learning how to use a test instrument, is to learn how to take the proper care of the instrument. Practically no test instrument will stand up under abuse. A damaged test instrument

that reads incorrectly is, in many instances, worse than having no instrument at all. A large percentage of test equipment failures can be avoided by careful handling, proper use of the equipments, and proper stowage at sea.

Much of the theory of operation and the practical application of the basic types of test instruments used in electric power and lighting circuits are included in Chapters 9 and 16 of *Basic Electricity*, NavPers 10086. A brief treatment of electronic test equipment is included in Chapter 13 of *Basic Electronics*, NavPers 10087. It is suggested that these chapters be reviewed at this time. Additional practical information will be found in the latest edition of *Handbook of Test Methods and Practices*, NavShips 91828(A), and in the instruction books that accompany the various equipments. Another very valuable source of information is *Electronic Test Equipment Application Guide*, NavShips 91727. This publication lists the preferred electronic test equipment in current use by the Navy and gives the characteristics of each piece of equipment.

Some idea of the extent of the test equipment needed aboard ship may be gained from the following list of equipments used for testing electronic gear. The list is not complete; however, it is representative. It is compiled from the available Maintenance Check-Off Books.

AUDIO OSCILLATOR: The Signal Generator TS-382/U series.

ECHO BOX: Echo Box TS-275/UP.

FREQUENCY METER: The LM, FR-4/U, AN/USM-29, and AN/URM-82 series. About 18 different frequency meters (including both the absorption and the heterodyne types) are included in *Electronic Test Equipment Application Guide*, NavShips 91727.

INSULATION TESTER: The Insulation Test Set AN/PSM-2 and Navy Models OCW and 60089 Insulation Resistance Testers.

MICROAMMETER: D-c Microammeter Navy Model 60107.

MULTIMETER (ELECTRONIC): The ME-25/U series.

ELECTRONIC VOLTMETERS: The ME-6/U series.

MULTIMETER (NONELECTRONIC): The AN/PSM-4 and TS-352/U series.

OSCILLOSCOPE: The OS-8A/U; AN/USM-24, 32, and 38 series; and TS-34/AP series.

POWER METER: The TS-230B/AP series. About 14 power-measuring equipments are listed in NavShips 91727. They cover various frequency ranges and have various degrees of accuracy.

RANGE CALIBRATOR: The TS-358/UP and TS-573/UP series.

SIGNAL GENERATOR: The AN/URM-25B series. Over 30 signal generators are listed in NavShips 91727.

SYNCHROSCOPE: There seems to be no clear line of distinction between synchrosopes and oscilloscopes. Actually, a synchroscope is a special type of oscilloscope. Several have already been listed under oscilloscopes—for example, the AN/USM-24 and 32, and TS-34/AP series.

WATTMETER, R-F: AN URM-43.

WAVE AND POWER METER: Wave and Power Meter Set TS-107A/TPM-1.

TYPES OF MEASUREMENTS

Current, Voltage, and Resistance Measurements

The instruments and methods of making current, voltage, resistance, and power measurements in power and lighting circuits are included in Chapters 9 and 16 of *Basic Electricity*, NavPers 10086. It should be noted that the ET's will, in general, use multimeters in their work rather than separate instruments for measuring current, voltage, and resistance. For example, the AN/PSM-4 multimeter (nonelectronic) measures from 0 to 1000 volts a-c in 9 ranges, 0 to 4000 volts d-c in 10 ranges, 0 to 100 megohms in 5 ranges, and 0 to 10 amperes in 8 ranges. The ME-25/U multimeter (electronic) measures from 0 to 1000 volts a-c or d-c in 7

ranges, 0 to 1000 milliamperes in 6 ranges, and 0 to 1000 megohms in 6 ranges.

Capacitance, Inductance, and Impedance Measurements

Combination capacitance, inductance, and resistance measuring instruments commonly make use of some type of bridge arrangement employing standard units of capacitance, inductance, and resistance and some means (for example, a meter) of determining bridge balance. If C , L , and R are determined, X_c and X_L , and Z may be computed for a chosen frequency. An elementary bridge circuit is treated in Chapter 13 of *Basic Electronics*, NavPers 10087.

The Capacitance-Inductance-Resistance Bridge, Type ZM-11/U can be used for measuring other quantities in addition to C , L , and R . It measures the turn ratios of transformers, the dissipation factor of inductors and capacitors, the storage factor (Q) of inductors at 1000 cps, and insulation resistance of capacitors and other parts, as well as leakage in electrolytic capacitors when direct current is used.

Power Measurements

D-c power measurements and power measurements at power frequencies are treated in Chapters 9 and 16 of *Basic Electricity*, NavPers 10086, and will not be repeated in this training course.

R-f and a-f power measurements are also important and will be included in this chapter. R-f power measurements require special equipment and special techniques, and therefore the methods of making these measurements will be described in some detail. Radar, radio, and sonar power measurements are treated in that order.

In the audio-frequency range, power-level measurements are usually expressed in decibels (db) or decibels with a reference level of one milliwatt (dbm). The technician must therefore become familiar with these units.

In the LF, MF, HF, and VHF bands, a dummy antenna and a thermocouple ammeter may be used to obtain reasonably accurate measurements of the power output of a transmitter.

In the UHF and higher portions of the r-f spectrum, special power-measuring equipments employing bolometers are used.

Frequency Measurements

It is necessary to make frequency measurements to ensure that electronic equipments remain on the assigned frequency.

Radio transmitters must be maintained on their assigned frequency (within the allowable deviation limits) in order not to interfere with other transmitters. It is also obvious that if the receiver is pretuned to a set frequency, and the transmitter is off frequency, communication may not be established. It is therefore important that a primary frequency standard be established so that frequency meters (secondary standards) may be accurately calibrated and used to keep the transmitters and receivers on frequency.

The primary frequency standard is supplied by station WWV in Washington and WWVH in Hawaii. Both stations are operated by the National Bureau of Standards. The schedule of services offered by these stations is published in *Radio Navigation Aids*, H. O. 205, issued by the USN Hydrographic Office.

To maintain its communication equipment on frequency, the Navy supplies good secondary frequency standards. These are discussed later in this chapter. Of course, the secondary frequency standard is of little value unless it is accurately calibrated against the primary standard.

Radar transmitters and receivers must likewise be maintained on the correct frequency if maximum use is to be made of the radar system. The components of a radar system are designed to be operated within certain

frequency limits, and these frequency limits must be respected.

Interference could result if radars in the same area were operated on the same frequency; therefore, certain radars may be tuned to operate in different parts of a radar band. Except for beacon operation, a knowledge of the receiver frequency is not very important as long as the receiver is carefully tuned to the transmitter frequency.

Frequency measurements are also important in sonar testing.

Field-Intensity Measurements

The field intensity, or strength, of a radio wave at a given point is, in most cases, a measure of the strength of the electric field component of the wave at that point. It is usually measured in terms of the number of millivolts or microvolts induced in an antenna one meter long.

Several types of test equipments for measuring field strength and interference are available to the technician. They are known generally as noise-field intensity meters. With this equipment, it is possible to measure either the **RELATIVE** or the **ABSOLUTE** magnitude of the field intensity produced by the energy radiated from an antenna. By the use of these instruments the directivity of an antenna may be determined, favorable antenna sites may be discovered, field patterns of an antenna may be plotted, and spurious radiation detected.

The measurement of relative field strength can be done with simple test equipment. It may consist of only a grid-dip meter or a pickup antenna, a tuner, a rectifier, and a microammeter.

For measuring the absolute field strength, more elaborate equipment is needed. These measurements are treated in more detail in the training course, *ET 1 and C*.

Interference Measurements

A brief treatment of interference (and field-intensity) measurements is included in Chapter 13 of *Basic Elec-*

tronics, NavPers 10087. Instruments similar to those used in making field-intensity measurements are used. One of the simplest methods of locating the source of noise interference is to move about with the noise meter in the suspected area and listen to the audio output by means of a headset. It is often possible to locate the source of interference simply by walking in the direction that gives the largest volume of noise.

Two types of antennas are available for close work: the probe and the loop. The probe is a short wire antenna (approximately 1 ft in length) and operates by electrostatic induction; the loop (approximately 1 ft in diameter) operates by electromagnetic induction. These antennas will often permit the discovery of the individual item in an equipment that is causing the interference—for example, a sparking relay contact.

Sensitivity Measurements

Receiver sensitivity measurements are made to determine whether or not the receiver is performing according to the required sensitivity specifications. The sensitivity is the value of signal voltage (in microvolts) fed to the receiver antenna terminals, which will produce a specified power output (for example, 6 mw) at the receiver output terminals when the signal-to-noise ratio is 10:1.

Receiver sensitivity measurements are very important in that they give a good indication of how well the receiver is performing its function. These measurements are made periodically aboard ship.

The details of how the measurements are made are given later in the chapter.

RESISTANCE, CAPACITANCE, AND INDUCTANCE MEASUREMENTS

A bridge-type instrument like the ZM-11/U may be used to make resistance, capacitance, and inductance measurements. A brief description of the basic circuitry

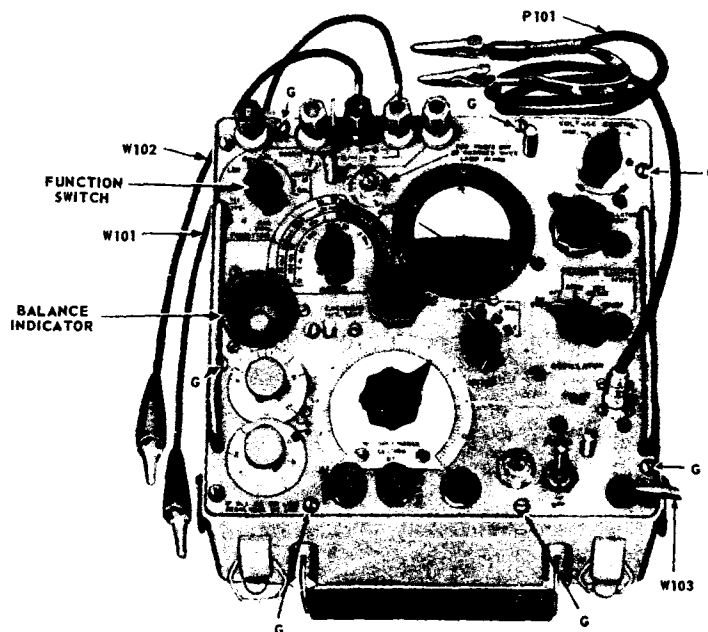


Figure 7-1.—ZM-11/U bridge.

of this instrument and the methods of making these measurements follows.

A view of the instrument is shown in figure 7-1.

Resistance Measurements

When the FUNCTION switch (upper left of figure 7-1) of the ZM-11/U is in the RESISTANCE (R) position, the circuit shown in simplified form in figure 7-2 is selected by the switch.

The four arms of the bridge are shown in the schematic diagram. Arm A contains the multiplier rheostat and a fixed resistor. When the multiplier rheostat is in position 1, arm A has a resistance of 1000 ohms; as it is moved to position 11, the resistance of arm A increases to 11,000 ohms. Arm B contains the range switch and

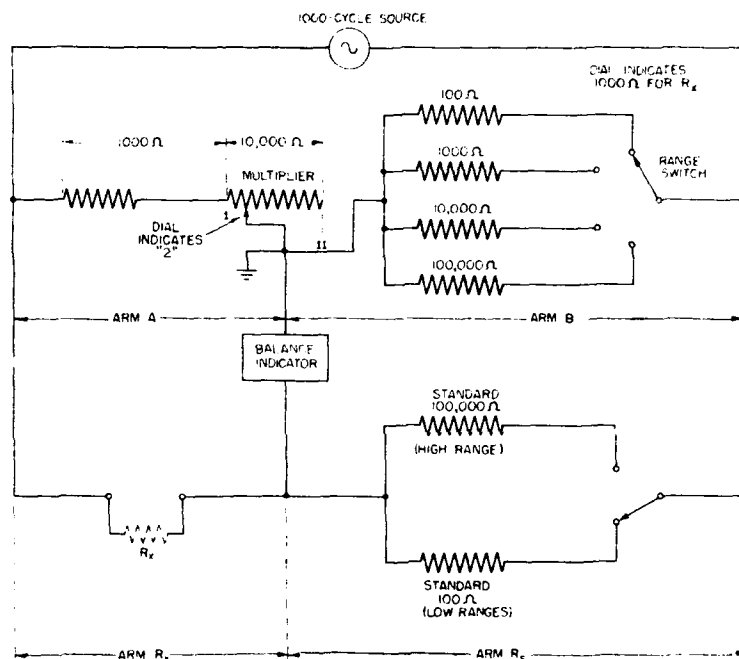


Figure 7-2.—Resistance bridge.

the range resistors. Arm R_s contains one of the standard resistors; the correct standard resistor is connected into this arm by the range switch. The resistor of unknown resistance is connected in arm R_x .

The balance indicator is an electron-tube tuning indicator. The maximum possible opening of the pattern indicates balance. Balance is approached by proper positioning of the range switch, which connects the correct resistor in arm B and the correct standard resistor in arm R_s ; balance is then completed by adjustment of the multiplier rheostat.

As the multiplier is moved through the point of balance, the balance indicator pattern increases to a maximum (point of balance) and then decreases again. This action results from the fact that the voltage across the

indicator decreases to zero as the exact point of balance is reached and then it increases again as the multiplier is moved beyond the point of balance. The same reasoning may also be applied to capacitance and inductance measurements.

As a practical example of resistance measurement, assume that at balance the multiplier is at position 2 (the resistance of arm A is 2000 ohms), the range switch is in the position shown (100 ohms in arm B), and that 100 ohms standard is used in arm R_s . These positions are indicated in the figure.

Under conditions of balance,

$$\frac{A}{B} = \frac{R_x}{R_s},$$

where A is the resistance of arm A, B is the resistance of arm B, R_x is the resistance of the unknown resistance, and R_s is the resistance of the standard resistor.

Substituting the values previously given,

$$\frac{2000}{100} = \frac{R_x}{100}$$

$$R_x = \frac{2000 \times 100}{100} = 2000 \text{ ohms.}$$

On the instrument itself, the range switch (which has a calibrated dial) will indicate 1000 ohms, and the multiplier dial (which is also calibrated in units and tenths—from 1 to 11) will indicate 2; the reading will therefore be 2000 ohms. That is, 1000 ohms on the range switch multiplied by 2 on the multiplier dial is equal to 2000 ohms.

The same procedure is followed in making capacitance and inductance measurements. In each case the range switch indication is multiplied by the multiplier dial indication to determine the value of the unknown capacitor or inductor.

Capacitance Measurements

When the FUNCTION switch of the ZM-11/U is in the CAPACITANCE (C) position, the circuit shown in simplified form in figure 7-3 is selected by the switch.

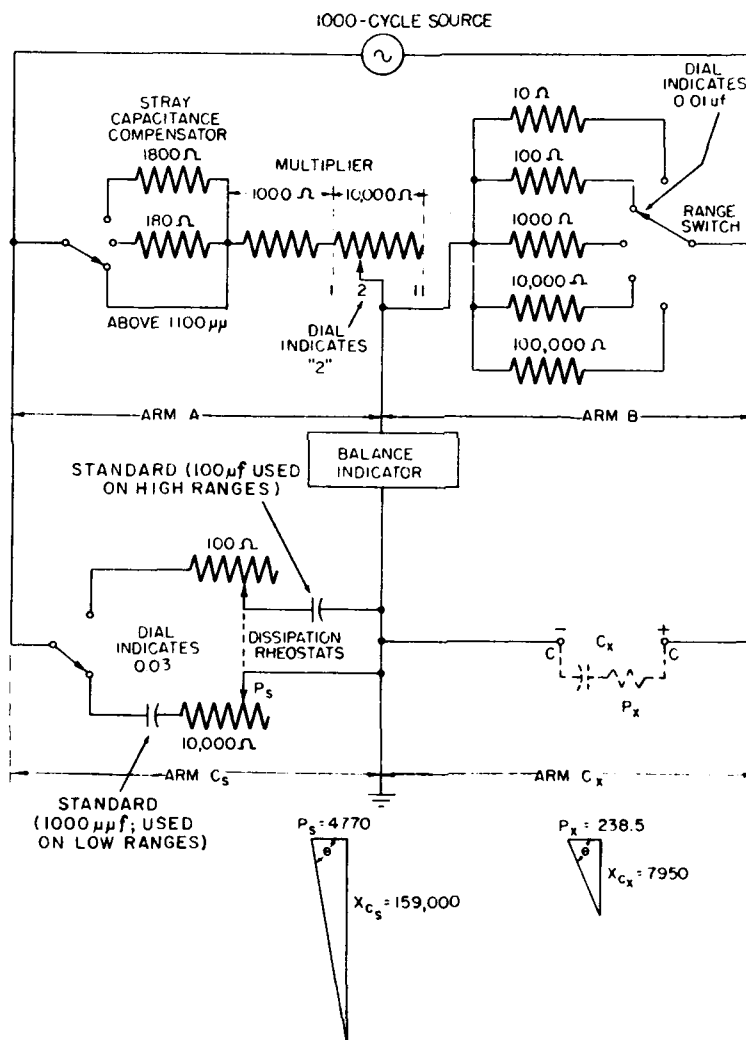


Figure 7-3.—Capacitance bridge.

The four arms of the bridge are shown in the figure. Arm A contains the stray capacitance compensator. This compensator is used only on the lower capacitance ranges, and is automatically positioned by the range switch. Its function is to compensate for stray capacitance associated with the connecting leads in arm C_x . The error that would otherwise be introduced is significant only when small capacitances are measured, and the lead capacitance is of the same order of magnitude as that of the capacitor itself. Arm A also contains the multiplier resistor and a 1000-ohm fixed resistor. When the multiplier is in position 1, the resistance of arm A is 1000 ohms. The resistance increases to 11,000 ohms when the multiplier is moved to position 11.

Arm B contains the range switch and the range resistors, and arm C_x contains the capacitor of unknown capacitance.

Arm C_s contains a standard capacitor (one of two), which is selected automatically by the range switch, and the necessary dissipation control rheostat. The dissipation (D) dial associated with the rheostat indicates the dissipation factor (power factor) of the capacitor under test. Each of the two standard capacitors has its associated dissipation control rheostat. When the 1000 $\mu\mu\text{f}$ standard is used, the 10,000-ohm rheostat is in the circuit. As the resistance of the rheostat is increased through the 10,000-ohm range, the D dial indicates a dissipation factor of from 0 to 0.06. When the 1.0 μf standard is used, the 100-ohm rheostat is in the circuit. As the resistance of the rheostat is increased through the 100-ohm range, the D dial again indicates a dissipation reading of from 0 to 0.06, but in this case, the reading must be multiplied by 10 to obtain the dissipation factor (0 to 0.6).

As a practical example, assume that at balance the controls are in the positions shown. Arm A has a resistance of 2000 ohms, arm B has a resistance of 100 ohms, arm C_s utilizes the 1000- $\mu\mu\text{f}$ standard with a cer-

tain amount of resistance in series with it, and arm C_r contains the capacitor of unknown capacitance with its effective series resistance. Because the purpose of the dissipation rheostat is to make the power factor of arm C_s equal to the power factor of arm C_r to perfect the bridge balance, the resistance of the rheostat need not be considered in the following bridge equation:

Under conditions of balance,

$$\frac{A}{B} = \frac{C_r}{C_s}$$

Performing the substitutions,

$$\frac{2000}{100} = \frac{C_r}{1000}$$

$$C_r = \frac{2000 \times 1000}{100} = 20,000 \mu\text{f} = 0.02 \mu\text{f}.$$

Under conditions of balance, the power factor ($\cos \theta = D$) of arm C_s is equal to the power factor of arm C_r . The calculations for the reactance and resistance of arms C_s and C_r for this example are

$$X_{Cr} = \frac{1}{2\pi f C_r} = \frac{10^{12}}{6.28 \times 10^3 \times 2 \times 10^4} = 7950 \text{ ohms}$$

$$X_{Cs} = \frac{1}{2\pi f C_s} = \frac{10^{12}}{6.28 \times 10^3 \times 10^3} = 159,000 \text{ ohms}$$

$$P_r = X_r \cos \theta = 7950 \times 0.03 = 238.5 \text{ ohms}$$

$$P_s = X_s \cos \theta = 159,000 \times 0.03 = 4770 \text{ ohms.}$$

On the instrument itself, the range switch will indicate 0.01 μf , and the multiplier dial will indicate 2; the reading will therefore be 0.02 μf . That is, 0.01 μf on the range switch multiplied by 2 on the multiplier dial is equal to 0.02 μf . The calibrated dissipation dial will indicate some value—for example, 0.03 (or a 3% power factor). The larger the dissipation of the capacitor under test the larger will be the value of the dissipation rheostat resistance in series with the standard.

The relation between resistance, reactance, and impedance in the capacitor arms of the bridge for the pre-

ceding example is represented by the two impedance triangles in the lower position of figure 7-3. The triangles are similar but not equal.

They are not drawn to scale; the length of the base lines is exaggerated in order to show clearly the effective series resistances, P_s and P_r , in their respective arms.

Because the power factor is low (0.03), θ is almost 90° , and the impedance (hypotenuse) is assumed to be equal to the reactance (altitude) of the right triangle. The base of the triangle represents the effective series resistance in each case.

Inductance Measurements

When the FUNCTION switch of the ZM-11/U is in an INDUCTANCE position (either $L (Q)$ or $L (D)$ position), the circuit shown in simplified form in figure 7-4, A, is selected by the switch.

Because this circuit is somewhat more complex than those discussed previously, the circuit is further simplified into parts B and C.

The circuit shown in part B is selected when the FUNCTION switch is in the $L (D)$ position. This circuit is used when the dissipation, D , is less than 0.05. Arm A contains the multiplier and a fixed resistor connected in series. Arm C_s contains one of the standard capacitors and its associated dissipation rheostat connected in series (capacitance standards are used in the inductance bridge to reduce the total number of standards needed). Arm B contains one of the range resistors, and arm L_r contains the inductor of unknown inductance. Arm L_r also contains P_r , the effective series resistance of arm L_r (P_r is, of course, a part of the impedance of arm L_r).

The circuit shown in part C is selected when the FUNCTION switch is in the $L (Q)$ position. This circuit is used when the dissipation, D , is greater than 0.05. This circuit is essentially the same as the one shown in part B, except for arm C_s . In arm C_s , the shunt rheostat, S , shunts

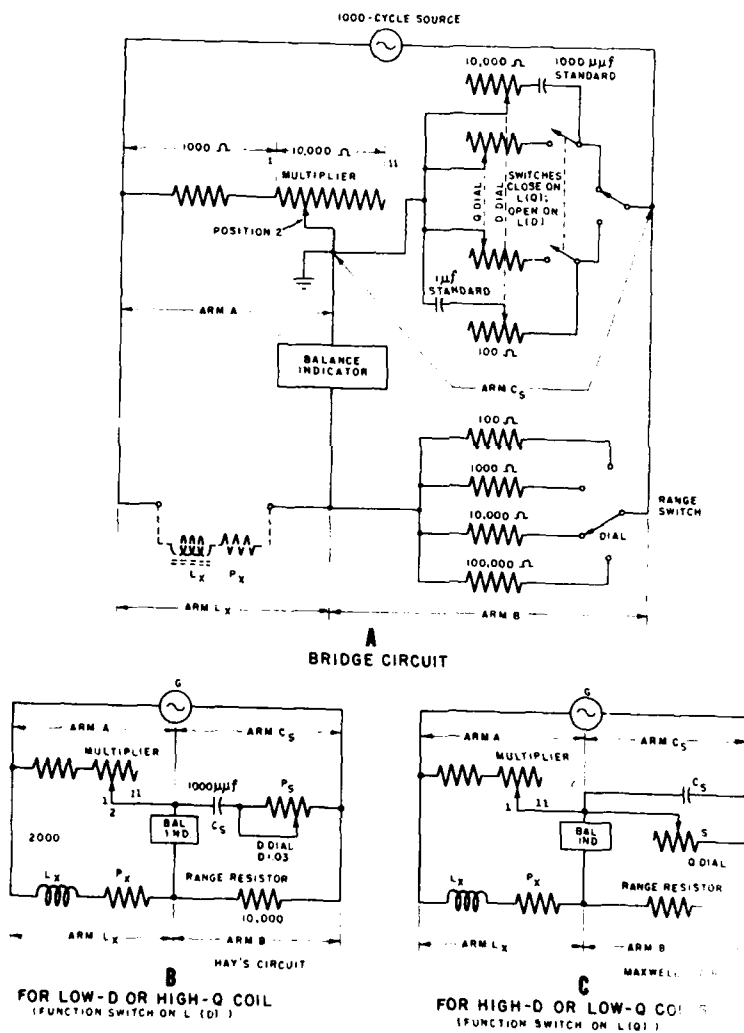


Figure 7-4.—Inductance bridge.

the standard capacitor, C_s . This rheostat is positioned by means of the Q dial. Q is the merit factor of a coil; it is the ratio of the inductive reactance (X_L) to the resistance (R). It is also the reciprocal of the dissipation factor—that is, $Q = \frac{1}{D}$.

As a practical example, assume that the inductance of a high- Q coil is being determined by means of the bridge circuit shown in part B. Assume that the inductor of unknown inductance is connected in arm L_r , that the resistance of arm A is 2000 ohms (multiplier dial in position 2) and that the 10,000-ohm range resistor is in arm B . Assume also that the dissipation rheostat connected to the D dial is adjusted to balance the bridge, and that the dial indicates 0.03, which is also the power factor of the inductor under test. The capacitance of the C_s arm is 1000 μmf . At balance,

$$\frac{Z_{\text{arm } L}}{A} = \frac{B}{Z_{\text{arm } C_s}}$$

The impedance triangles shown in figure 7-5 will be helpful in illustrating how the reactance of L_r may be determined. For a power factor of 0.03, the phase angle is above 88° and so close to 90° that, for practical purposes, X_L is equal to $Z_{\text{arm } L}$, and X_{C_s} is equal to $Z_{\text{arm } C_s}$ in the figure. Therefore, the preceding equation may be written as

$$\begin{aligned}\frac{X_L}{A} &= \frac{B}{X_{C_s}} \\ \frac{\omega L_r}{A} &= \frac{B}{\frac{1}{\omega C_s}} \\ L_r &= C_s BA.\end{aligned}$$

Substituting the known values,

$$L_r = 1000 \times 10^{-12} \times 10,000 \times 2000 = 2 \times 10^{-2} = 0.02 \text{ h.}$$

Converting to millihenries,

$$L_r = 0.02 \times 10^3 = 20 \text{ mh.}$$

On the meter itself the range switch will be on the 10-mh position, and the multiplier dial will indicate 2. The inductance of the unknown inductor will then be 10 mh x 2, or 20 mh. The dissipation will be 0.03, as previously stated.

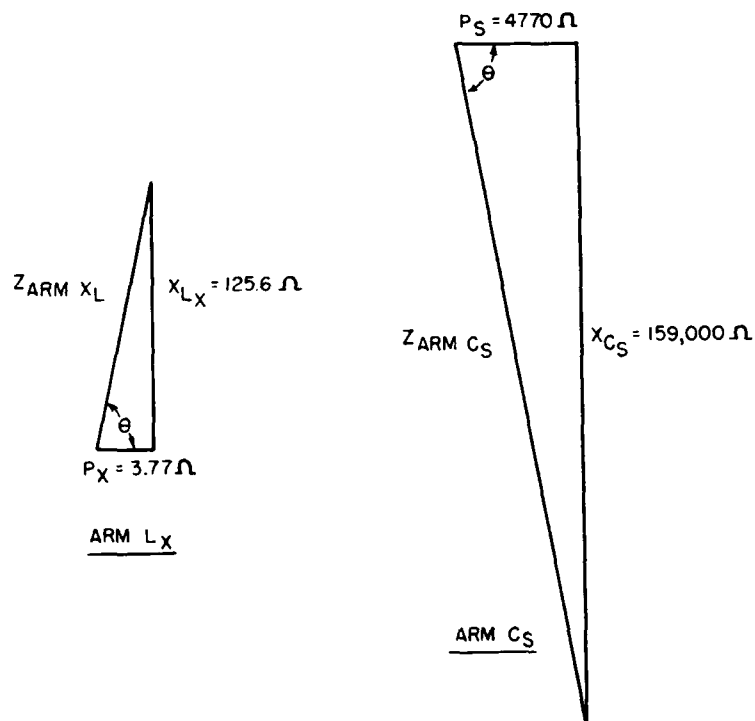


Figure 7-5.—Impedance triangles.

The relationship between resistance, reactance, and impedance in the capacitance and inductance arms of the bridge for the preceding example is represented by the two impedance triangles of figure 7-5. The calculations are

$$X_L = 2\pi fL = 6.28 \times 10^3 \times 2 \times 10^{-2} = 125.6 \text{ ohms}$$

$$X_C = \frac{1}{2\pi fC} = \frac{10^{12}}{6.28 \times 10^3 \times 10^3} = 159,000 \text{ ohms}$$

$$P_z = X_L \cos \theta = 125.6 \times 0.03 = 3.77 \text{ ohms}$$

$$P_s = X_C \cos \theta = 159,000 \times 0.03 = 4770 \text{ ohms.}$$

RADAR POWER MEASUREMENTS

The power output of a radar transmitter may be measured in terms of relative values or absolute values. Relative values are useful in indicating CHANGES in output power. For this purpose a suitable rectifier (for example, a crystal) may be used in a suitable circuit with a d-c meter to indicate relative power in terms of needle deflection.

If the same meter and rectifier are used each time a measurement is made, and if no defect occurs in the setup, changes in power output will be indicated. On the basis of a change in power output, corrective maintenance may be undertaken.

There are obvious disadvantages in the use of relative values such as these. When the initial reading is taken, the equipment may be operating below the operational standards set for it. The readings may vary because of some defect in the crystal or meter or because of the way the technician makes the connections. Finally, the equipment is rated in watts by the manufacturer and by the engineer who set up the performance standards, and output power readings in watts are therefore more meaningful to the technician.

Before discussing the methods of making radar power measurements, it is necessary to have a clear understanding of what is meant by PEAK power and AVERAGE power. Because a radar transmitter generates r-f energy in the form of extremely short pulses and is turned off between pulses for comparatively long intervals, there is considerable difference between the peak power and the average power.

The relationship between peak and average power is treated in Chapter 14, Introduction to Radar, of *Basic Electronics*, NavPers 10087.

An understanding of the use of the DECIBEL as a unit of power gain or loss is likewise necessary before a technician can acquire a clear understanding of the various methods of making radar power measurements. This subject is treated in Chapter 6 of *Basic Electronics*, NavPers 10087.

Methods of Sampling Radar Power

There are three common methods of taking a sample of radar power. They include the use of the R-F PROBE, the DIRECTIONAL COUPLER, and the TEST ANTENNA. For the purpose of this chapter, only the methods of extracting power and making power readings are given; the theory of operation is left to other courses of study in the ET series.

The R-F PROBE (in older radar systems) was used extensively for power sampling. It has been largely replaced by some form of directional coupler. The r-f probe consists of a small probe (or antenna) which when inserted into the waveguide or coaxial line extracts a small amount of power. The further the probe is pushed in, the greater the amount of power pickup. Most r-f probes provide 20 db or more attenuation between the main transmission line and the probe output.

Although the probe allows the radar equipment to be operated normally during tests, it has several disadvantages. The attenuation figure (and therefore the accuracy of the readings) is affected by line reflections and reflections from nearby objects. Other disadvantages may be summarized as follows: (a) The probe penetration is critical, (b) the probe is frequency sensitive, and (c) the attenuation figure depends on the type of load connected to the probe.

The DIRECTIONAL COUPLER couples, or samples, the energy traveling in one particular direction in a waveguide. A cutaway view of one type of directional coupler

is illustrated in figure 7-6. If properly used, reflected power has little effect on the accuracy of the power measurements.

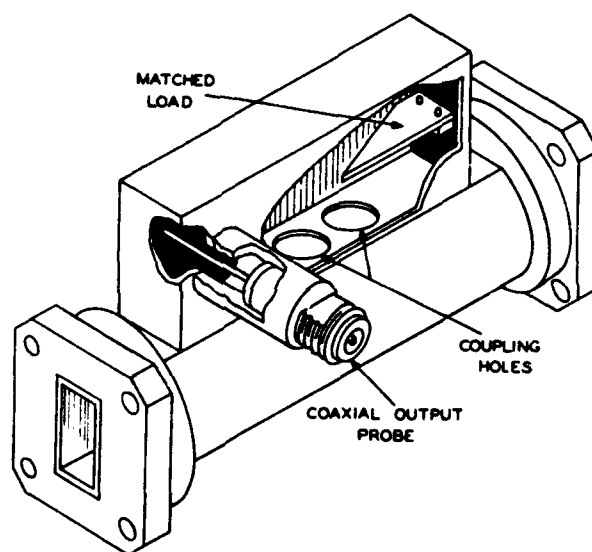


Figure 7-6.—Cutaway view of directional coupler.

The amount of energy coupled from the waveguide to the coaxial output depends on the size of the two coupling holes. A small portion of the energy flow from right to left is coupled to the probe. However, energy flow from left to right is not coupled to the probe, but is largely dissipated in the matched load.

Generally, the power available at the probe is over 20 db down from the power level in the guide—that is, when the energy is moving from right to left through the directional coupler. This loss in power is called the ATTENUATION, COUPLING FACTOR, or DIRECTIONAL COUPLER LOSS and is stamped on the coupler. The ability of the coupler to reject energy that moves through the guide in the reverse direction is called the DIRECTIVITY.

A BIDIRECTIONAL COUPLER is used to sample direct or reflected power. A cutaway view of a bidirectional coupler is shown in figure 7-7. It consists of a straight section of waveguide, with an enclosed section attached to each side along the narrow dimension. Each enclosed section contains an r-f pickup probe at one end and an impedance termination at the other end. The sections are supplied with energy from the main waveguide through coupling holes.

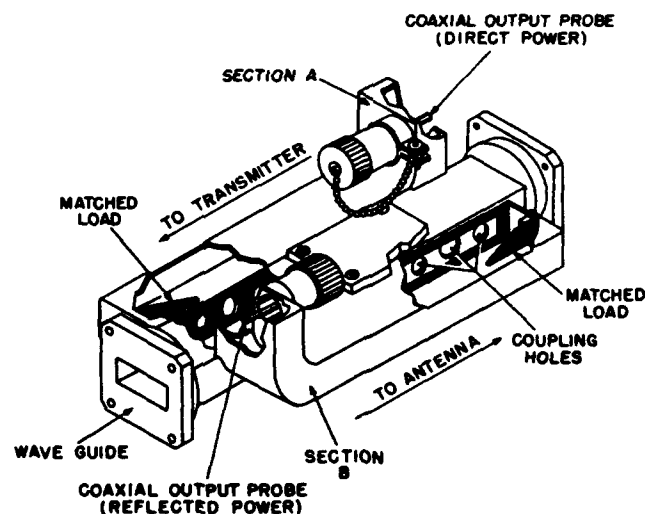


Figure 7-7.—Cutaway view of bidirectional coupler.

The TEST, or PICKUP, ANTENNA tunes broadly to the radar band being used. It may be placed in front of the radar antenna at a distance equal to the diameter of the radar antenna and so directed that it will pick up maximum energy. The space attenuation (output from pickup antenna compared to output from radar antenna) is then about 30 db; but it is generally given, or at least will have to be determined.

A simplified test arrangement employing a pickup horn (pickup antenna) is shown in figure 7-8. The space loss of the pickup antenna is measured by comparison with the loss in the directional coupler. Once the space loss for a particular radar is determined, it is unlikely that the measurement will have to be repeated for each system of the same type, provided the same pickup antenna location is always used and the distance chosen is the least critical.

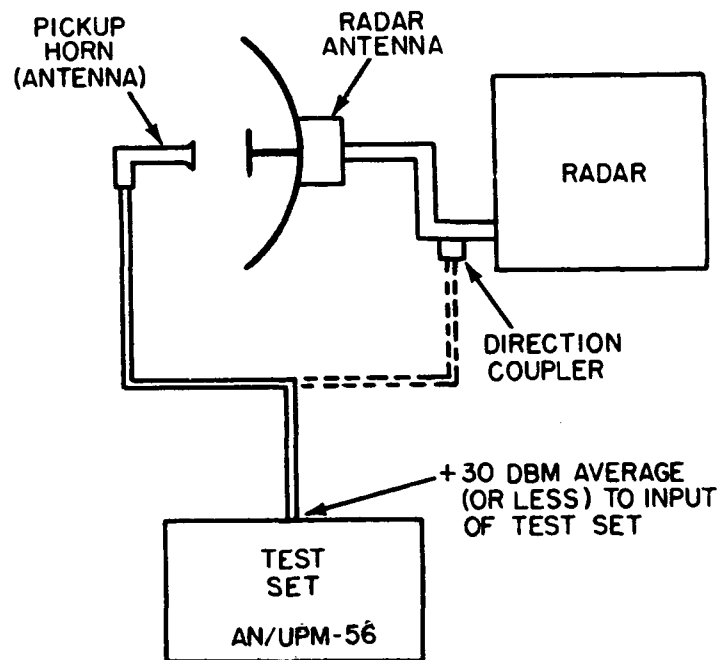


Figure 7-8.—Simplified test arrangement employing pickup horn.

To ensure that the antenna is placed at the least critical location, the pickup antenna is positioned where a change in its position produces a minimum change in the amount of the meter reading on the test set. This usually occurs when the pickup antenna is placed from

3 to 5 ft from the radar antenna and at a maximum power point of the antenna pattern.

In the case of the test set used in this figure, care must be taken not to apply more than +30 dbm (1 watt in 600 ohms) to the r-f input/output connector. The test set is connected as shown, first using the directional coupler and then the pickup antenna. In each case the average power of the antenna is recorded.

The loss (space loss, plus antenna loss, transmission-line loss, etc) for the pickup antenna in conjunction with the particular radar system is the difference between the dbm dial reading on the test set meter when the test set is connected to the directional coupler and the dbm dial reading when the test set is connected to the pickup antenna, added to the db (attenuation) value of the directional coupler.

A brief description of two representative types of test equipment (Frequency Power Meter TS-230B/AP and Radar Test Set AN/UPM-56) used by the Navy for measuring radar power will give the technician a general idea of how the measurements are made. Detailed descriptions of these equipments (as well as other similar equipments) and their use, together with maintenance instructions, are found in the instruction books that accompany the equipment.

Frequency-Power Meter

CIRCUIT OPERATION.—Frequency-Power Meter TS-230B/AP measures the power (and frequency) of unmodulated and pulsed signals in the range from 8500 to 9600 mc. It measures average power within the limits of 0.1 and 1000 mw (-10 to +30 dbm). A front view of the meter is shown in figure 7-9.

A general idea of how the power-measuring circuit in the meter works can be obtained from the following consideration. The thermistor (fig. 7-10) is actually the heart of the power-measuring circuit. This circuit operates on the basic principle of applying the r-f power

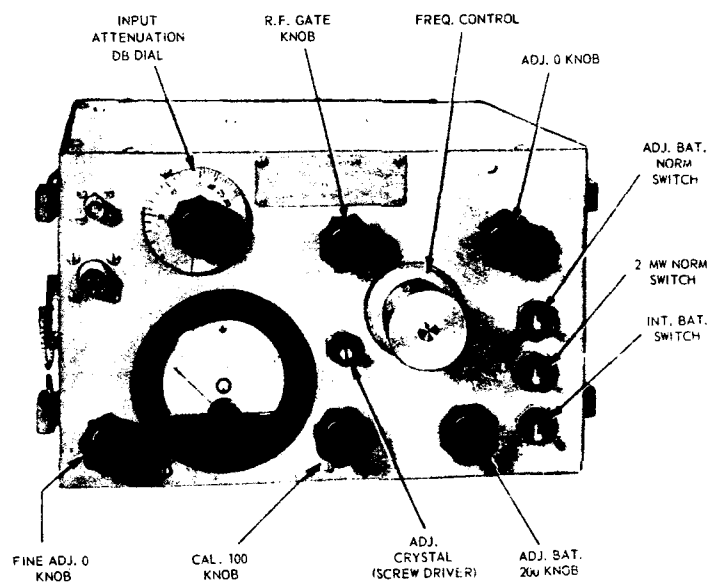


Figure 7-9.—Front view of Frequency-Power Meter TS-230B/AP.

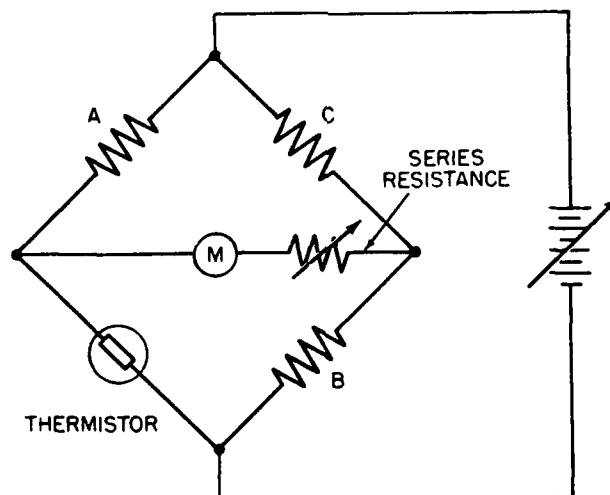


Figure 7-10.—Thermistor bridge circuit.

to be measured to a thermistor and observing the heating effects of that power in changing the thermistor resistance. A thermistor has a high negative temperature coefficient; that is, its resistance decreases rapidly as its temperature increases.

The thermistor is used in one arm of a balanced bridge so that any change in its resistance can be detected and measured. The thermistor is placed so that it will absorb r-f energy from the r-f field without applying r-f voltage directly to the bridge. Thus the d-c meter, M , is not subjected to an r-f voltage and the bridge is isolated electrically from the r-f source.

The power required to bring the thermistor to the right resistance for balancing the bridge varies from about 2 to 20 mw, depending on the individual thermistor and the surrounding temperature. This type of bridge is balanced when the meter reads zero. The condition of balance may be expressed mathematically as:

$$\frac{\text{thermistor resistance}}{\text{resistance of } A} = \frac{\text{resistance of } B}{\text{resistance of } C}.$$

In the simplified circuit, the bridge is balanced by varying the d-c supply to the bridge, thereby heating the thermistor with enough d-c power to bring it to the right temperature so that its resistance will balance the bridge (meter reads zero). When the bridge has been balanced, the addition of power (either d-c or r-f) to the thermistor will, through the associated heating effect, unbalance the bridge and cause the meter to move up scale. The meter sensitivity is adjusted so that 1 mw of added power in the thermistor will give a meter reading of 100 (center of dial). Over a limited range (up to 1 mw) the meter reading is directly proportional to the added power.

When measurements are made, the bridge is first balanced by applying the correct amount of d-c power to the thermistor; the resistance in series with the meter is then adjusted so that 1 mw of added power from the d-c supply will cause the meter to read 100. The d-c power is then reduced until the meter deflection is again zero.

The r-f power to be measured is applied to the thermistor and the meter deflection again noted. One milliwatt of r-f power is equivalent to one milliwatt of d-c power and will cause the meter to read 100 divisions.

A correct impedance match between the thermistor and the waveguide in the meter is obtained so that substantially all of the r-f power will be absorbed—that is, will be converted to heat energy.

A functional block diagram of the equipment is shown in figure 7-11, A. R-f power is fed to the waveguide by means of an r-f cable adaptor.

The guillotine db input attenuator moves an energy-absorbing element (carbon-coated blade) into the waveguide. The position of the blade is calibrated on the attenuator db dial in terms of loss in decibels.

The thermistor is mounted between top and bottom faces at the center of the waveguide and parallel with the electric lines of force. The bottom end of the thermistor is grounded to the waveguide face, and the top end connects through an r-f by-pass capacitor, which consists of a plastic disc between the outside face of the waveguide and thermistor mount. The d-c power-measuring circuit is connected between this post and ground. Short-circuited coaxial stubs are in the top and bottom faces of the waveguide—one at each end of the thermistor. The bottom stub is tunable; also, the reflector plate at the end of the waveguide section can be tuned by means of a screw. The stub and reflector (in combination with the thermistor adjustment) serve to match the thermistor to the impedance of the waveguide, thus making the standing-wave ratio satisfactory.

The r-f gate is used for making a check of zero balance in the bridge without disturbing the setting of the attenuator. When the r-f gate plunger in the waveguide is pushed in, nearly all the r-f power will be reflected and will not reach the thermistor.

The thermistor may be heated with power from the battery in the battery case. This is the most convenient method for locations remote from external power, espe-

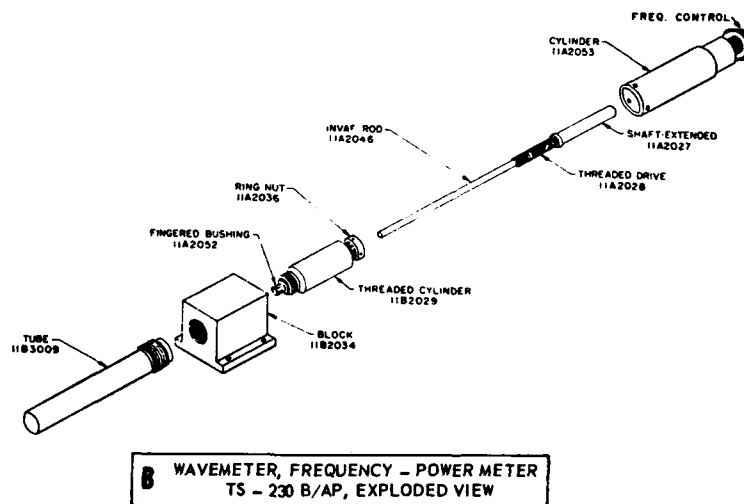
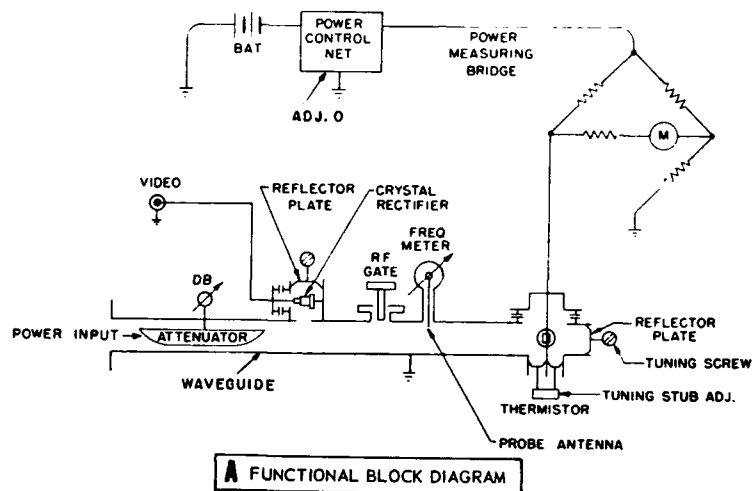


Figure 7-11.—Functional block diagram and r-f plumbing of frequency-power meter.

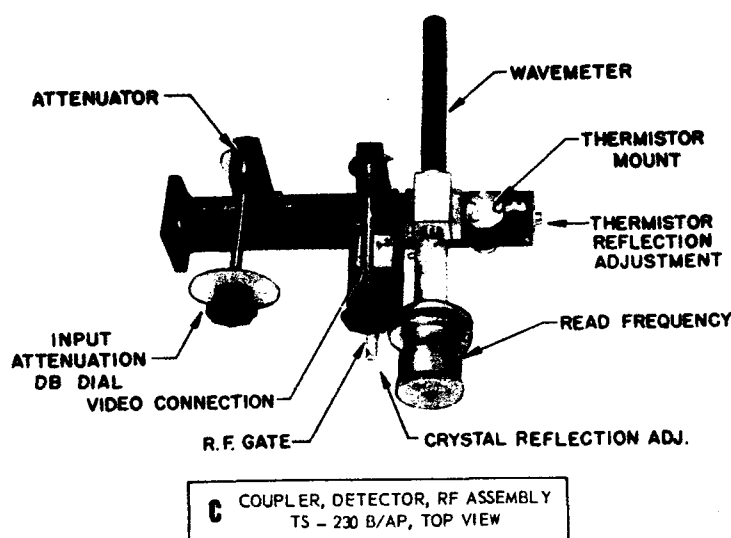


Figure 7-11.—Continued.

cially when the tests are made during a short period of time. If the internal battery is used for extended periods, its voltage decreases and frequent adjustments are needed during tests. External batteries may be connected to the external battery jack.

MEASURING POWER.—In order to measure power, the frequency-power meter is calibrated (as outlined in the instruction book) and the ADJ ZERO control (in the main control circuit from the battery to the bridge network) is set to the position that makes the meter read zero. The frequency-power meter is connected to the radar system; the radar transmitter is turned on and the input attenuator adjusted until a reading of 100 is obtained on microammeter, M. The input attenuator reading then represents the level in db above 1 mw at the input of the waveguide. If the input attenuator dial is turned toward zero and the meter reads progressively less than 100, the meter reading will represent the power

absorbed by the thermistor in hundredths of a milliwatt (one division equals 0.01 mw).

To obtain the average power output in the radar waveguide, the input attenuator reading is added to the db loss of the directional coupler (not shown in the figure) between the radar waveguide and the frequency-power meter. The loss in the directional coupler is stamped on the coupler; if a horn pickup antenna is used, the accompanying instruction book will give instructions on figuring losses. The power in watts corresponding to the total dbm (db above 1 mw) figure can be read directly from table 17. This represents the average power of the radar output.

As an example of determining radar power, assume that the attenuation dial is set at 22 db when the meter reads 100. Assume also that the directional coupler loss is 25 db. The total loss is therefore 47 db. From table 17, it is determined that the power corresponding to 47 db above 1 mw equals approximately 50 w.

PEAK-TO-AVERAGE POWER CONVERSION.—The meter reading indicates only the average levels of pulsed power throughout the pulse cycle. The peak power can be computed from the average power if the duty cycle ratio is known. The duty-cycle ratio is obtained from the radar instruction book or by assuming a rectangular pulse shape and using the following formula:

$$\text{Duty-cycle ratio} = \frac{\text{time power is on}}{\text{total time}} = \frac{\text{pulse length} \times \text{repetition rate}}{1,000,000},$$

where pulse length is in microseconds and the pulse repetition rate is given in number of pulses per second.

Representative duty-cycle ratios for radars in the band covered by this instrument are shown in table 18, which shows ratios in terms of decimal fractions, common fractions, and db. In table 18, and in the preceding formula, a perfect square-wave pulse is assumed. For this reason,

TABLE 17
RELATION OF POWER TO $\pm$ DBM

$\pm$ DBM	Milliwatts for (+ DBM)	Milliwatts for (- DBM)	$\pm$ DBM	Watts for (+ DBM)	Microwatts for (- DBM)	$\pm$ DBM	Kilowatts for (+ DBM)	Micro- watts for (- DBM)
0	1	1	30	1	1	60	1	1,000
0.5	1.122	0.891	31	1.259	0.794	61	1.259	794
1.0	1.259	0.794	32	1.585	0.631	62	1.585	631
1.5	1.412	0.708	33	1.995	0.501	63	1.995	501
2.0	1.585	0.631	34	2.512	0.398	64	2.512	398
2.5	1.778	0.562	35	3.162	0.316	65	3.162	316
3.0	1.995	0.501	36	3.981	0.251	66	3.981	251
3.5	2.239	0.447	37	7.943	0.200	67	5.012	200
4.0	2.512	0.398	38	6.310	0.158	68	6.310	158
4.5	2.818	0.355	39	5.012	0.126	69	7.943	126
5.0	3.162	0.316	40	10.00	0.100	70	10.00	100
5.5	3.548	0.282	41	12.59	0.0794	71	12.59	79.4
6.0	3.981	0.251	42	15.85	0.0631	72	15.85	63.1
6.5	4.467	0.244	43	19.95	0.0501	73	19.95	50.1
7.0	5.012	0.200	44	25.12	0.0398	74	25.12	39.8
7.5	5.623	0.178	45	31.62	0.0316	75	31.62	31.6
8.0	6.310	0.158	46	39.81	0.0251	76	39.81	25.1
8.5	7.080	0.141	47	50.12	0.0200	77	50.12	20.0

9.0	7.943	0.126	48	63.10	0.0158	78	63.10	15.8
9.5	8.913	0.112	49	79.43	0.0126	79	79.43	12.6
10	10.00	0.100	50	100.0	0.0100	80	100.0	10.0
11	12.59	0.0794	51	125.9	0.00794	81	125.9	7.94
12	15.85	0.0631	52	158.5	0.00631	82	158.5	6.31
13	19.95	0.0501	53	199.5	0.00501	83	199.5	5.01
14	25.12	0.0398	54	251.2	0.00398	84	251.2	3.98
15	31.62	0.0316	55	316.2	0.00316	85	316.2	3.16
16	39.81	0.0251	56	398.1	0.00251	86	398.1	2.51
17	50.12	0.0200	57	501.2	0.00200	87	501.2	2.00
18	63.10	0.0518	58	631.0	0.00158	88	631.0	1.58
19	79.43	0.0126	59	794.3	0.00126	89	794.3	1.26
20	100.0	0.0100	60	1,000.0	0.00100	90	1,000	1.0
21	125.9	0.00794				91	1,259	0.794
22	158.5	0.00631				92	1,585	0.631
23	199.5	0.00501				93	1,995	0.501
24	251.2	0.00398				94	2,512	0.398
25	316.2	0.00316				95	3,162	0.316
26	398.1	0.00251				96	3,981	0.251
27	501.2	0.00200				97	5,012	0.200
28	631.0	0.00158				98	6,310	0.158
29	794.3	0.00126				99	7,943	0.126
30	1,000.	0.0010				100	10,000	0.100

TABLE 18
RADAR DUTY CYCLES

Repetition Rate (PPS)	Pulse Length (Micro-second)	Duty Cycle Ratio		Repetition Rate (PPS)	Pulse Length (Micro-second)	Duty Cycle Ratio	
		Decimal Fraction	Common Fraction*			Decimal Fraction	Common Fraction*
2,000	0.05	0.000100	1/10,000	600	0.25	0.00015	1/6,600
1,800	0.3	0.00054	1/1,800	600	0.5	0.00030	1/3,300
1,640	0.5	0.00082	1/1,200	480	0.75	0.00036	1/2,800
1,520	0.5	0.00076	1/1,300	400	2.25	0.00090	1/1,100
1,348	0.5	0.00067	1/1,500	400	1.00	0.00040	1/2,500
1,200	0.25	0.00030	1/3,300	400	0.5	0.00020	1/5,000
1,000	2.0	0.00200	1/500	375	2.25	0.00084	1/1,200
1,000	0.75	0.00075	1/1,300	375	1.125	0.00042	1/2,400
1,000	0.5	0.00050	1/2,000	350	2.5	0.00087	1/1,100
800	2.25	0.00180	1/600	350	2.25	0.00079	1/1,300
800	1.25	0.00100	1/1,000	270	2.25	0.00061	1/1,600
800	0.6	0.00048	1/2,100	200	5.0	0.00100	1/1,000
760	1.25	0.00095	1/100	200	4.00	0.00080	1/1,300
760	0.333	0.00025	1/4,000	200	1.00	0.00020	1/5,000
750	1.125	0.00084	1/1,200	60	20.0	0.00120	1/800
600	2.0	0.00120	1/800	60	5.0	0.00030	1/3,300
600	1.0	0.00060	1/1,600	60	1.5	0.00009	1/11,000
600	0.75	0.00045	1/2,200				

* Denominator to nearest 100.

duty-cycle ratios given in instruction books for particular radars may differ somewhat from these computed values. The handbook value should be used if it is available.

The peak power is obtained by dividing the average power by the duty-cycle ratio. As an example, let it be assumed that the average power of a radar transmitter, as determined by the frequency-power meter, is 25 w. Assume also that the transmitter radiates pulses 0.5 μ s long 600 times per second. The calculations are as follows:

1. The duty-cycle ratio (on a square-wave basis) is the product of the pulse length in microseconds and the repetition rate in pulses per second divided by 10^6 . That is,

$$\text{duty-cycle ratio} = \frac{0.5 \times 600}{10^6} = 3 \times 10^{-4}.$$

2. The peak power is equal to the average power divided by the duty-cycle ratio, or

$$\text{peak power} = \frac{25}{3 \times 10^{-4}} = 83,000 \text{ w.}$$

Radar Test Set

FUNCTIONAL DESCRIPTION.—In general, radar test sets will perform more functions than frequency-power meters. For example, Radar Test Set AN/UPM-56 (fig. 7-12) is a portable microwave signal generator, power meter, and frequency meter; in addition, many allied functions can be performed. In this portion of the chapter we are concerned principally with its use as a power meter.

This test set can make r-f power measurements of pulsed or c-w power in the frequency range of 8500 to 9600 mc/s. The range of power that can be measured directly is from +1 to +30 dbm average (1 mw to 1000 mw). Power in excess of +30 dbm average can be measured by using an external attenuator. Power down to -9 dbm (0.126 mw) can be measured on the bridge meter, but this measurement is somewhat less accurate.

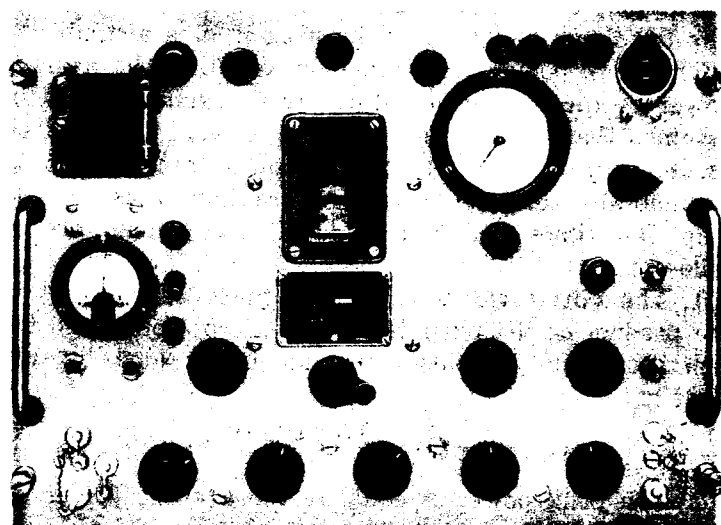


Figure 7-12.—Front view of Radar Test Set AN/UPM-56.

Power measurements are made by attenuating the unknown power down to a reference level of 1 mw. The amount of attenuation is then read on a calibrated dial. The 1-mw reference is established in a thermistor bridge circuit.

ATTENUATORS.—The attenuators in the test set consist of waveguide sections within which are glass strips coated with a resistive material such as carbon, which absorbs r-f energy. These attenuators are shown in the simplified phantom view of the r-f plumbing in figure 7-13. The glass strips run lengthwise in the waveguide. One of the attenuators, AT103 (calibrated attenuator) is continuously variable and has a 1 to 30 dbm calibrated range. It is the r-f level control on the panel of the test set. Attenuators AT101 and AT102 are of the step type, each having a 0.db position and a 35-db position. The step attenuators are controlled from the same knob (R-F LEVEL SELECTOR), which also controls the r-f cutoff

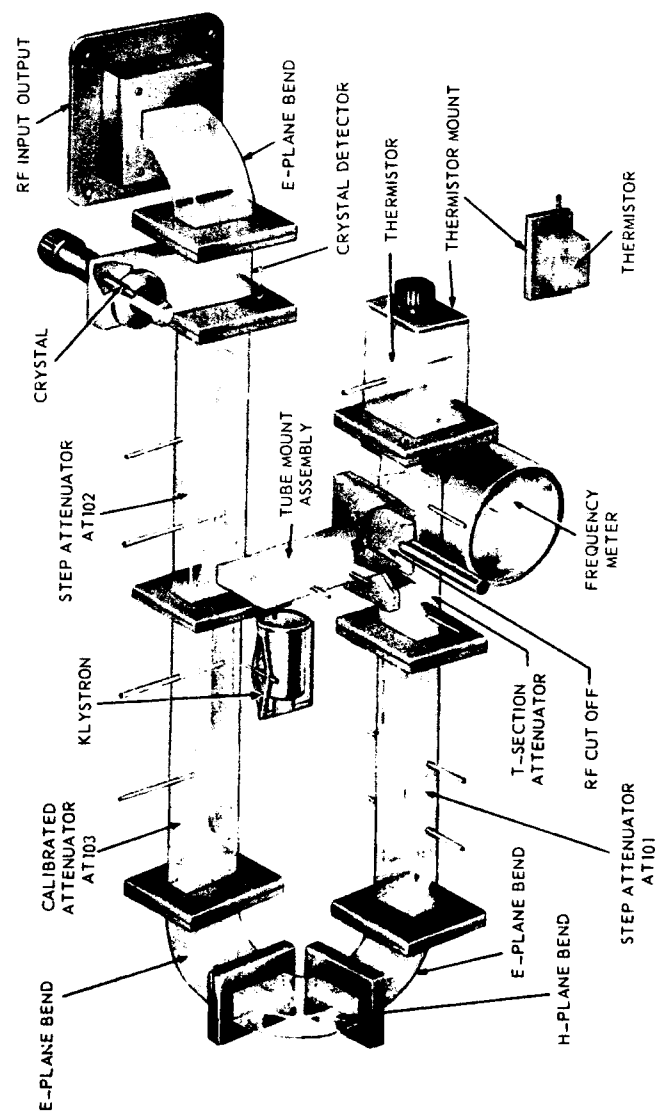


Figure 7-13.—Simplified phantom view of r-f plumbing.

in the T-section that connects the klystron oscillator mount to the waveguide and the T-section attenuator.

When the power of external signals is being measured AT101 and AT102 are in the 0-db position (r-f in on the r-f level selector (fig. 7-12)) the klystron oscillator is shut off, and the T-section attenuator is in a position of minimum attenuation. The calibrated r-f level control is used for adjusting attenuation. The lowest attenuation of the r-f level control is 1 dbm; this results from the attenuation inherent in the waveguide, from the attenuators in the zero position, and from other waveguide losses.

THERMISTOR BRIDGE.—A simplified schematic diagram of the thermistor bridge wattmeter is shown in figure 7-14, A; the bead thermistor is illustrated in part B.

A bead thermistor is a temperature-sensitive device whose resistance decreases with an increase in temperature. There are three causes of temperature variations that affect the resistance of the bead thermistor—the ambient temperature (surrounding temperature), the heating effect due to an applied voltage, and the heating effect due to an applied r-f field.

The thermistor bridge wattmeter contains two bridge circuits; one is a control bridge, and the other a power-measuring bridge. The control bridge provides a means of compensating for ambient temperature changes that would normally affect the calibration of the power-measuring bridge. The control bridge employs thermistor RT101 in one arm to balance a 150-ohm resistor, R233, in another arm. The remaining two arms contain 470-ohm resistors (R232 and R234).

The power-measuring bridge consists basically of bead thermistor RT102 and resistors R239, R241, and R242. Bead thermistor RT102 is mounted in waveguide section Z103 (fig. 7-13) where r-f power is applied to it from the r-f input/output connector. The resistance of thermistor RT102 at room temperature is higher than that

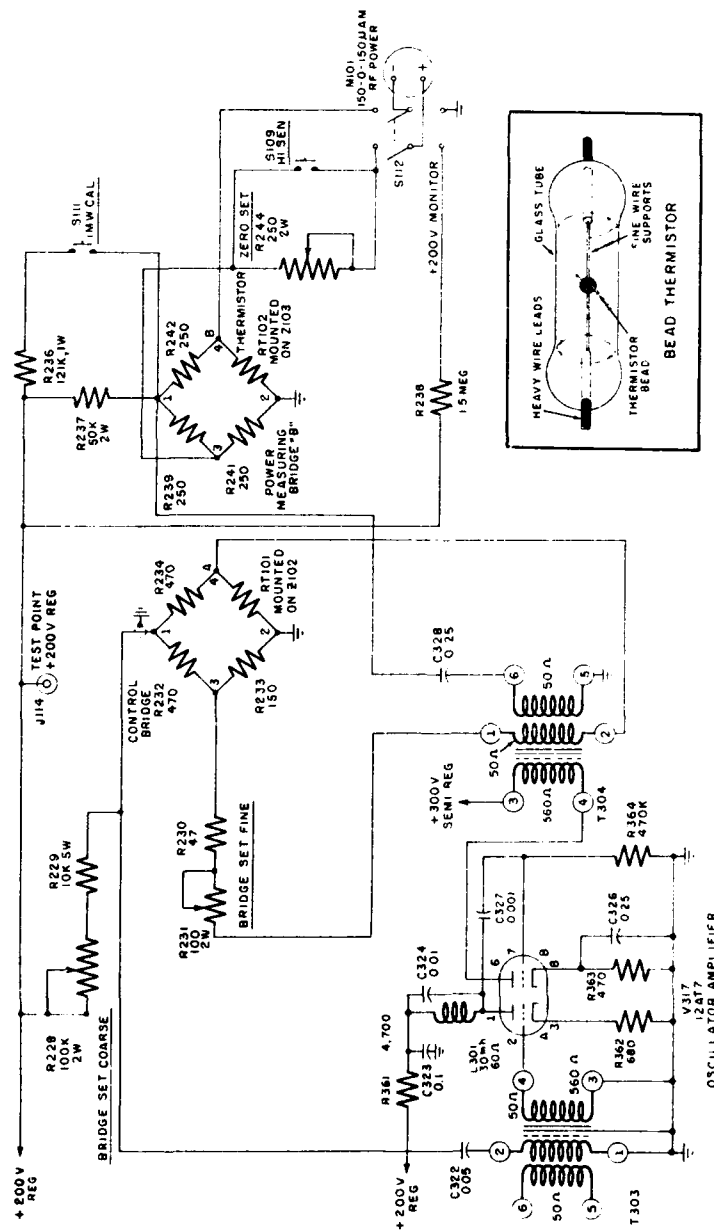


Figure 7-14.—Simplified schematic diagram of the thermistor bridge wattmeter.

of resistors, R239, R241, and R242, each having a resistance of 250 ohms.

The object is to obtain bridge balance (all four resistances equal) when 1 mw of r-f power is applied to thermistor RT102. In order to do this, two voltages are applied simultaneously across terminals 1-2 of the power-measuring bridge.

One voltage is a regulated +200 volts d-c applied through R237. This voltage accomplishes two purposes: first, it supplies the d-c voltage that causes the bridge meter to indicate balance or degree of unbalance; and, secondly, it reduces the resistance of thermistor RT102 by dissipating heat in it.

The other voltage is a variable a-c voltage of about 10 kc. This voltage also accomplishes two purposes: first, it dissipates heat in RT102 in varying amounts to compensate for changes in ambient temperature; and, secondly, it allows for the initial setting of the bridge. This voltage is obtained from the 10-kc oscillator, V317. The oscillator output voltage is regulated by the control bridge.

Another d-c voltage is applied to the power-measuring bridge when the 1-mw calibrated pushbutton switch, S111 is closed. This voltage exactly corresponds in temperature effect to the application of 1 mw of r-f power to RT102.

Before r-f power is applied to RT102, the BRIDGE SET FINE control, R231, is positioned (with S111 closed) so that meter M101 reads SET POWER (1-mw level). Switch S111 is then released and the ZERO SET control, R244, adjusted until the meter indicates SET ZERO (0 mw). The BRIDGE SET FINE control, R231, is again positioned (with S111 closed) so that the meter reads SET POWER (1-mw level). Switch S111 is then released again.

When 1 mw of the r-f power being measured is applied to thermistor RT102, the meter again reads SET POWER (1 mw).

The output of the oscillator-amplifier is fed through

T304 to both the control bridge and the power-measuring bridge. A regulated direct voltage is applied to terminals 1-2 of the control bridge through the BRIDGE SET COURSE control and R229. The 10-kc output from T304 is applied to terminals 3-4. The amount of a-c voltage appearing across terminals 1-2 depends on the resistance of bead thermistor RT101. This voltage is applied through C322 to input transformer T303. This is the feedback loop for the oscillator. For an initial setting, the amount of feedback is determined by the resistance of thermistor RT101 and the amount of voltage applied from the output winding of T304, as controlled by the BRIDGE SET FINE adjustment.

After the initial setting, any changes in ambient temperature are reflected in resistance changes in thermistor RT101, in feedback, and in oscillator-amplifier output to the power-measuring bridge. Thus, changes in ambient temperature that normally would cause power-measuring thermistor RT102 to change resistance are compensated by adding or subtracting heat effects caused by the alternating voltage applied to its bridge.

MEASURING POWER.—The following example will illustrate the principles of power measurement. Assume that a certain radar transmitter with a built-in directional coupler having a 20-db attenuation is connected to the test set with an r-f cable having a 3.5 db loss.

The test set power-measuring bridge is first properly calibrated. When r-f power is applied, the dbm dial reads 17.5 dbm when the bridge R-F power meter indicates 1 mw. The total db attenuation with reference to 1 mw is

$$20 \text{ db} + 3.5 \text{ db} + 17.5 \text{ db} = 41 \text{ dbm (1-mw reference).}$$

The average power output of the radar transmitter in watts is 41 db above 1 mw. From the dbm-to-watts conversion chart (fig. 7-15), the corresponding average power output of the radar system in watts is approximately 12.5 w.

The peak power is equal to the average power divided

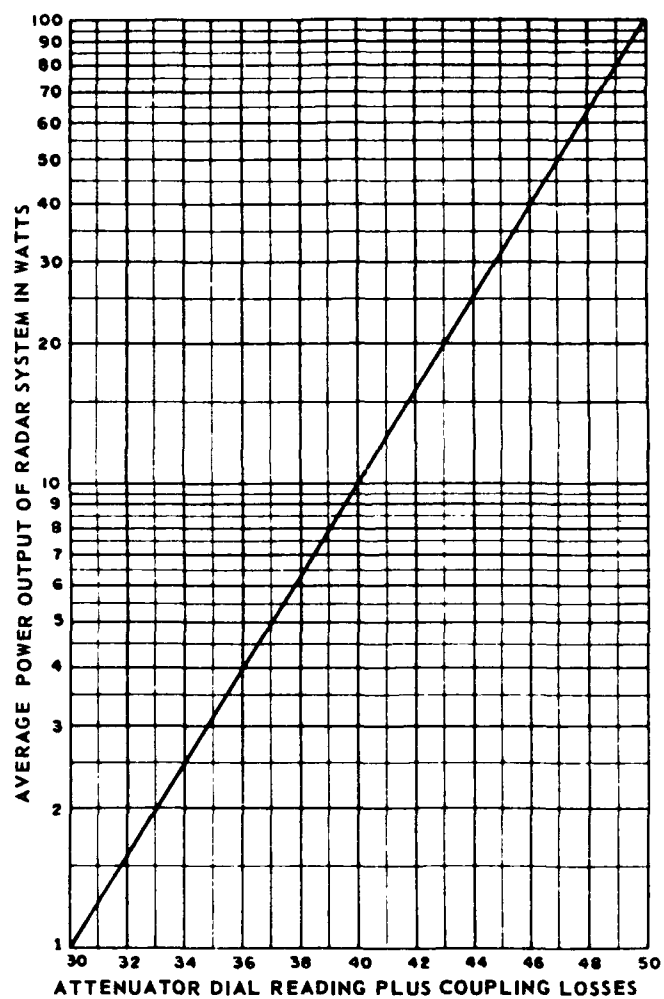


Figure 7-15.—Dbm-to-watts conversion chart.

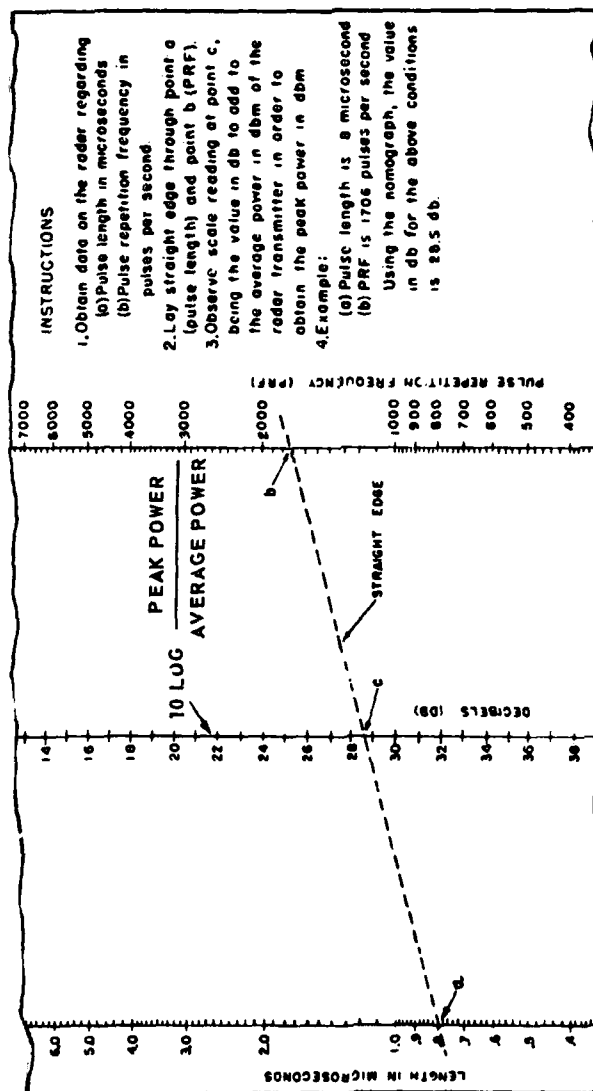


Figure 7-16.—Average-to-peak power conversion chart.

by the duty-cycle ratio. The duty-cycle ratio (for a square wave) is equal to the product of the pulse length in microseconds and the pulse repetition rate, PRF, in pulses per second, divided by 10^6 . Expressed as a formula, the peak power is

$$\text{peak power} = \frac{\text{average power}}{\text{duty-cycle ratio}} = \frac{\text{average power}}{\text{pulse length} \times (\text{PRF})} = \frac{\text{average power} \times 10^6}{\text{pulse length} \times (\text{PRF})},$$

where the peak power and the average power are in watts.

If the pulse length is $0.8 \mu\text{s}$, the pulse repetition rate is 1706 pulses per second, and the average power is 12.5 w, the peak power will be

$$\text{peak power} = \frac{12.5 \times 10^6}{0.8 \times 1706} = 9150 \text{ w.}$$

A chart for converting average power to peak power is illustrated in figure 7-16. From this chart the db value is indicated for the example being considered as 28.65 db at point C. From this value the peak power is found from the formula,

$$\begin{aligned} \text{db} &= 10 \log \frac{\text{peak power}}{\text{average power}} \\ 28.65 &= 10 \log \frac{\text{peak power}}{\text{average power}} \\ \frac{\text{peak power}}{\text{average power}} &= 733 \\ \text{peak power} &= 733 \times 12.5 = 9150 \text{ w.} \end{aligned}$$

RADIO POWER MEASUREMENTS

Introduction

In d-c circuits, power is the product of the current through a component and the voltage appearing across the component. Actually, if the resistance of the component is known, the power can be determined by the use of only one instrument (ammeter or voltmeter). The three basic power formulas are

$$P = E \times I$$

$$P = \frac{E^2}{R}$$

$$P = I^2 R.$$

If the resistance is unknown, it may be determined by the use of an ohmmeter or a resistance bridge.

Below the UHF band, it is usually possible to measure the effect of a-c power directly in much the same manner as d-c measurements are made. In fact, modifications of this basic procedure utilizing the thermocouple ammeter are commonly used. The following power relationship is applicable:

$$P = I^2 R,$$

where P is the power delivered by the transmitter, I is the r-f current in the antenna, and R is the effective resistance (principally radiation resistance) of the antenna.

A typical circuit for determining antenna input power is shown in figure 7-17. The meter may be calibrated to indicate the square of the current. The input power is

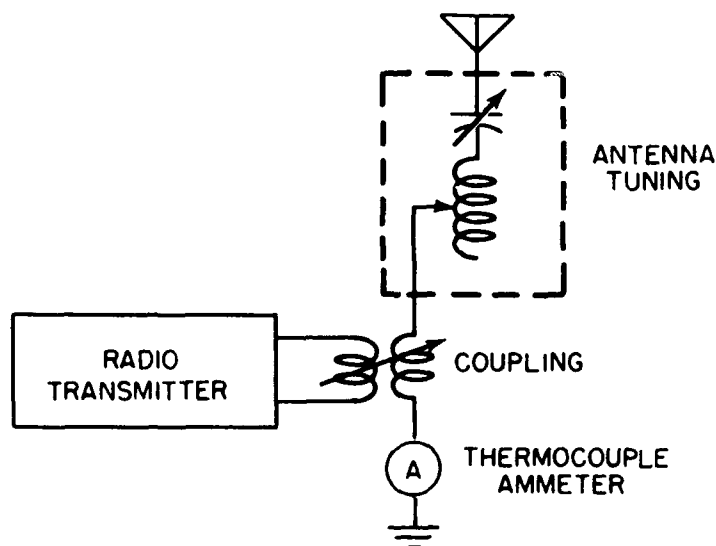


Figure 7-17.—Typical circuit for measuring antenna input power.

equal to the product of the meter reading and the antenna effective resistance. Several methods are used for determining the effective resistance of the antenna. They include the VARIATION, SUBSTITUTION, and BRIDGE methods.

Antenna Resistance Measurements

BASIC VARIATION METHOD.—This method of making antenna resistance measurements is illustrated in figure 7-18, A.

The antenna resistance at the natural frequency of the antenna (tuning network not used—that is, L and C in ZERO positions) is determined first. The antenna is connected to ground through the coupling coil and the milliammeter, A ; the shorting switch is in the CLOSED position (R_s is out of the circuit). Care should be taken to ensure that no signal is coupled to the antenna except through the coupling coil.

The r-f oscillator is then tuned to the resonant frequency of the antenna system. There should be a gradual dip in the grid-circuit milliammeter (not shown in the figure), reaching a maximum at the resonant frequency of the antenna system. If the dip in grid current is too abrupt, the coupling should be reduced. At the instant of lowest grid-current reading, the antenna milliammeter reading (I_a) should be maximum. The precision resistor, R_s , is next inserted in the antenna circuit (by opening the shorting switch), and the antenna current, I_s , is again read. During these readings no adjustments should be made in the coupling (the voltage induced in the antenna secondary should be constant). The antenna resistance, R_a , is determined by the formula,

$$R_a = \left(\frac{I_s}{I_a - I_s} \right) R_s.$$

Example: Find the antenna resistance if the antenna current is reduced from 2.5 amperes to 1.0 ampere after inserting a standard resistance of 60 ohms.

$$R_a = \frac{1.00}{2.50 - 1.00} (60) = 40 \text{ ohms.}$$

The frequency of transmission is not necessarily the same as the natural frequency of the antenna.

The resistance of the antenna at the frequency of transmission is next determined. The tuning network is connected into the circuit to resonate the antenna to the frequency of transmission. The shielding eliminates stray coupling paths.

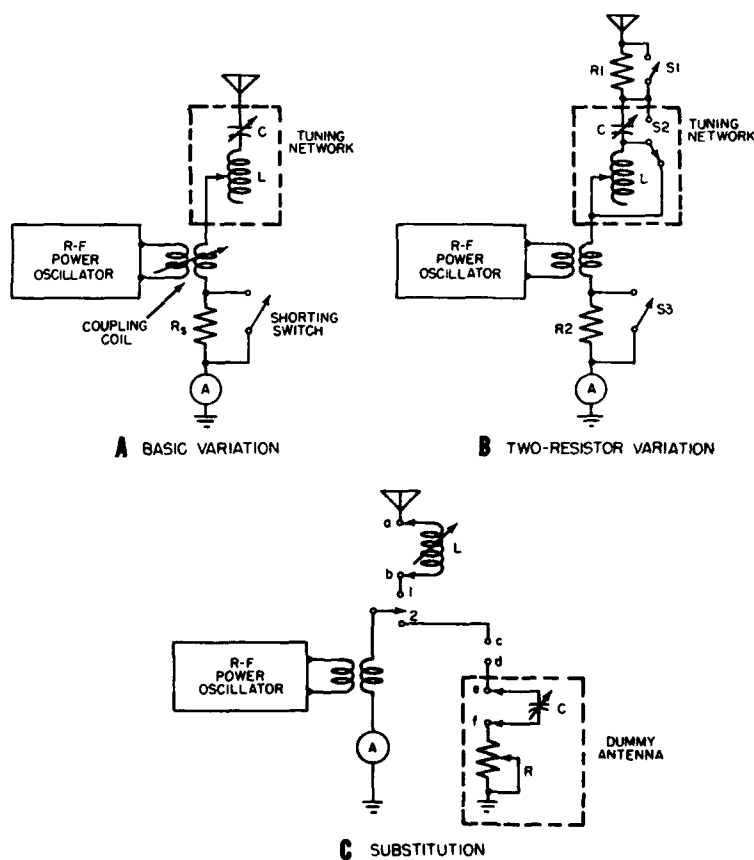


Figure 7-18.—Methods of making antenna resistance measurements.

The antenna is tuned to resonance (by means of the tuning network) at the frequency of transmission, and the current readings are taken with R_s out of the circuit and with R_s in the circuit, as was done previously. R_a is computed the same as before.

The same procedure should be repeated for frequencies above and below the natural resonant frequency of the antenna and a graph (essentially a straight line) of antenna resistance vs frequency plotted. Antenna resistance without the tuning network should not vary greatly from the antenna resistance with the tuning network.

TWO-RESISTOR VARIATION METHOD.—This method of making antenna resistance measurements is helpful in determining if stray capacitive paths to ground are shunting the system. Although a variable inductor and capacitor are shown (fig. 7-18, B), it is likely that only one or the other would be used. The inductor or capacitor should have calibrated dials. Two standard resistors are used instead of the single resistor that was used in the previous method. One resistor is located on the grounded side of the antenna transformer secondary; the other is located on the antenna side of the tuning network.

At the beginning of the test, both resistors are shorted out of the circuit, and the antenna circuit is tuned to the frequency of transmission (to the frequency of the oscillator). The oscillator output is then adjusted to produce the desired deflection, I_a , on the r-f milliammeter in the antenna circuit. No readjustment of the output should be made during the remainder of the test.

Switch S_1 is then opened to insert R_1 into the antenna circuit, and the antenna current, I_a , noted.

The antenna resistance, R_a , is computed by the formula that was given previously.

Next, S_1 is closed to short out R_1 , and S_3 is open to place R_2 in the antenna circuit. The antenna resistance, R_a , is again computed by means of the formula.

If the two values of R_a do not agree, there is appreciable stray capacitance between the measuring circuit and ground or elsewhere. Proper grounding, shielding, and arrangement of the components will permit the two readings to be essentially the same.

The reactance of the antenna at the frequency of transmission may be determined by noting the value of L or C that is required to resonate the system. If C is required, the reactance of the capacitor will be

$$X_c = \frac{1}{2\pi fC}$$

The antenna reactance, X_L , will have the same magnitude as X_c . If L is required to resonate the system, the reactance of the inductor will be

$$X_L = 2\pi fL.$$

The antenna reactance, in this case, X_c , will have the same magnitude as X_L .

SUBSTITUTION METHOD.—This method of making antenna resistance measurements is illustrated in figure 7-18, C. In this method, the antenna is replaced by equivalent amounts of reactance and resistance (a dummy antenna). Before making the resistance measurements, the antenna system is made resonant at the operating frequency. The oscillator should be well shielded and a fairly high energizing current should flow in the antenna circuit.

The antenna current is noted when the switch is in position 1. The switch is then placed in position 2. If a coil is used to resonate the antenna, as indicated in the figure, a capacitor will be used in the dummy antenna. If a capacitor is used to resonate the antenna, an inductor will be used in the dummy antenna. The antenna tuning element (inductor in this case) is then connected between points C and D , and the capacitor is tuned to resonance, as indicated by a maximum deflection of the milliammeter. The resistance of R is then varied until the meter reads the same as it did when the antenna was connected in the circuit. The resistance of R is

equal to the antenna resistance, and the reactance of C is equal to the reactance of the antenna circuit (with the coil shorted out) at the resonant frequency.

Other Methods of Measuring Power

The R-F BRIDGE METHOD of determining the impedance of an antenna is both rapid and accurate, if shielding is sufficient and if the connections are properly made. The exact method of making the measurements with a bridge depends on the type of bridge used.

R-F POWER METERS (similar to those discussed under the section on Radar Power Measurements) may be used to obtain a direct reading of the power output of a transmitter when a high degree of accuracy is not required and the power output is less than 500 w. With proper termination of the transmission line, the standing-wave ratio will be negligible, and essentially all of the power will be absorbed in the power meter.

There are several indirect methods of measuring r-f power—for example, the lamp-load, resistor-load, and bolometer methods.

In the LAMP-LOAD METHOD a pair of identical lamps are placed side by side. One lamp is fed by the r-f source, and the other is fed by a d-c source through a potentiometer. An ammeter is connected in series with the lamp fed by the d-c source, and a voltmeter is connected across the lamp.

The potentiometer is varied until the lamp fed from the d-c source has the same brilliancy as that of the lamp fed from the r-f source. The d-c and r-f power dissipated in the lamps are then equal. All that is necessary to determine the power dissipated in the lamp connected to the r-f source is to multiply the ammeter reading by the voltmeter reading.

To make the readings more accurate, a photoelectric cell may be used with a sensitive meter to determine when the lamps have the same brilliancy. It is assumed, of course, that the transmission line feeding the r-f energy to the lamp is properly terminated in the lamp.

In the RESISTOR-LOAD METHOD of measuring r-f power the temperature rise of a noninductive resistor fed by the r-f power is determined by means of thermocouples placed in a stream of air that is blown over the resistor. This method is somewhat involved in that the rate of air flow and the temperature rise must be determined before the power dissipation can be calculated.

BOLOMETER METHODS of measuring r-f energy, especially in the UHF range, are becoming standard procedure. The bolometer is a loading device that changes in resistance as the power dissipated in it changes. The two main types of bolometers are the thermistor and the barretter. Their changes in resistance with temperature change are opposite. When the thermistor dissipates more power (increased temperature) its resistance decreases; when the barretter dissipates more power, its resistance increases. (The use of the thermistor in making power measurements was described under the section on Radar Power Measurements.)

Regardless of which type of bolometer is used, the method of making power measurements is essentially the same. The resistance of the bolometer is measured before and after the application of r-f power. A d-c source of power, which may be varied, is then connected to the bolometer, and the power is adjusted to give the same change in bolometer resistance as was obtained when r-f power was applied. The readily measured d-c power is equal to the r-f power. A bridge arrangement calibrated in units of power is commonly used along with the necessary attenuation devices. The thermistor is more widely used because of the high degree of precision that can be obtained, especially when compensating thermistors are used.

Because of the low power that the thermistor is capable of dissipating (1 mw is standard), the power must be attenuated before it is applied to the thermistor bridge. The amount of attenuation must be accurately known before the r-f power being measured can be determined.

RADAR FREQUENCY MEASUREMENTS

Radar frequency measurements involve transmitter frequency and receiver frequency measurements.

The radar transmitter must operate within its assigned band of frequencies because radar beacon stations will respond only to signals within an assigned frequency range, and because the waveguide tuning adjustments cover only a limited range of frequencies. Also, two radar transmitters operating in the same band could cause serious interference.

The radar receiver must operate at the same frequency as the transmitter. A knowledge of the receiver frequency is not so important as long as the receiver is tuned exactly to the transmitter frequency.

Radar transmitter frequency measurements are often made with a combination frequency and power meter—for example, Frequency-Power Meter TS-230B/AP, a functional block diagram of which is shown in figure 7-11, A. An exploded view of the wavemeter is shown in part B, and the r-f assembly is shown in part C. The open-circuited coaxial transmission line (in the wavemeter) is coupled to the waveguide in the meter by means of a probe antenna. The micrometer FREQ control (fig. 7-9) varies the length (and thus the resonant frequency) of the resonant coaxial line comprising the wavemeter (fig. 7-11, B). The motion of the drive can be accurately calibrated in terms of resonant frequency. When the wavemeter is in resonance, more energy is extracted from the waveguide, leaving less to be absorbed by the power thermistor; thus, there is a decrease in the meter, M, reading. (The bridge approaches a balance when the thermistor absorbs the least r-f energy.) The setting of the micrometer can then be translated into frequency by reference to the calibration chart inside the front cover of the meter.

This meter is designed to measure the frequency of unmodulated and pulsed signals in the range from 8500

to 9600 mc. It is suitable for use in a temperature range between -40° F and $+131^{\circ}\text{ F}$.

The following is a brief summary of the procedure for making a frequency measurement, using the Frequency-Power Meter TS-230B/AP. The meter is turned on, adjusted, and calibrated as outlined in the instruction book. It is not necessary to have the meter adjusted to precisely zero when frequency alone is being measured. The ADJ zero control is next set to the position that

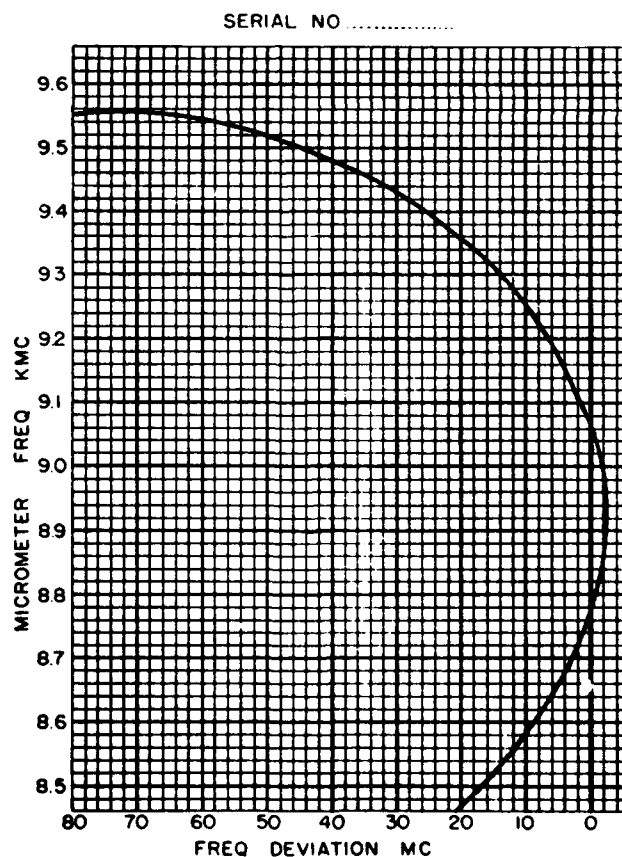


Figure 7-19.—Sample calibration chart.

makes the meter read close to zero, and the meter is connected to the radar system by means of the connector or adapter furnished with the meter.

The radar transmitter is then turned on, and the input attenuation control is adjusted to give a meter reading between 50 and 100 μ a at *M* (fig. 7-11, A).

The FREQ control is moved to an initial setting of 9600; then it is turned slowly clockwise until the meter reads the exact minimum. This should be done slowly because there is a slight time lag in the change in resistance of the thermistor in the bridge circuit.

The FREQ setting is recorded, and the calibration curve is used to obtain the frequency in megacycles corresponding to the micrometer (FREQ dial) setting.

The following sample calculation is taken from the instruction book. For purposes of illustration, the micrometer setting at resonance is assumed to be 8555.0. From the sample calibration chart (fig. 7-19) the point on the curve corresponding to 8555 mc (8.555 kmc) corresponds to 13 mc on the frequency deviation axis. The frequency is calculated by adding 13 mc to 8555 mc to give 8568 mc. Frequency measurements are also included under the section on echo box in the next chapter.

RADIO FREQUENCY MEASUREMENTS

It is very important to keep Navy transmitters on their assigned frequencies. To aid the technician or operator in keeping the transmitters within the frequency tolerances, the Navy provides accurate frequency meters. These meters must be calibrated periodically against the primary standard frequencies transmitter by the U. S. Bureau of Standards. These primary frequency standards are transmitted continuously, day and night.

Where extreme accuracy is not of prime importance, as in making preliminary adjustments or for general experimental work, rapid frequency checks may be made with the simple resonant-circuit wavemeter of the absorption type.

The ABSORPTION-TYPE WAVEMETER, the grid dip meter, and secondary frequency standards are discussed in Chapter 13 of *Basic Electronics*, NavPers 10087.

A REACTION-TYPE WAVEMETER may also be used. In this type of wavemeter the indicating device is in the circuit under test; otherwise, the setup is essentially the same as that used with the absorption-type wavemeter. The reaction-type wavemeter absorbs very little energy from the source and is therefore advantageous when the frequency of low-power sources is being measured.

Where great accuracy is needed, oscillating frequency standards (FREQUENCY METERS) are used. These instruments are similar to signal generators, but are more stable and accurate; however, they have lower output than a signal generator. The frequency meter is used to measure frequency and to tune transmitters and receivers to the desired frequency. As has been mentioned, they must be compared with the primary frequency standard transmissions of WWV (Washington) or WWVH (Hawaii) at frequent intervals.

A frequency meter (one of the LM series) used extensively on small craft is shown in figure 7-20. Several models of this meter have been built. These models are similar except for the power supply and some minor mechanical differences. The LM-18 frequency meter covers the band of frequencies from 125 to 20,000 kc.

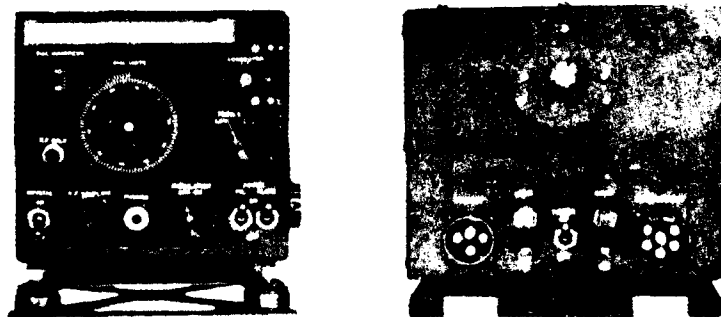


Figure 7-20.—LM-18 frequency meter.

This equipment has accuracies within 0.02 percent in the 125- to 2000-kc band and within 0.01 percent in the 2000- to 20,000-kc band.

Two oscillators are used in the LM-18—a crystal oscillator and a heterodyne oscillator. The crystal oscillator is used to calibrate the heterodyne oscillator at several different points over the entire band covered by the frequency meter. The LM-18 also contains an a-m detector, an audio amplifier, and a modulator.

The fundamental frequency of the crystal oscillator is 1000 kc. However, the oscillator output has a high harmonic content. A small trimmer capacitor is placed across the crystal so that if the crystal frequency changes, an adjustment can be made to keep the crystal frequency close to 1000 kc. Most of the frequency-determining components, including the crystal, are hermetically sealed to keep out moisture and dirt.

The band of frequencies measured by the LM-18 is covered in two ranges. The heterodyne oscillator has two continuously variable ranges that may be selected by the frequency band switch. In the LOW position a fundamental range of 125 to 250 kc is used. By calibrating the first, second, fourth, and eighth harmonics of this range, continuous coverage from 125 to 2000 kc is obtained. In the HIGH position of the switch, the fundamental range of 2000 to 4000 kc is calibrated over the first, second, fourth harmonics, and part of the fifth harmonic to provide continuous coverage through the range of 2000 to 20,000 kc.

The LM-18 frequency meter can be used to tune transmitters and receivers (both c-w and m-c-w) and to determine the frequency of a received signal. Figure 7-21 shows a block diagram of the frequency meter when it is used to calibrate the heterodyne oscillator with the crystal oscillator.

The output of the heterodyne oscillator is coupled to the grid of V102. Tube V102 is used as a crystal oscillator and mixer. The two oscillator frequencies beat

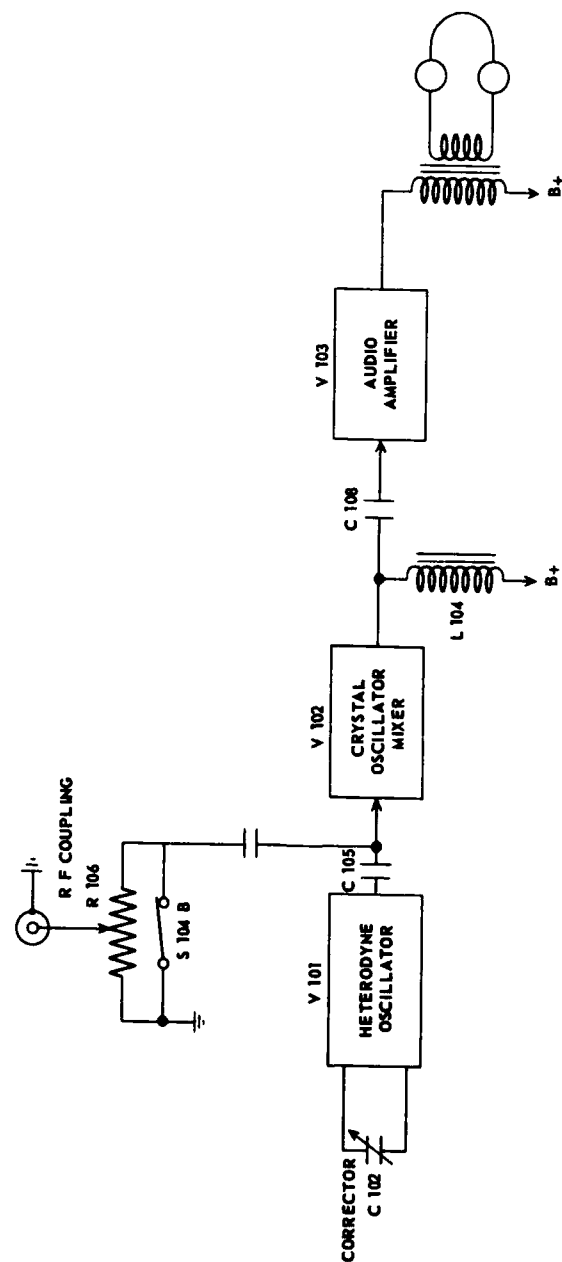


Figure 7-21.—Block diagram of LM-18 frequency meter when calibrating the heterodyne oscillator.

together and the difference frequency is developed across choke *L104*. An audio amplifier, *V103*, amplifies the beat note and supplies it to a set of headphones. If a beat note is heard, the corrector, *C102*, is adjusted until a zero beat is obtained. Thus the heterodyne oscillator is corrected to the crystal check point nearest the frequency to be measured, as shown in the calibration book. During the calibration procedure, r-f coupling *R106* is grounded by a section of *S104* to prevent interference from external r-f signals.

Figure 7-22 is a block diagram of the LM-18 frequency meter when it is used to tune a receiver or a transmitter to a given frequency. The modulation and crystal switches are in the OFF position for this operation. When a receiver is tuned, the heterodyne oscillator output is coupled through capacitors *C105*, *C106*, and potentiometer *R106* to the receiver. The beat-frequency oscillator of the receiver is turned on, and the receiver is tuned until a zero beat is heard in the output of the receiver (not shown in the figure).

When a transmitter is tuned, a portion of the transmitter oscillator signal is coupled into the frequency

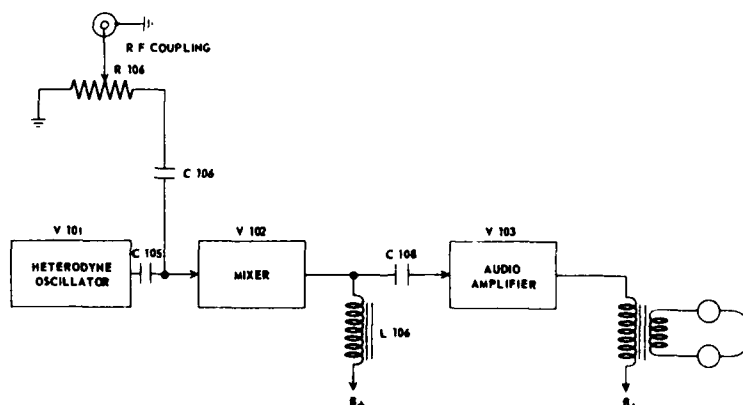


Figure 7-22.—Block diagram of the LM-18 frequency meter when tuning a transmitter or a receiver.

meter through *R106* and *C106* to the mixer tube, *V102*. This signal from the transmitter is mixed with the output of the heterodyne oscillator. The difference frequency is developed across *L104* and amplified by *V103*. The output of *V103* may be fed to a phone jack in the switching system for convenience because the transmitter may be located at a distance from the frequency meter. A zero beat occurs when the transmitter frequency is the same as the frequency of the heterodyne oscillator.

Figure 7-23 shows a block diagram of the LM-18 frequency meter when it is used to tune an m-c-w re-

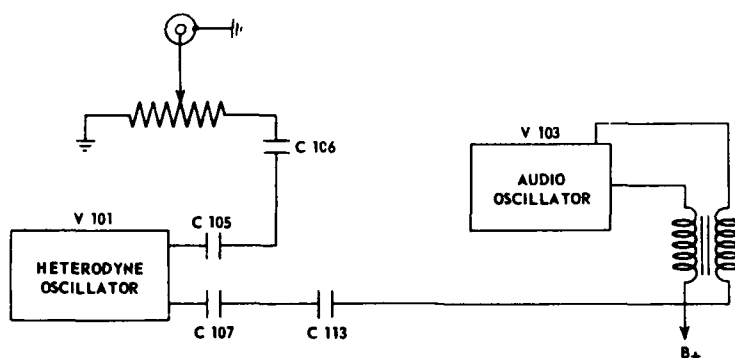


Figure 7-23.—Tuning an m-c-w receiver with the LM-18 frequency meter.

ceiver. The modulation switch is ON and the crystal switch is OFF. In this arrangement, the crystal oscillator-mixer is not used in the circuit. When the modulation switch is ON, the audio amplifier, *V103*, becomes a 500-cycle audio oscillator. The output of the audio oscillator is fed to the suppressor grid of the heterodyne oscillator where it modulates the r-f signals generated by this tube. The output is fed to the m-c-w receiver (not shown in the figure). No zero beat is heard. Instead, the receiver is tuned for maximum output of the 500-cycle modulating signal. The r-f coupling control, *R106*, is adjusted to produce the desired output signal.

The power supply is a separate unit. This unit supplies the a-c filament voltage and the relatively high d-c plate voltage. The plate voltage is regulated so that the output frequency is stable, regardless of variations of the line voltage to the power supply.

Other types of heterodyne frequency meters are the LR, the OCP, the TS-186/UP, and the TS-535/U.

RADAR RECEIVER SENSITIVITY MEASUREMENTS

The loss of radar receiver sensitivity has the same effect on reducing the range as a decrease in transmitter power. For example, a 6-db loss in receiver sensitivity shortens the effective range of a radar just as much as a 6-db decrease in transmitter power. Such a drop in transmitter power may be easily detected, but a comparable drop in receiver sensitivity is not so easy to detect unless accurate measurements are made.

A sensitive receiver is one that can pick up weak signals. The minimum discernible signal (MDS) is the weakest signal that produces a visible receiver output above the noise level of the receiver.

In the microwave range of operation, virtually all of the noise originates within the receiver. Atmospheric and man-made noise or static is normally too small to be considered.

Not all receiver noise originates in electron tubes. For example (because of the heat in the circuit conductors) there are certain amounts of random motion of the electrons other than the motion associated with the signal current. These motions produce voltages within the conductor that likewise vary in a random manner. The frequencies with which these voltages vary are distributed throughout the r-f spectrum and appear as noise in the receiver.

The power in watts developed by this form of noise is given by

$$\text{noise power} = KT \Delta F,$$

where K is Boltzmann's constant (1.37×10^{-23} watt-sec-

onds per degree Kelvin), T is the temperature in degrees Kelvin ($C^{\circ} + 273$), and ΔF is the bandwidth ($f_2 - f_1$) in cycles per second. Frequencies f_2 and f_1 are the upper and lower noise frequency limits (frequencies at which the noise voltage falls to 0.7 of the maximum).

This formula shows that thermal-agitation noise varies directly as the temperature and the bandwidth. In a theoretically perfect receiver having no noise except thermal-agitation noise, this noise could be considered as a voltage across the antenna terminals, and the power represented could be calculated on the basis of temperature and bandwidth.

In practice, the noise generated in a receiver is not limited to thermal-agitation noise. Additional noise sources are carbon resistors, which generate noise when current flows through them; crystal mixers; and electron tubes. Electron tubes generate noise because of random variations in electron emission from the cathode, random variations in current division between plate and screen, etc. In general, the more grids a tube has the more noise it generates.

The term, NOISE FIGURE (NF), indicates the amount of noise that is to be expected for a given receiver. It is the ratio of measured noise to calculated noise and may be expressed as a power ratio or in decibels. There are, however, variations in the way the noise figure may be expressed.

The three main sources of noise in a radar receiver are: first, the crystal mixer; second, the i-f preamplifier; and third, the local oscillator.

If the noise in a certain radar receiver becomes too high, something must be done to reduce it. First of all, another crystal mixer is substituted; in practice, several may be used in turn and the one with the lowest noise chosen. The same procedure is used for the i-f preamplifier tubes. If the noise is still high, the local oscillator tube is replaced. It should be noted that the noise of a reflex klystron is much greater than normal

when the tube is tuned off the center of a mode (a proper operating frequency).

The noise figures of early radars were in excess of 20 db, but modern receivers have noise figures between 6 and 18 db.

The noise figure of a radar receiver may be determined by the use of a noise generator or a c-w signal generator. The noise-generator method is more accurate.

A practical example will illustrate how a noise generator may be used to determine the noise figure of a radar receiver. The following are the steps that are involved in making the measurement:

1. A 0-1 milliammeter is connected in series with the diode load resistor of the second detector.

2. The receiver input is grounded, and the receiver gain control adjusted to produce a 0.5-ma reading. This reading is due to the internal noise alone.

3. The input ground is removed and the noise generator connected to the input of the receiver.

4. The output of the noise generator is adjusted until the meter reads 0.707 ma—that is $(1.4 \times 0.5 \text{ ma})$. The receiver gain control is NOT adjusted after the initial adjustment in step (2).

5. If in step (4) a further increase in noise input does not cause a corresponding increase in meter reading, the receiver is limiting and the readings will not be accurate. The procedure is to start with step (2) again and to reduce the receiver gain-control setting until the meter reads less than 0.5 ma. For example, reduce the reading to 0.3 ma. In step (4) the output of the noise generator should be adjusted to make the meter read 0.42 ma—that is $(1.4 \times 0.3 \text{ ma})$.

6. The noise-generator power output is now equal to the receiver noise power. This may be understood from the following. The resistance of the diode load resistor remains constant, and therefore the power dissipated in it varies as the square of the current, as read on the meter.

A simple analogy is shown in figure 7-24. As may be seen in the figure, when the current increases from 0.5 ma to 0.707 ma, the power is doubled. When the output of the noise generator is added to the receiver noise, and the output across the 1M resistor is doubled, the output of the noise generator is equal to that developed by the receiver noise. A chart is usually furnished with the instrument for converting the dial reading to power for various load resistances.

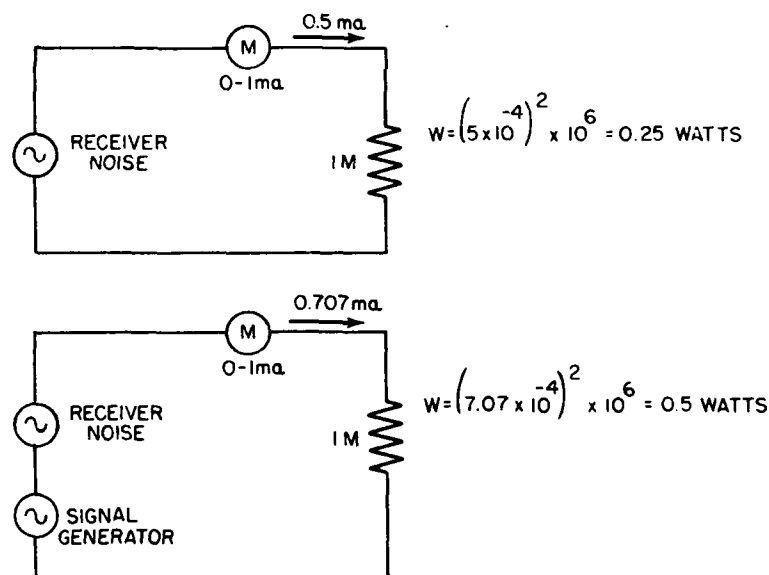


Figure 7-24.—Simple power analogy.

7. The noise figure (NF) is determined as follows:

$$NF (db) = 10 \log \frac{\text{power measured}}{\text{power calculated}}$$

Noise energy (calculated) has already been given as

$$NP = 4 KT \Delta f.$$

Assume that the temperature is 20° C and that the receiver bandwidth is 4×10^6 cycles ($f_2 - f_1$).

$$\begin{aligned}
 NP &= 4(1.37 \times 10^{-23}) \times (20 + 273) \times (4 \times 10^6) \\
 &= 6422.56 \times 10^{-17} \\
 &= 0.06423 \mu\mu\text{W}.
 \end{aligned}$$

Assume that the noise power fed to the receiver is 1.018 $\mu\mu\text{W}$. The noise figure in db is then

$$\begin{aligned}
 NF \text{ (db)} &= 10 \log \frac{1.018}{0.0642} \\
 &= 10 \log 15.86 \\
 &= 10 \times 1.2 \\
 &= 12 \text{ db.}
 \end{aligned}$$

Over-all radar system sensitivity measurements are included in the following chapter under the treatment of the echo box.

RADIO RECEIVER SENSITIVITY MEASUREMENTS

The one measurement that provides maximum information about receiver condition in field operation is that of sensitivity.

The sensitivity of a radio receiver is an indication of its ability to give a satisfactory output with a weak signal input. Although there may be some variation in the exact wording of the definition, sensitivity is the value of input carrier voltage that must be fed from the signal generator to the receiver input to develop a specified output power. The settings of the various controls are specified as well as the modulation frequency and percentage of modulation.

In many Navy receivers, sensitivity is the magnitude of signal voltage (in microvolts) that must be fed to the receiver antenna terminals in order to produce a standard output of 6 mw across a 600-ohm noninductive resistance substituted for the headphones or other device at the receiver output terminals. A signal-to-noise ratio of 10:1 is maintained for this test.

This measurement ordinarily requires the application of a calibrated input signal voltage to the antenna terminals of the receiver through an impedance, which approximates that of the antenna with which the receiver is to be used. This impedance is usually known as a

DUMMY antenna. The dummy antenna ensures that the signal current in the input circuit of the receiver is the same as would appear with the calibrated signal voltage induced in an ideal receiving antenna. It also ensures that the input circuit of the receiver is "loaded" the same as it would be by an ideal antenna.

A dummy antenna that may be used with high-impedance input receivers is shown in figure 7-25. In the case of low-impedance input receivers of 50 to 70 ohms nominal impedance, a signal generator with a 50-ohm output, may be directly connected without the use of an external dummy antenna. Other generator impedances may require special dummy-antenna networks to load the generator and the receiver properly.

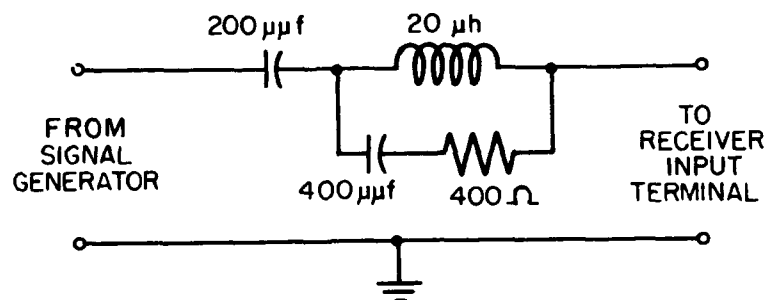


Figure 7-25.—Dummy antenna circuit.

For sensitivity measurements, the receiver is adjusted for the type of reception desired. Facilities, such as AGC, silencer, noise limiter, etc, are set according to the instructions in the instruction book. The power-line voltage and frequency applied to the receiver should be within the recommended operating range. The receiver output terminals should be properly loaded by substituting for the headphone or audio-line termination a 600-ohm noninductive resistor capable of dissipating the maximum output power (approximately 6 mw for this test).

High-impedance headphones may be used in shunt with the load for monitoring the output. Low-impedance headphones would load the output appreciably. The output voltage is measured with a high-impedance audio voltmeter capable of accurate indication from 0.1 v to 100 v. Although some receivers are equipped with audio output meters, their meters may not indicate the required standard noise levels with sufficient accuracy.

Detailed instructions for making sensitivity measurements are included in the instruction book that accompanies a particular receiving equipment. In some of these instruction books (for example, the one accompanying the RDZ receiver) detailed information for making sensitivity checks for the various sections of the receiver are given. In other instruction books (for example, the one supplied with the AN/URR-23A receiver) instructions for making sensitivity tests are included in receiver final testing.

A general idea of one method of making sensitivity measurements on c-w and facsimile receivers may be obtained from the following considerations. The test setup is shown in figure 7-26.

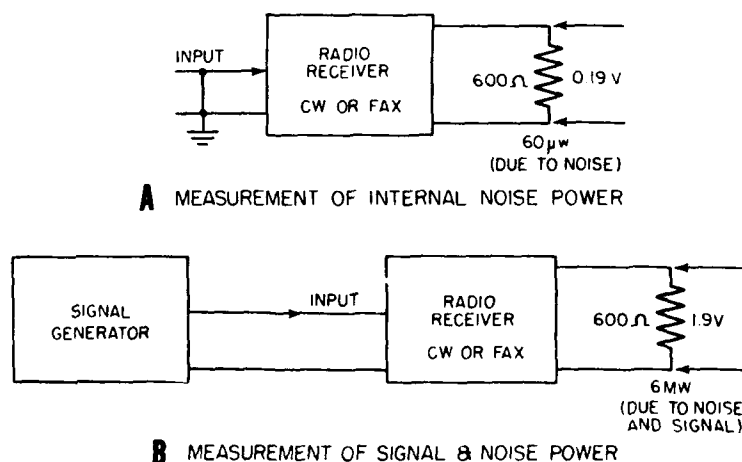


Figure 7-26.—One method of making radio receiver sensitivity measurements.

In part A, no signal is applied (input grounded), and the r-f gain control is adjusted to produce $60 \mu\text{w}$ (0.06 mw) of noise at the output—that is, 0.19 v across 600 ohms . This is the power developed by the noise. No further adjustment of the gain controls (either r-f or a-f) is made during the remainder of the test.

If a db meter is used to obtain this indication of noise level, the meter reading will be in decibels. For example, if the total resistance of the load is 600 ohms , and zero db is equivalent to 1 db (1 mw in 600 ohms), the indication of the output meter will be $10 \log \frac{0.06 \times 10^{-3}}{1 \times 10^{-3}}$, or -12.2 db .

In part B, the unmodulated carrier signal is applied. The c-w oscillator frequency (receiver BFO) control is adjusted to produce a 1000 cps beat note. The input signal voltage to the receiver from the signal generator is then adjusted to produce an output of 6 mw —that is, 1.9 v across 600 ohms .

If the same db meter is used to obtain this indication, the signal generator output is adjusted so that the meter reading will be $10 \log \frac{6 \times 10^{-3}}{1 \times 10^{-3}}$, or 7.78 db .

The output signal-to-noise ratio (actually the signal-plus-noise to noise ratio), using the output voltages, is

$$\text{signal-to-noise ratio} = \frac{1.9 \text{ volts}}{0.19 \text{ volts}} = 10,$$

or a $10:1$ ratio, the power ratio is $100:1$. The signal-to-noise ratio in db in terms of the power ratio is

$$\text{db} = 10 \log \frac{6 \times 10^{-3}}{60 \times 10^{-6}} = 20 \text{ db}.$$

The receiver sensitivity, in terms of input signal voltage in microvolts, is obtained from the signal-generator voltage calibration chart. For the example being considered, the input signal voltage is approximately $5 \mu\text{v}$. Thus, the receiver sensitivity is expressed as $5 \mu\text{v}$ input to produce an output of 6 mw when the signal-to-noise ratio is 10 to 1 . The correct sensitivity will appear

in the Performance Standards Book for the receiver as a part of the data provided with the receiver.

SONAR TESTS AND MEASUREMENTS

Typical Test Equipment

Most sonar system tests and measurements may be made with Sonar Portable Testing Equipment, Navy Model OCP-3, which has a frequency range of from 7 kc to 70 kc in four bands. For example, sonar receiver frequency-response measurements made with this equipment indicate the frequency response of the complete sonar receiver section, including the ship's transducer, transmission line, preamplifiers, and the receiver, rather than the response of the receiver alone. Receiver sensitivity measurements likewise furnish information about the over-all sensitivity of the receiver. The ship's sonar transmitter frequency and power measurements may also be made with this equipment. Additional measurements that may be made are transmitting and receiving directivity patterns and transmitter and receiver tuning.

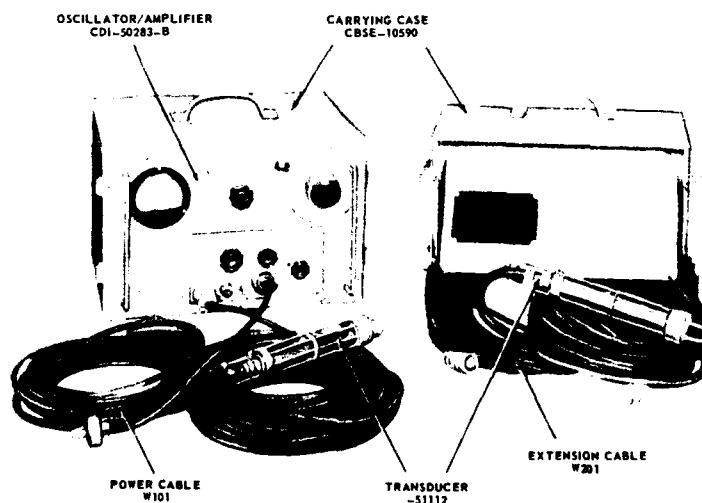


Figure 7-27.—Model OCP-3 equipment.

The Sonar Portable Testing Equipment, called the MONITOR, is shown in figure 7-27. The monitor consists of the transducer assembly, the oscillator/amplifier unit, and the carrying case.

When mounted as in figure 7-28, it functions as (1) a source of ultrasonic signal energy in the water for checking sonar receiving-type circuits of the ship's equipment, and (2) a means of receiving and measuring (relatively) any ultrasonic signal energy within its frequency and sensitivity range in the water. This function is for checking the sonar transmitting circuits of the ship's equipment. Other uses are described later.

The transducer is of the magnetostrictive type mounted in a protective cage. Metal yokes are fitted at each end of the cage to facilitate suspension of the transducer over the side of the ship. Two transducers are provided with the equipment; each is connected to a 60-ft length of two-conductor shielded cable; a 75-ft extension cable is also provided.

The oscillator/amplifier unit serves both as a source of electrical energy for driving the transducer (to generate the outgoing signals) and also as an amplifier for increasing the amplitude of the electrical signal output from the transducer (for example, when signals are picked up from the water). Means are provided for measuring the RELATIVE level of the portable test transducer signal output and for making this signal audible. Also, a circuit is provided to assure a constant output signal when the monitor is used to transmit. All controls are located on the front panel of the oscillator/amplifier unit.

The various controls and dials are shown in figure 7-29. The selector switch determines the function of the monitor. The four positions are:

1. RECEIVE 33-93 db, high sensitivity receiving position.

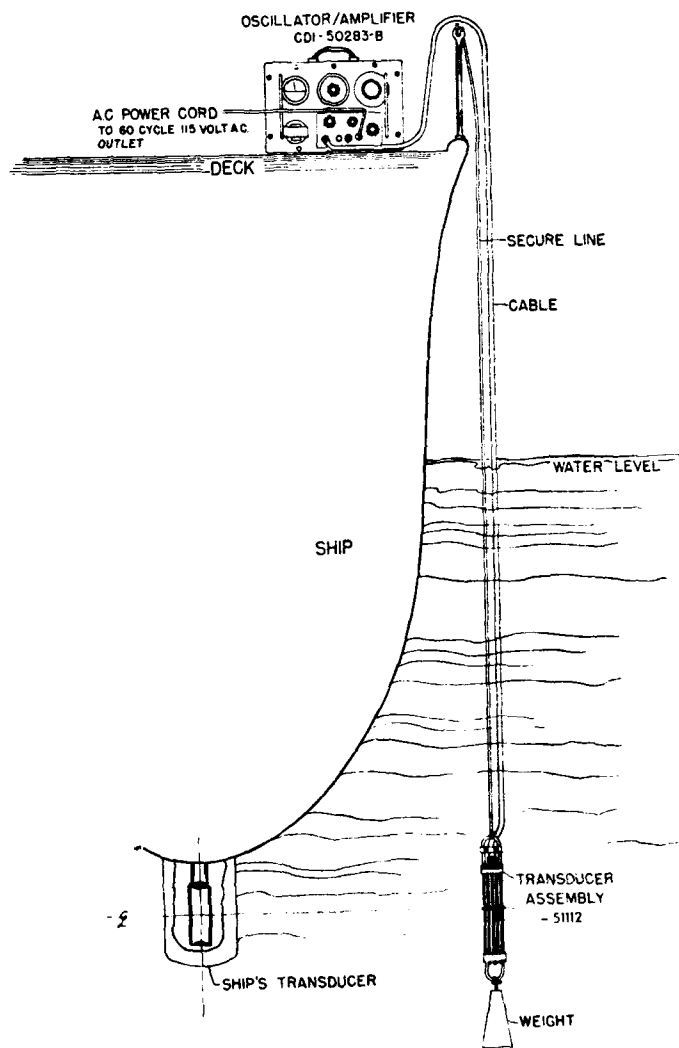


Figure 7-28.—Monitor setup.

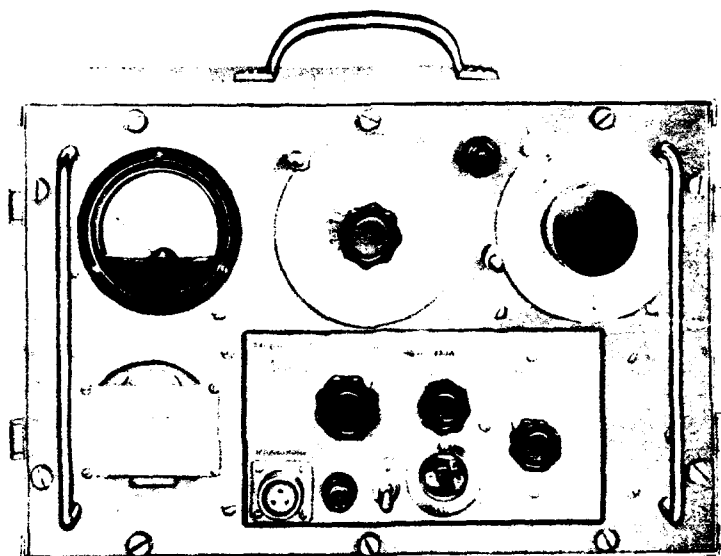


Figure 7-29.—Controls and dials of the oscillator/amplifier.

2. RECEIVE 63-123 db, normal sensitivity receiving position (on either receive position the monitor receives equally well all frequencies between 7 and 70 kc).

3. BEAT, monitor is in the normal sensitivity receiving condition, with beat-frequency oscillator action introduced.

4. SEND 18 to +42 db, monitor transmits signal energy to transducer or other load.

The band-change switch selects the frequency band of operation from four bands available. This switch is effective only when the selector switch is in position 3 or 4. These bands are (1) 5-11 kc, (2) 10-22 kc, (3) 20-44 kc, and (4) 40-88 kc.

The frequency dial designates the frequency of the oscillator. The four scales on this dial correspond to the frequency bands listed in the preceding paragraph.

The attenuator dial gives the setting of the receiver input, or transmitter output attenuator. The dial has three scales, one for transmitting and two for receiving.

The zero-set potentiometer is used for adjusting the transmitting level to zero db, as read on the output meter. The output meter is the signal reference-level indicator.

Transmitting and Receiving Frequency Response Curves

The frequency response curves of a sonar equipment are plots of relative output while transmitting, or relative sensitivity while receiving, plotted against frequency.

Sample frequency response curves are shown in figure 7-30. The transmitting response curves are shown in part A. The exact methods of setting up the equipment and making the readings are included in the equipment instruction book (NavShips 91601). The measurements are made when the monitor transducer is suspended at the correct depth, the ship's transducer is directed at the monitor transducer, and the ship's sonar driver is tuned initially to the peak transmitter frequency (frequency at which the output is a maximum).

A sample receiving frequency response curve is illustrated in figure 7-30, B. This type of curve is an over-all

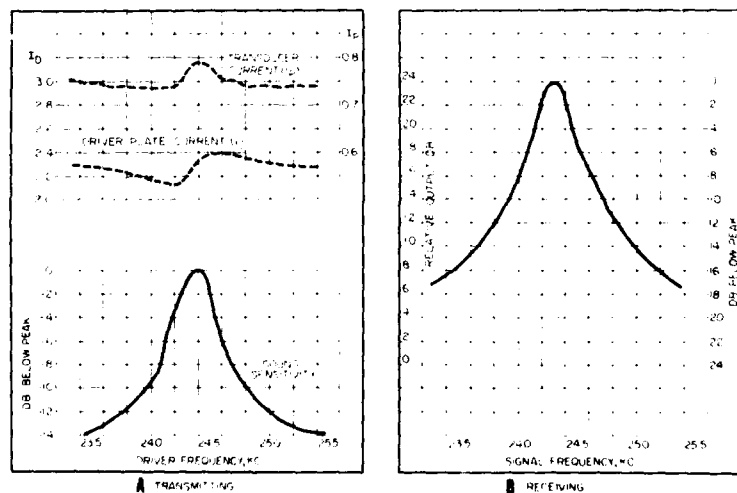


Figure 7-30.—Frequency response curves.

receiving sensitivity curve of the receiving section of the sonar equipment. This includes the characteristics of both the transducer and the receiver. The exact procedure for making this graph is included in the instruction book.

Transmitting and Receiving Directivity Patterns

Assume that the monitor transducer is suspended at a particular bearing (for example, 090° relative, as in figure 7-31), that the ship's sonar gear is of the searchlight type and transmitting continuously, and that the monitor is used to receive the signal put into the water by the ship's transducer. If the ship's transducer is rotated through 360° in 5 steps and the intensity of the signal received by the monitor is recorded at each bearing, the recorded values can be plotted on polar graph paper, as shown in figure 7-31. A smooth curve drawn through the plotted points is called a TRANSMITTING DIRECTIVITY PATTERN. This pattern shows the manner in which the sound intensity (measured at a particular bearing) varies as the ship's transducer is trained through a complete circle.

The directivity pattern has important applications in judging the performance of an echo-ranging, searchlight-type sonar installation. In figure 7-31 the sound intensity falls off quite rapidly as the ship's transducer is trained away from the bearing of the monitor transducer. This implies that the echo returned from the target would rapidly decrease in intensity as the ship's transducer is trained away from the target bearing. Such a characteristic permits the sonar operator to determine the bearing of the target with considerable accuracy. The increase in sound intensity in the direction to which the ship's transducer is trained is called the MAJOR LOBE of the directivity pattern. The sharpness of the major lobe is usually specified in terms of the angle between the 10-db down points. Thus, the major lobe in figure 7-31 is about 29° wide at the 10 db down points.

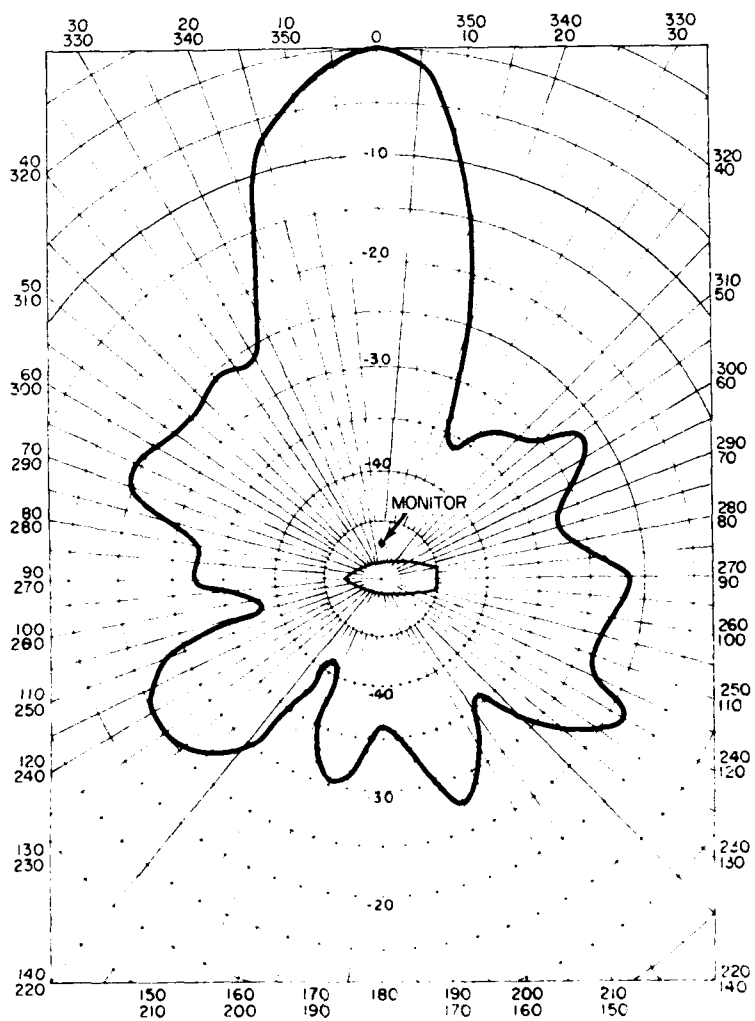


Figure 7-31.—Satisfactory transmitting directivity pattern for searchlight-type sonar transducer.

Receiving directivity patterns for searchlight-type sonars have the same general appearance as transmitting patterns and have comparable significance.

Assume that the monitor transducer is suspended at a particular relative bearing and that it is used to transmit a signal of constant intensity into the water. The ship's receiver is tuned to the same frequency. The ship's receiver output will vary as the ship's transducer is trained through 360° . If the receiver output is plotted on polar graph paper at each 5-degree step as the ship's transducer is trained and a smooth curve is drawn through the plotted points, this curve is called a RECEIVING DIRECTIVITY PATTERN.

To judge the performance of a sonar installation, it is desirable to have both transmitting and receiving directivity patterns. The transmitting pattern tells how the training of the ship's transducer affects the intensity of the signal arriving at a target and, therefore, the intensity of the echo leaving the target. The receiver directivity patterns tells how the training of the ship's transducer affects the response of the ship's receiver to the echo.

For example, if the receiving pattern of the sonar installation is exactly the same as the transmitting pattern of figure 7-31, the response of the system to a target 10° to the right of the major lobe is 14 db less than the response would be if the target were in line with the major lobe. The 14-db decrease is due to a 7-db decrease in the intensity of the transmitted signal plus a 7-db decrease in receiver sensitivity.

As another example, consider figure 7-31 as both a transmitting and a receiving pattern. Assume that a target is 10° to the right of the major lobe when the ship's transmitter sends out a signal and that before the echo returns, the sonar operator has trained the transducer an additional 5° . According to the pattern of figure 7-31, there is a loss in transmission of 7 db and a loss in reception of 15 db. The total response of

the system is therefore $7 + 15$ or 22 db less than it would be if the transducer were pointed at the target throughout the ranging time.

As a third example, assume that the sonar operator is listening to sound produced by a target (for example, noise produced by the target's screws). The transmitting directivity pattern, in this case, gives no useful information because the sound in question does not originate in the ship's sonar gear. The effect of training the ship's transducer away from the target would depend on the receiving directivity pattern.

QUIZ

1. Which one of the following classes of instruments is generally used for measuring currents, voltage, and resistance: separate meters or multimeters?
2. How are power-level measurements in the audio-frequency range usually expressed?
3. What two basic components are used to measure the power output of a transmitter in the LF, HF, and VHF bands?
4. What two radio transmitting stations are used as primary frequency standards to accurately calibrate Navy-type frequency meters as secondary standards?
5. What general type of test equipment is used to measure the magnitude of the field intensity produced by the energy radiated from an antenna?
6. What is the name given to the value of signal voltage fed to the receiver antenna terminals which will produce a specified power output (for example 6 mw) at the receiver output terminals when the signal to noise ratio is 10:1?
7. In the resistance bridge circuit of figure 7-2, assume that a balance occurs when the multiplier dial indicates "5" (arm A = 5000 ohms), and the range switch is set at 1 k (arm B = 100 τ and R_s = 100 ohms). What is the value of R_x ?
8. In the capacitance bridge circuit of figure 7-3, assume that the bridge is balanced when the range switch is in the 0.01 μ f position (arm B = 100 ohms), the multiplier dial indicates "4" (arm A = 4000 ohms), and arm C, utilizes the 1000 μ mf standard. Find the value of C, in microfarads.
9. In the inductance bridge circuit of figure 7-4, B, assume that the bridge is balanced when the range switch is set at 10 mH (arm B = 10,000 τ), the capacitance of the C, arm is 1000 μ mf, and the multiplier dial is set at 3 (arm A = 3000 ohms). Find the value of L in millihenries.

10. What are three common methods of sampling radar power?
11. What is the heart of the r-f power-measuring circuit in the Frequency Power Meter, TS-230B/AP?
12. In figure 7-10, how is the bridge balanced?
13. In figure 7-10, what is the meter deflection when either 1 *mw* of r-f power or 1 *mw* of d-c power is applied to the thermistor?
14. What is the function of the carbon-coated blade that is inserted into the waveguide in figure 7-11, A?
15. What is the function of the r-f gate in figure 7-11, B?
16. What is the radar duty-cycle ratio if the pulse length is 2 micro-seconds and the pulse repetition rate is 1000 pulses per second?
17. What is the peak power of a radar if the duty-cycle ratio is 0.002 and the average power is 20 *w*?
18. What is the function of the control bridge in the thermistor bridge wattmeter shown in figure 7-14, A?
19. Assume that Test Set AN/UPM-56 is connected with an r-f cable having a 3-db loss to a certain radar transmitter via a built-in directional coupler having a 25-db attenuation. After calibrating the power measuring bridge, r-f power is applied and the continuously variable attenuator is set at 19.5 db when the bridge r-f power meter indicates 1 *mw*. What is the total db attenuation with respect to 1 *mw*?
20. If the average power output of a radar is 40 db above 1 *mw*, what is the corresponding average power output in watts?
21. Name three methods of determining the effective resistance of a radio transmitting antenna.
22. Find the antenna resistance (fig. 7-18, A) if the antenna current is reduced from 3 amperes to 2 amperes after inserting a resistance of 15 ohms.
23. What is the relative resistance of the antenna (fig. 7-18, A) without the tuning network compared to the antenna resistance with the tuning network?
24. What is the relative magnitude of *R* (fig. 7-18, C) compared to that of the antenna resistance when the meter is made to read the same for both positions of the switch?
25. What is the relative magnitude of the r-f power supplied to an incandescent lamp compared to the d-c power supplied to a similar lamp if they have equal brilliancy?
26. What is a bolometer?

27. What are the two main types of bolometers?
28. How is the open-circuited coaxial transmission line in the wavemeter (fig. 7-11, B) coupled to the waveguide in the meter?
29. When the wavemeter (fig. 7-11, A) is in resonance, why is there a decrease in the meter, M, reading?
30. In figure 7-21, how is the heterodyne oscillator corrected to the crystal check point nearest the frequency to be measured?
31. In figure 7-21, what is the function of S104-B?
32. In figure 7-23, how is the 500-cycle modulation developed on the r-f carrier of the heterodyne oscillator?
33. What is meant by the noise figure (NF) of a radar receiver?
34. In figure 7-24, when the output of the noise generator is added to the receiver noise and the output across the 1-M resistor is doubled, what is the relation between the magnitude of the output of the noise generator and the magnitude of the noise developed by the receiver?
35. In figure 7-26, A, if the noise level is indicated on an output db meter as -10 db and zero db is equivalent to 1 mw in 600 ohms, what is the noise output in milliwatts?

CHAPTER

8

USE OF THE OSCILLOSCOPE, SYNCHROSCOPE, AND ECHO BOX

INTRODUCTION

The basic operating principles of the cathode-ray oscilloscope are described and the operating controls identified in Chapter 13 of *Basic Electronics*, NavPers 10087. In this chapter the use of the oscilloscope, synchroscope (a special kind of oscilloscope), and echo box is stressed.

A knowledge of the proper use of these instruments is one of the most valuable tools that an ET can have. Therefore, this chapter is devoted to the practical aspects of the subject. It should be emphasized that all of the details of the subject cannot be covered in one chapter of reasonable length. The technician will find additional helpful information in the *Handbook of Test Methods and Practices* (latest edition), NavShips 91828, and in the instruction books that accompany the test instruments.

THE OSCILLOSCOPE

The cathode-ray oscilloscope is generally used to permit the technician to observe voltage waveforms in testing electronic circuits. Because voltage waveforms are observed, an ELECTROSTATIC cathode-ray tube (CRT), which employs voltage to deflect the electron beam, is used.

Some oscilloscopes may use an ELECTROMAGNETIC CRT, which employs current to deflect the electron beam. This type of oscilloscope is used for certain applications, other than general testing, where its properties make it more suitable than the electrostatic-deflection type.

In general, test oscilloscopes are used to align and test electronic equipment, to make hum measurements, to make frequency comparisons (to determine an unknown frequency), to observe complex waveforms, and to take percentage modulation measurements.

A Typical Oscilloscope

The OS-8/U series of oscilloscopes supersedes the older Navy models, OBL and OBT, which were either inferior in performance or heavier in weight. Improvements are also being made in the OS-8/U series. For example, the OS-8A/U has a better square-wave response than the OS-8/U, although it is slightly heavier and larger.

BLOCK DIAGRAM.—A simplified block diagram of the OS-8A/U oscilloscope is shown in figure 8-1; views of the controls are shown in figure 8-2.

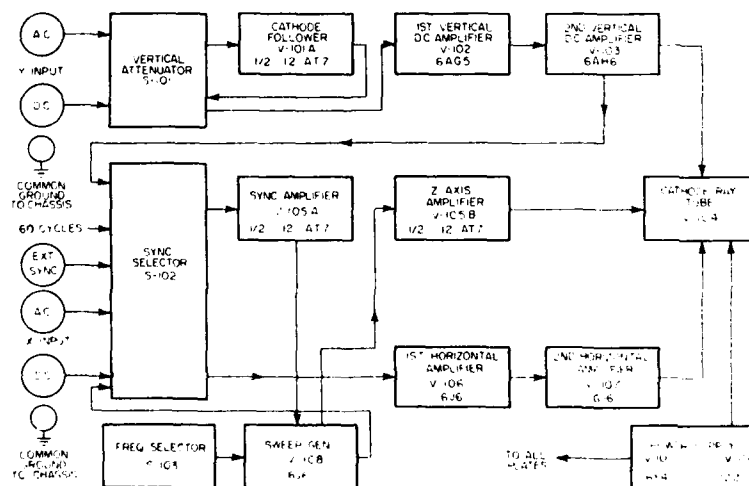


Figure 8-1.—Simplified block diagram of the OS-8A/U oscilloscope.

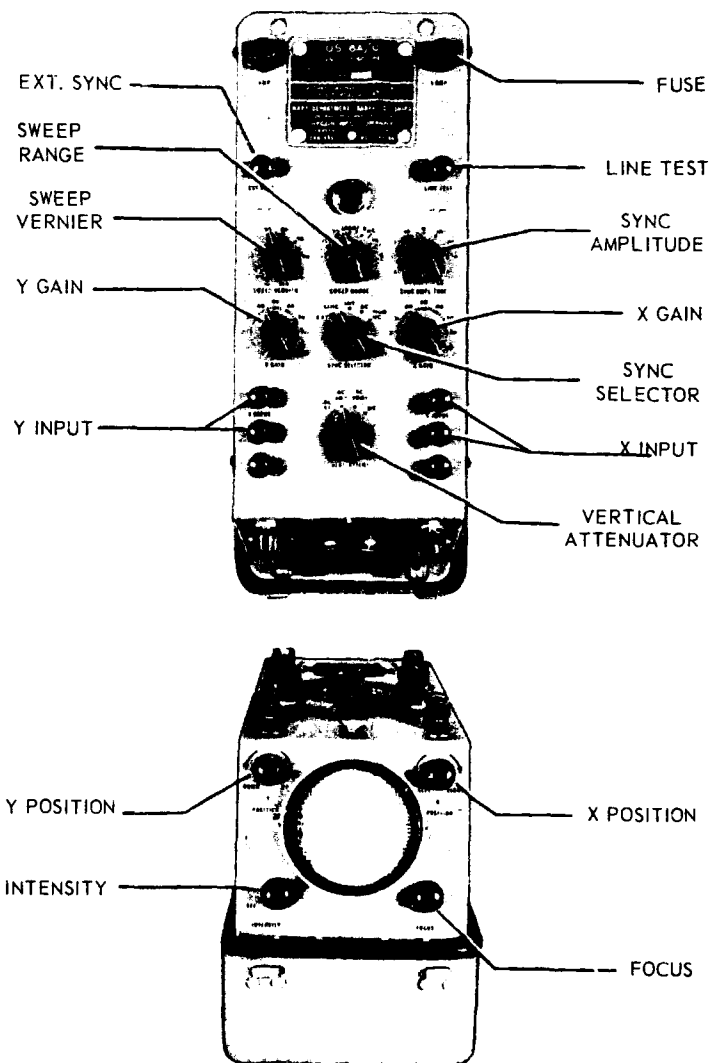


Figure 8-2.—Oscilloscope OS-8A/U controls.

The VERTICAL ATTENUATOR determines the fraction of the a-c input voltage that is to be applied to the vertical amplifier via the cathode follower. The a-c input to the vertical amplifier may not be reduced at all (vertical attenuator in the 1:1 position), or it may be reduced 10:1 or 100:1, depending on the position of the vertical attenuator switch. The purpose of this arrangement is to avoid overloading the vertical deflection amplifier of the oscilloscope.

The cathode follower provides a high-input impedance and a low-output impedance, at which point the vertical Y GAIN control is inserted. The high-input impedance prevents excessive loading of the circuit under test. Inserting the gain control at the low-output impedance point avoids frequency discrimination caused by circuit distributed capacitances.

The vertical amplifiers boost the amplitude of the applied signal so that the desired vertical displacement may be obtained on the screen of the CRT. When the SYNC SELECTOR switch is in the INTERNAL position, a portion of the vertical output voltage is used to synchronize the horizontal sweep.

The horizontal amplifiers amplify the saw-tooth signal that is to be applied to the horizontal deflection plates. The length of the horizontal sweep line, as it appears on the CRT screen, is determined by the setting of the horizontal X GAIN control.

The Sync Selector switch determines the source of the synchronizing voltage. The source may be the signal applied to the vertical plates, the line voltage, or the signal applied to the external sync terminal.

The sweep generator generates a linear voltage waveform (saw-tooth waveform), which, when applied to the horizontal deflection plates of the CRT, results in a trace that progresses across the screen from left to right at a constant rate of speed. The frequency of the internally generated sweep is determined by the setting of the SWEEP RANGE switch and the SWEEP VERNIER.

The sync amplifier amplifies the sync signal and feeds it to the sweep generator.

The Z axis (blanking) amplifier and its associated circuit control the variation of the intensity of the trace throughout the sweep cycle. A jumper is normally connected across the blanking terminals of the terminal board at the CRT in order to blank the sweep return trace. If desired, the jumper may be removed and an external voltage introduced across the terminals to intensity modulate the trace throughout the cycle.

CONTROL FUNCTIONS.—The INTENSITY control decreases or increases the bias on the grid of the CRT so that the number of electrons allowed to pass through the control grid is regulated. This control also turns off the power supply when rotated to its extreme counter-clockwise position.

The FOCUS control changes the voltage on the focusing electrode of the CRT and thus permits the sharpening of the trace on the screen.

The Y POSITION control moves the beam or trace up or down on the face of the tube; the X POSITION control moves the beam or trace horizontally on the face of the tube. By means of these controls, the trace may be positioned at any place on the screen.

The SYNC AMPLITUDE control varies the strength of the signal applied to the sweep generator. It may be set so that the sweep generator will be synchronized on either positive or negative signals.

The SWEEP RANGE control is a coarse setting for the sweep frequency desired; the sweep vernier is a fine setting for the same signal and is continuously variable within the limits set by the sweep range.

The sync selector permits different sync sources to be applied to the sync amplifier. In the EXTERNAL position, the sweep is synchronized with the voltage source connected to the external sync terminal. When in the LINE position, the sweep is synchronized with the power-supply frequency; and in the INTERNAL position, the sweep is synchronized with the signal being applied to

the Y INPUT. In each of these three positions the sync signal is under the control of the sync amplitude potentiometer. When the sync selector is in the A-C or D-C position, the sweep generator is cut out of the circuit, and the horizontal deflection is controlled entirely by the voltage connected to the X-INPUT terminals. A capacitor is connected in series with the a-c terminal, and the response is limited at the low-frequency end to approximately 25 cycles per second. When the d-c terminal is used, the deflection will respond to low frequencies as well as to direct current.

The Y gain controls the amplitude of the vertical amplifier output, and the X gain controls the amplitude of the horizontal amplifier output.

The Vertical Attenuator determines the fraction of the a-c input voltage that is applied to the vertical amplifier. Thus, in the 1:1 position, no reduction takes place; in the 10:1 position, the voltage is reduced to one-tenth; in the 100:1 position, the voltage is reduced to one-hundredth. In the d-c position, the attenuator and the cathode follower are bypassed. In this position, low frequencies (up to 1000 cycles) may be connected between the d-c input terminal and ground with essentially no resulting distortion.

The exact method of operating the controls is given in the instruction book that accompanies the equipment.

General Information About Oscilloscopes

To obtain an accurate presentation of the voltage waveform, a few precautions must be observed. The approximate magnitude of the voltages in the circuit under test must be known so that the operator can take steps to safeguard himself from shock and the oscilloscope from a voltage breakdown.

Dependable data can be obtained from the oscilloscope only if its sensitivity and frequency characteristics are known. To make certain that the waveform will not be distorted it is essential that the manner in which dis-

tortion takes place be understood and that precautions be taken to minimize such distortion.

INPUT CIRCUIT.—The input to most oscilloscopes is between an input terminal (which is above ground potential) and the common ground terminal. The input terminal is almost always coupled to the grid of the amplifier through a capacitor. Seldom do the capacitors used have voltage ratings in excess of 450 volts. Therefore, unless the approximate magnitude of the voltage under test is known, damage to the oscilloscope through breakdown of the input capacitor may result.

VOLTAGE DIVIDERS.—In some cases, it may be necessary to observe waveforms in circuits where the voltage is much greater than the components within the oscilloscope can withstand. A voltage divider may be used in such instances to reduce the voltage to a value that will not damage the equipment. In any case, it is very important that the oscilloscope be adequately grounded. Grounding the oscilloscope is a precaution that must be taken for the protection of the operator, because a failure of some part of the voltage divider can raise the potential of the whole oscilloscope to a dangerous level if the oscilloscope case is not solidly connected to ground.

If the voltage divider used is a capacitance divider, a wise precaution is to shunt each capacitor with a high resistance in order to maintain the proper voltage distribution across each capacitor. Two voltage dividers are shown in figure 8-3. In figure 8-3, A, the capacitance alone causes the voltage across C_2 to be one-tenth of the voltage across C_1 . However, the leakage resistances, R_1 and R_2 , may be of such values that they divide the voltage by a very different ratio. If the leakage resistance of the capacitors is high with respect to the magnitude of the X_c ohms, the leakage resistance will have negligible effect on the voltage distribution across the capacitors. However, if the leakage resistance is of the same order of magnitude as that of the X_c ohms, the leakage resistance may have a pronounced effect on the

distribution of the voltage across the capacitors. This condition might cause excessive voltage across one capacitor and result in a breakdown. To prevent this unbalanced distribution of voltage, resistors $R3$ and $R4$ may be added, as in figure 8-3, B. Because the leakage resistance of a good capacitor is of the order of 1000 megohms and because $R3$ and $R4$ are relatively low in resistance, the two resistors fix the voltage division at

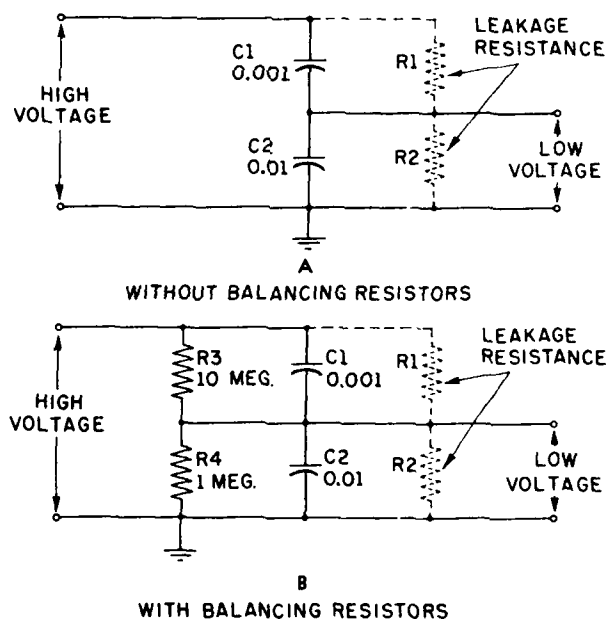


Figure 8-3.—Capacitance voltage divider.

the same ratio as do the capacitors, and the voltage divider may be easily designed to withstand the high voltage.

FREQUENCY RANGES.—The range of sweep frequencies in a given oscilloscope is usually indicated on the front panel of the instrument. The frequency range that the

vertical and horizontal amplifiers are capable of amplifying properly is given in the manufacturer's instruction book. Generally, only the best oscilloscopes use amplifiers that will amplify voltages whose frequency is below 20 or above 1,000,000 cycles per second. Oscilloscopes that do not cover as wide a range of frequencies as this may be satisfactory for most uses, but distortion is likely to occur when saw-tooth or rectangular waveforms of a high recurrence rate are investigated. High performance oscilloscopes are capable of amplifying over a broader frequency range, and, accordingly, may be used on rectangular and saw-tooth waveforms of high recurrence rates without distorting the shape of the waveform.

DEFLECTION SENSITIVITY.—The deflection sensitivity of an oscilloscope may be defined as the distance in millimeters that the spot is moved on the screen when 1 volt is applied to the deflecting plates. The deflection sensitivity in this case is expressed in millimeters per volt. The most accurate way of measuring this quantity is to apply a known d-c potential directly to the deflecting plates and measure the distance that the spot is moved by this voltage. The number of millimeters that the spot moves, divided by the voltage applied, is the deflection sensitivity in millimeters per volt.

The deflection sensitivity (or factor) may also be expressed as the input voltage to the amplifier (horizontal or vertical) for a deflection of 1 inch of the spot on the CRT screen. In this case, the amplifier gain control is adjusted to a suitable value that is arbitrary (for example, midscale). The magnitude of the input sine-wave voltage is measured with an accurate a-c voltmeter. Most a-c voltmeters indicate the root-mean-square (rms) value of voltage. However, the deflection of the spot on the screen is proportional to the amplitude of the sine wave from the positive peak to the negative peak (peak-to-peak voltage). To convert the rms voltage at the input to peak-to-peak voltage, the input meter reading must be multiplied by 2.828.

Thus, the effective sensitivity (gain) of the oscilloscope in volts per inch is the peak-to-peak voltage applied at the input of the amplifier divided by the peak-to-peak amplitude of the trace in inches. For example, if the peak-to-peak voltage applied to the vertical amplifier is 2.8 millivolts and the peak-to-peak amplitude of the trace is 2.8 inches, the vertical deflection sensitivity will be $\frac{0.0028}{2.8} = 0.001$ volt per inch. If the gain control is changed, the effective sensitivity will also change.

However, the sensitivity of the CRT itself is not affected by the use of the amplifier. The only factor changed, when changing the gain control, is the amplitude of the voltage applied to the deflecting plates.

If the peak-to-peak voltage applied directly to the vertical deflection plates without going through the amplifier is 48 volts and the peak-to-peak amplitude of the trace is 1 inch, the vertical direct deflection sensitivity will be 48 volts per inch.

STRAY PICKUP.—To avoid pickup of stray signals, the leads from the circuit under test to the oscilloscope should be as short as possible. If the leads are long, a greater voltage can be induced in them by stray fields than would be induced if the leads were short. The pickup may be so disturbing in some cases that it will be almost impossible to use the oscilloscope. A few things can be done to reduce the effect that stray fields have on the oscilloscope.

First, the cathode-ray tube must be very carefully shielded from all stray fields. In most cases, this shielding is provided by the Aquadag coating on the inside of the tube, by a metallic shield outside the tube, and by the oscilloscope case.

Second, the common side of the oscilloscope circuit should be connected to a ground point in the circuit under test and to a good external ground connection. This connection will aid in eliminating most of the stray voltages that are picked up by the leads.

Third, a low-capacitance coaxial cable may be used to reduce still more the effect of stray fields.

DISTORTION.—Several sources of distortion are possible in the production of CRT display. Although distortion can be eliminated by simple precautions in some cases, it is very difficult to eliminate in other cases. A summary of some of the major factors to be considered follows.

1. Perhaps the most obvious component in which distortion can enter is the deflection amplifier. It is important, therefore, to know the frequency response of the amplifier being used. An estimate may then be made of the possibility of distortion for a given signal.

2. If the sweep is nonlinear, the shape of the wave on the screen will not be a true picture of the voltage under test. However, if the oscilloscope is not defective, the sweep will generally be linear enough for most purposes.

3. When signals of relatively high frequency are to be observed, the time of fly-back may become an appreciable fraction of the period of the signal. To avoid distortion of this type, it is well to adjust the sweep frequency so that several cycles of the signal will appear on the screen.

4. If the magnitude of the synchronizing voltage is too great, the image may be distorted because the sweep is terminated too soon. This condition may be avoided most simply by setting the synchronization control at zero while the sweep frequency is adjusted. When the sweep frequency is some integral multiple of the signal frequency, the image will be stationary on the screen. The synchronizing voltage should then be turned up just enough to stop the apparent motion of the image on the screen.

5. In general, the input impedance of the oscilloscope will be much higher than the impedance of the circuit at the point where the test is to be made. Therefore, the input impedance of the oscilloscope will not change appreciably the circuit load nor the voltage at the con-

nection point, and a true picture of the voltage may be observed. In some circuits, however, the impedance may be very high (perhaps up to 100 megohms), and the input impedance of the oscilloscope may load the circuit and change the voltage so radically that it will be difficult to obtain a true picture.

6. The input shunting capacitance of an oscilloscope is generally small (of the order of 20 to 60 $\mu\mu\text{f}$), but it may be sufficient to alter the characteristics of a video amplifier or the tuning of a high-frequency oscillator.

7. When one specific type of equipment is to be maintained, many of the preceding sources of distortion may become of academic interest only. When, for example, the same oscilloscope is used with the same pair of leads to check repeatedly a given set of waveforms, the distortion will always be the same if the circuits are operating properly. If the waveforms through the system are recorded when the system is working properly, the maintenance testing need consist only of a comparison of the waveforms obtained with the recorded standard waveforms. In such a case, it is not necessary to eliminate all distortion, because the test will consist of a comparison of two sets of data that are distorted in the same way. It is desirable, however, to eliminate distortion as much as possible in order that the operation of the circuit under test may be better understood. However, successful testing may be performed regardless of distortion, if the same test equipment is used in the same way in every check.

Use of the Oscilloscope for Signal Tracing

SINE WAVEFORM.—The cathode-ray oscilloscope (CRO) is used chiefly for checking the waveform of the signal voltage in electronic circuits. The most commonly found waveform in a-c power circuits is the sine wave. Most cathode-ray oscilloscopes (for example, the OS-8A/U) have a line-test signal binding post internally connected to a low-voltage winding of the power-supply trans-



Figure 8-4.—Signal tracing with the CRO.

former so that an a-c voltage at power-line frequency (60 cycles) is available to the operating for testing purposes. A jumper may be connected between the line test signal binding post and the a-c Y input. If the sweep range is set on the line between 15 and 75 and the sweep vernier is adjusted to 60, a single cycle of sine waveform will appear on the cathode-ray screen. This pattern may be used for comparison with other sine waveforms.

OTHER WAVEFORMS.—Oscilloscope TS-239A/UP is an equipment for displaying a luminous plot of the time variation of a voltage pulse or wave, with self-contained means for measuring its duration and instantaneous magnitude. It is intended for use in testing all types of electronic equipment in the radar and communications fields. The waveforms may be square wave, saw-tooth, peaked, sinusoidal, or modifications of any or all of these.

In general, the method of obtaining the signal waveform is to adjust the horizontal sweep frequency to approximately the frequency of the signal voltage to be presented on the screen and then to apply the signal voltage to the Y input binding post, making sure that the ground terminal is returned to the ground on the equipment from which the test voltage is derived. The horizontal gain control is then adjusted for full horizontal deflection and the vertical gain control adjusted for slightly less than full scale deflection. If the pattern is not properly centered on the screen, the horizontal and vertical positioning controls should be adjusted until the desired centering is obtained.

The CRO is used in signal tracing to determine the location of a fault. The signal voltage is derived from various test points (for example, in the circuit shown in figure 8-4) and the pattern compared with the pattern for each particular check point, as indicated in the figure. The bandwidth and the sweep frequency of test CRO are indicated for specified conditions of equipment

operation. For example, at test point *TP107* in figure 8-4, the sweep frequency (*SF*) of the test oscilloscope is designated as 60 cycles; the duration of the zero voltage condition is 15,000 μ s (*T'*), and the length of the negative-going pulse (-100 v) is 1670 μ s (*T*). The letter, *R*, designates the range setting of the equipment. The illustration represents a portion of the servicing block diagram of the Range-Azimuth Indicator AN/SPA-4A.

Oscilloscope as a Measuring Device

D-C VOLTMETER.—The electrostatic CRT is a voltage operated device. The amount of deflection of the spot is proportional to the magnitude of the voltage applied to the deflecting plates. If the deflection sensitivity of the CRT is known, the oscilloscope can be used as a voltmeter on either direct or alternating voltages. The oscilloscope has the advantage of having extremely high input impedance when the voltage to be measured is applied directly to the deflecting plates. However, because both the range of voltage measurements and the accuracy of indication are less than that available in commercial d-c voltmeters, the oscilloscope is not widely used for the measurement of d-c voltages.

A-C VOLTMETER.—The CRO is a better device for measuring alternating voltages than most conventional a-c voltmeters. The principal difficulty with the oscilloscope is the calibration of its deflection sensitivity. If this factor can be determined accurately, the magnitude of the alternating voltage can be determined very simply. The advantages of the oscilloscope as an a-c voltmeter are its very high input impedance, its ability to measure equally well voltages of a wide frequency range, and its ability to indicate magnitude, regardless of waveform.

The oscilloscope shows the peak value of the applied a-c voltage; whereas, standard a-c meters show the rms values of the sine-wave, a-c voltage. Peak values may be readily converted to rms values, but the results may

be misleading for voltages whose waveforms are other than sinusoidal.

AMMETER.—The electromagnetic CRT is a current operated device. Accordingly, it could be used to measure current magnitudes directly if it were properly calibrated. This type of tube, however, is rarely used in test oscilloscopes. The electrostatic CRT, as mentioned previously, is widely used in test oscilloscopes, and it may be used to measure currents indirectly. If the current to be measured is passed through a calibrated resistor, the resulting voltage across the resistor may be indicated on the oscilloscope screen. By application of Ohm's law, the current may be calculated; that is, R is known, E is measured, and I can be calculated by the equation,

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

WATTMETER.—The same method that is used to measure current can also be employed to measure power. The power dissipated in a resistor is equal to the product of the current through the resistor and the voltage across it. Therefore, the power dissipated in the resistor may be expressed as

$$P = EI = \frac{E^2}{R}.$$

If the voltage measured by means of the oscilloscope is substituted in this equation, the power may be calculated (if the resistance is known).

Lissajous Figures

A Lissajous figure is a pattern created on an oscilloscope screen when sine-wave voltages (usually of differing frequencies) are applied simultaneously to both the horizontal and vertical deflecting plates. One of the principal uses of Lissajous figures is to determine an unknown frequency by comparing it with a known frequency.

DEVELOPMENT OF SIMPLE FIGURES.—The development of four types of Lissajous figures is shown in figure 8-5.

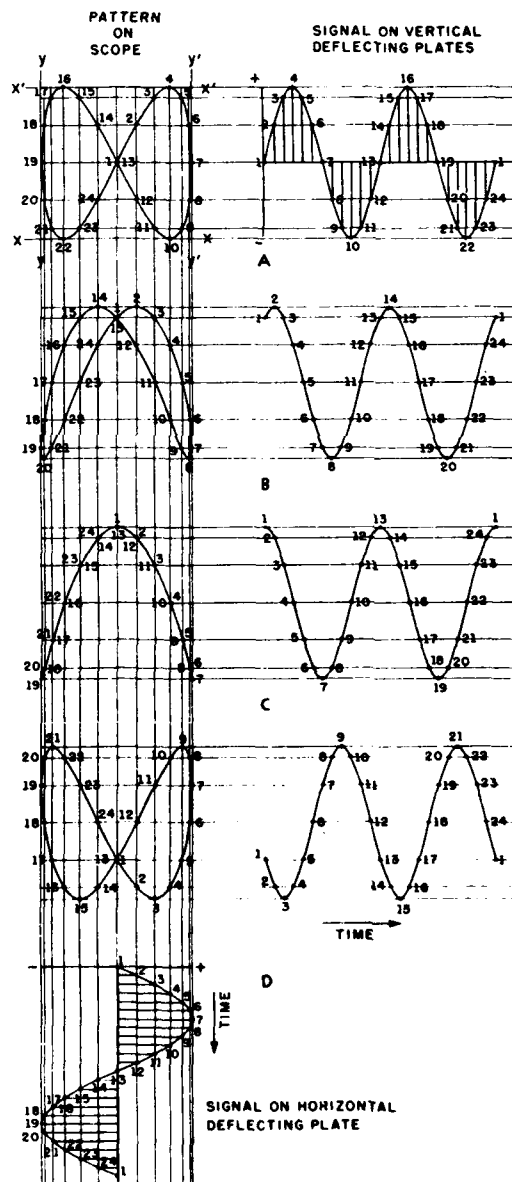


Figure 8-5.—Lissajous figures for a 1:2 horizontal to vertical input frequency ratio.

Each Lissajous figure is developed by plotting a smooth curve through points formed by the intersection of horizontal and vertical lines projected from corresponding points on two sine curves (bottom and right side of Lissajous figures). Adjacent points on the sine curves at the right are separated by equal intervals (30°). Those on the sine curve at the bottom are separated by an interval of 15° . The ratio (horizontal to vertical) of the frequencies applied to the two pairs of deflecting plates is 1:2; that is, in this figure the frequency on the horizontal deflecting plates is one-half the frequency on the vertical deflecting plates. It does not matter what the actual frequencies are, as long as one of the frequencies is known.

If the two voltages are in phase; that is, if both voltages are passing through zero and going positive at the same instant, a figure eight pattern will be traced (fig. 8-5, A). As the phase changes slightly, the pattern will change, as shown in figure 8-5, B, C, and D. When the phase angle is 90° , the loops will close, as in figure 8-5, C. If the phase angle is greater than 180° , the pattern will be inverted, as in figure 8-5, D.

INTERPRETATION OF PATTERNS.—One feature that all of these images have in common is that the pattern touches the horizontal lines (xx or $x'x'$ of figure 8-5, A) at two points. This is true of the remaining patterns of the figure, even for the line tangent to the top of figure 8-5, C, because the trace passes point 1 on the figure twice during each cycle. Likewise, the vertical lines (yy or $y'y'$ of fig. 8-5, A) are touched by the pattern at only one point. The ratio of the number of points of tangency is equal to the ratio of the two frequencies. Expressed as an equation,

$$\frac{f_h}{f_v} = \frac{\text{number of tangent points on vertical line}}{\text{number of tangent points on horizontal line}}$$

where f_h is the frequency of the signal applied to the horizontal deflecting plates and f_v is the frequency of the signal applied to the vertical deflecting plates.

The number of tangent points on the horizontal and vertical lines is most easily counted when the Lissajous figure is stable (not moving) and when it is symmetrical as in figure 8-5, A. In this figure the ratio of the number of points of tangency on the vertical line to the number on the horizontal line is 1:2. If $f_v = 120$ cycles,

$$f_h = f_v \frac{\text{number of tangent points on vertical line}}{\text{number of tangent points on horizontal line}} \\ = 120 \times \frac{1}{2} = 60 \text{ cycles.}$$

MISCELLANEOUS FIGURES.—In figure 8-6, several varieties of Lissajous figures are shown. The ratio (horizontal to vertical) of the two input frequencies is indicated in each case. Unless the oscilloscope screen is very large, ratios higher than 10:1 are difficult to interpret. The circle shown in figure 8-6, A, is the simplest type of Lissajous figure. The pattern in figure 8-6, B is for a 2:1 ratio. Compare this with the pattern shown in figure 8-5, A, in which the ratio is 1:2.

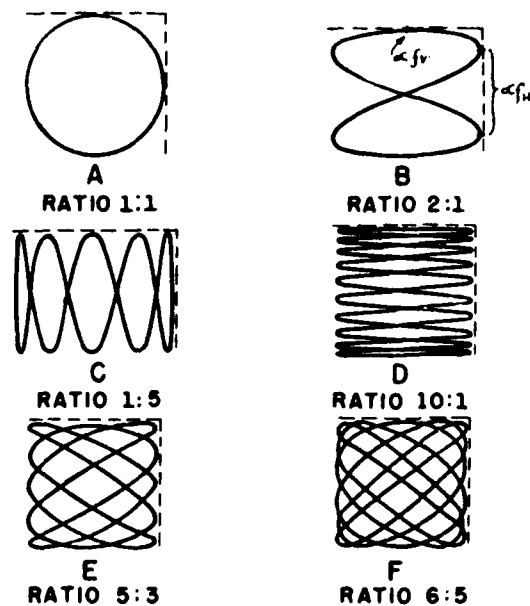


Figure 8-6.—Lissajous figures for various frequency ratios.

Figure 8-6, C through F, indicates the increasing complexity that is encountered in ratios of higher order.

INDICATION OF PHASE.—The patterns of figure 8-7 are formed by applying to the deflecting plates sine-wave voltages having the same frequency and amplitude, but having various phase differences. It can be seen in figure 8-7, A, that the resultant trace is a line at a 45° angle when the voltages are exactly in phase (0° or 360°). As the phase angle is made greater, the straight line opens into a broadening ellipse, as in figure 8-7, B and C. When the phase difference is 90° , the ellipse becomes a circle, as in figure 8-7, D. As the phase difference is increased beyond 90° (fig. 8-7, E through G), the circle begins to collapse toward another straight line, but this time the line is at 135° when the voltages are out of phase by 180° .

The patterns shown in figure 8-7 can be obtained only if the amplitude of the voltage applied to the vertical deflecting plates is the same as the amplitude of the voltage applied to the horizontal deflecting plates. If one voltage is greater than the other, the pattern will never become circular, but will always be elliptical. Therefore, if such patterns are to be used to measure the phase difference between two sine-wave voltages, care must be taken to ensure that both voltages are of the same amplitude, so that the screen can be calibrated.

Modulation Measurements

Amplitude modulation measurements are made by the observation of one of two basic modulation patterns—the wave-envelope or the trapezoidal pattern—either of which gives a continuous, direct picture of the modulated output of the transmitter.

The **WAVE ENVELOPE** pattern gives a direct indication of the shape of the modulation envelope, as indicated in figure 8-8, A. A small pickup loop is coupled inductively to the final tank circuit of the transmitter and connected directly to the vertical deflection plates. The

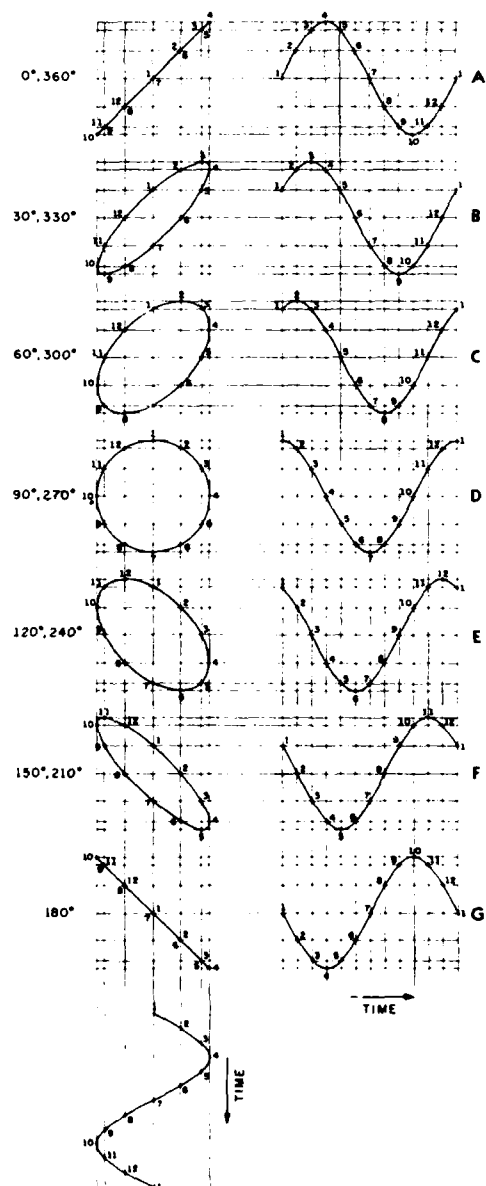


Figure 8-7.—Lissajous figures that indicate phase difference.

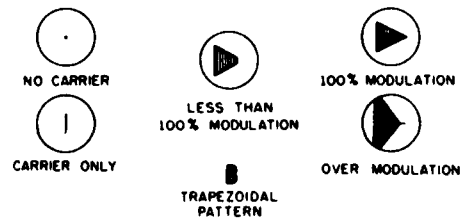
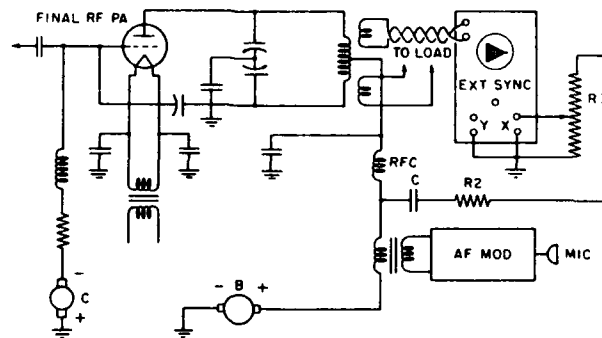
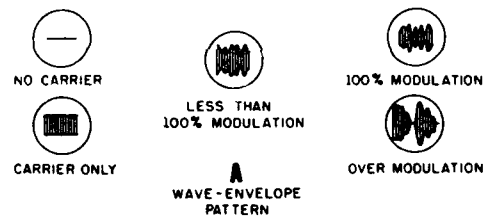
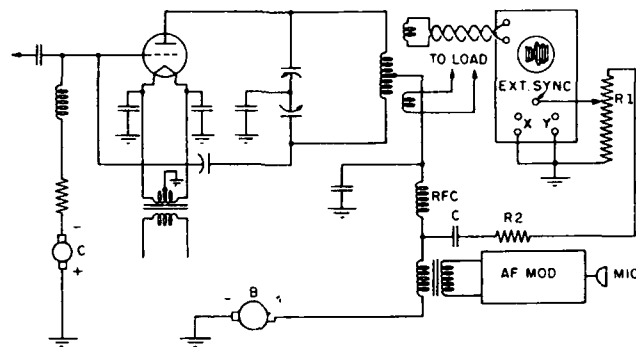


Figure 8-8.—Modulation measurements.

CRO saw-tooth generator is used to provide the horizontal sweep frequency.

When an audio signal generator is used in place of the microphone voice input, a voltage of sine waveform is supplied to the modulator, and the pattern on the CRT is easily stabilized by applying a portion of the audio voltage to the external sync terminal of the oscilloscope. The audio voltage is obtained from the voltage divider composed of $R1$, $R2$, and C . Capacitor C blocks the d-c component and couples the a-f component to the sync input. The frequency-range vernier and sync-signal controls are adjusted until the audio component of the modulated wave is synchronized with the sweep, as indicated by a stationary pattern. When voice modulation is used, a rapidly changing pattern of varying height is obtained.

When the maximum height of the pattern is twice that of the unmodulated carrier, the carrier is modulated 100 percent. Several operating conditions are shown in figure 8-8, A. In order to determine the modulation percentage for any value below 100-percent modulation, the following procedure is followed:

The peak-to-peak height (H_2) of the unmodulated carrier is subtracted from the peak-to-peak height (H_1) of the modulated carrier, and the difference divided by the peak-to-peak height (H_2) of the unmodulated carrier. The result is then multiplied by 100 to give the percentage of modulation. As a formula,

$$\text{modulation percentage} = \frac{H_1 - H_2}{H_2} \times 100.$$

The TRAPEZOIDAL pattern is more difficult to obtain, but it gives more accurate information, particularly when nonsinusoidal waveforms are encountered. As indicated in figure 8-8, B, the vertical plates of the CRT are connected via the small pickup loop to the final tank circuit. The voltage divider, $R1$ and $R2$, across the modulation transformer secondary and the high voltage power supply provides the a-f voltage component that

is applied to the horizontal input in lieu of the saw-tooth sweep frequency. Potentiometer *R1* is varied until a satisfactory sweep is obtained on the screen of the CRT. The percentage of modulation is calculated in the same manner as that of the wave-envelope pattern.

THE SYNCHROSCOPE

Similarity to the Oscilloscope

The synchroscope is a test instrument that has a wide range of applications because it includes the features of an oscilloscope plus such additional features as pulse synchronizing adaptations and markers that make it highly useful in radar testing or other testing where pulse analysis is necessary.

There are several synchrosopes available—for example, the TS-34/AP, TS-239/UP, AN/USM-32, TS-28/UPN, and AN/USM-24. Certain instruments that are, in fact, synchrosopes are sometimes designated as oscilloscopes.

A general idea of the operating characteristics of synchrosopes may be obtained from the following technical data.

For the model TS-28/UPN, the video amplifier has a frequency range of 1000 cycles to 5 megacycles.

Sweep for the oscilloscope can be internally triggered or it can be triggered by an external pulse or signal.

The internal trigger generator provides a self-generated internal triggering pulse to the apparatus under test and to the sweep and calibration mark circuits of the synchroscope when an external trigger source is not being used. The trigger frequency range is from 330 cycles to 4000 cycles.

Marker pips, synchronized with the sweep (whether internally or externally triggered), can be superimposed upon the trace of the CRT. These markers (having time ranges of 2, 10, or 25 microseconds between pips) can be used for measuring pulse width determining pulse repetition rates, and for calibrating the sweep.

The synchroscope can also supply a synchronizing pulse of either positive or negative polarity for triggering radar or other equipment under test so that the trace appears stationary on the face of the CRT.

A Representative Synchroscope

The following description of a representative synchroscope (oscilloscope AN/USM-24) will give the technician a general idea of the operating principles of this versatile piece of electronic test equipment. A front view of the instrument is shown in figure 8-9, A, and the accessories are shown in figure 8-9, B.

The instrument consists basically of nine channels, which are described in the following paragraphs. During the discussion, reference should be made to the block diagram of figure 8-10.

DISPLAY CHANNEL.—The heart of the display channel is the CRT. In general, the operation of the CRT is

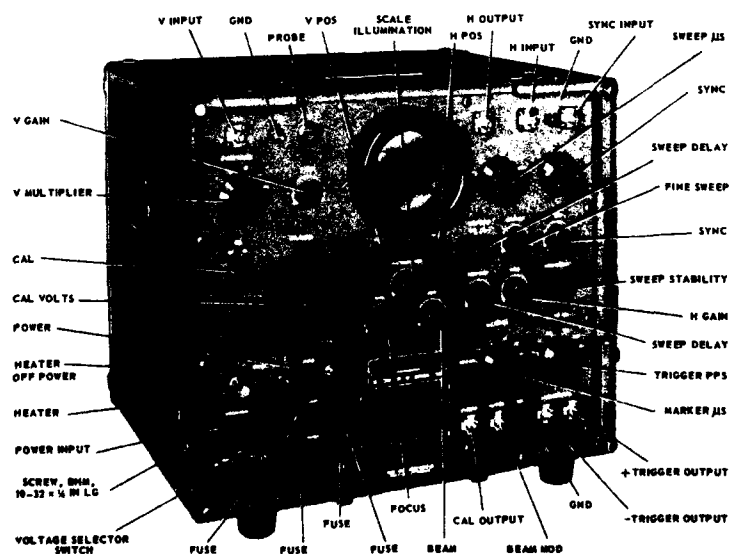


Figure 8-9.—Front view of oscilloscope AN/USM-24.

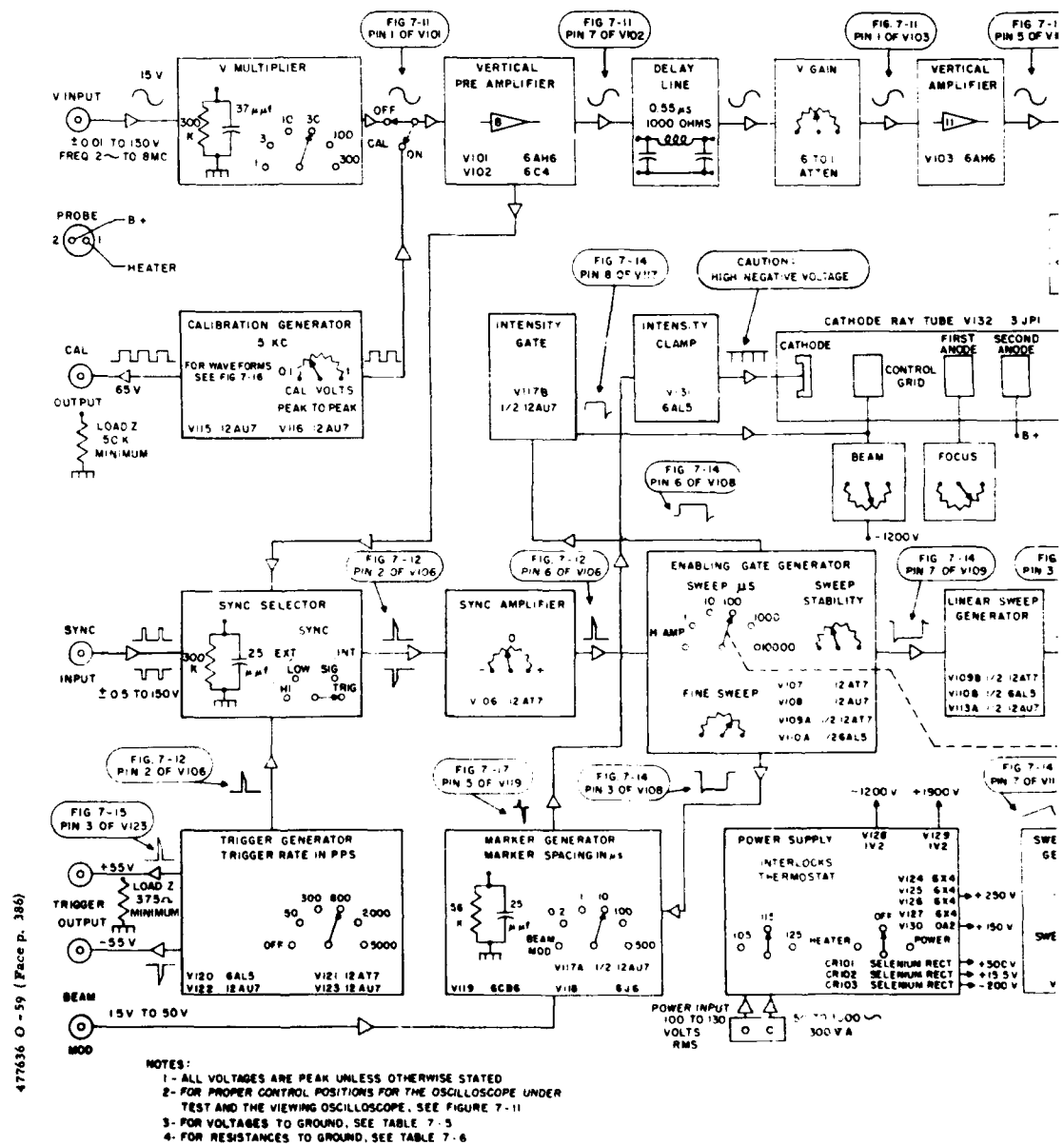


Figure 8-10.—Block diagram of oscilloscope AN/USM-24.

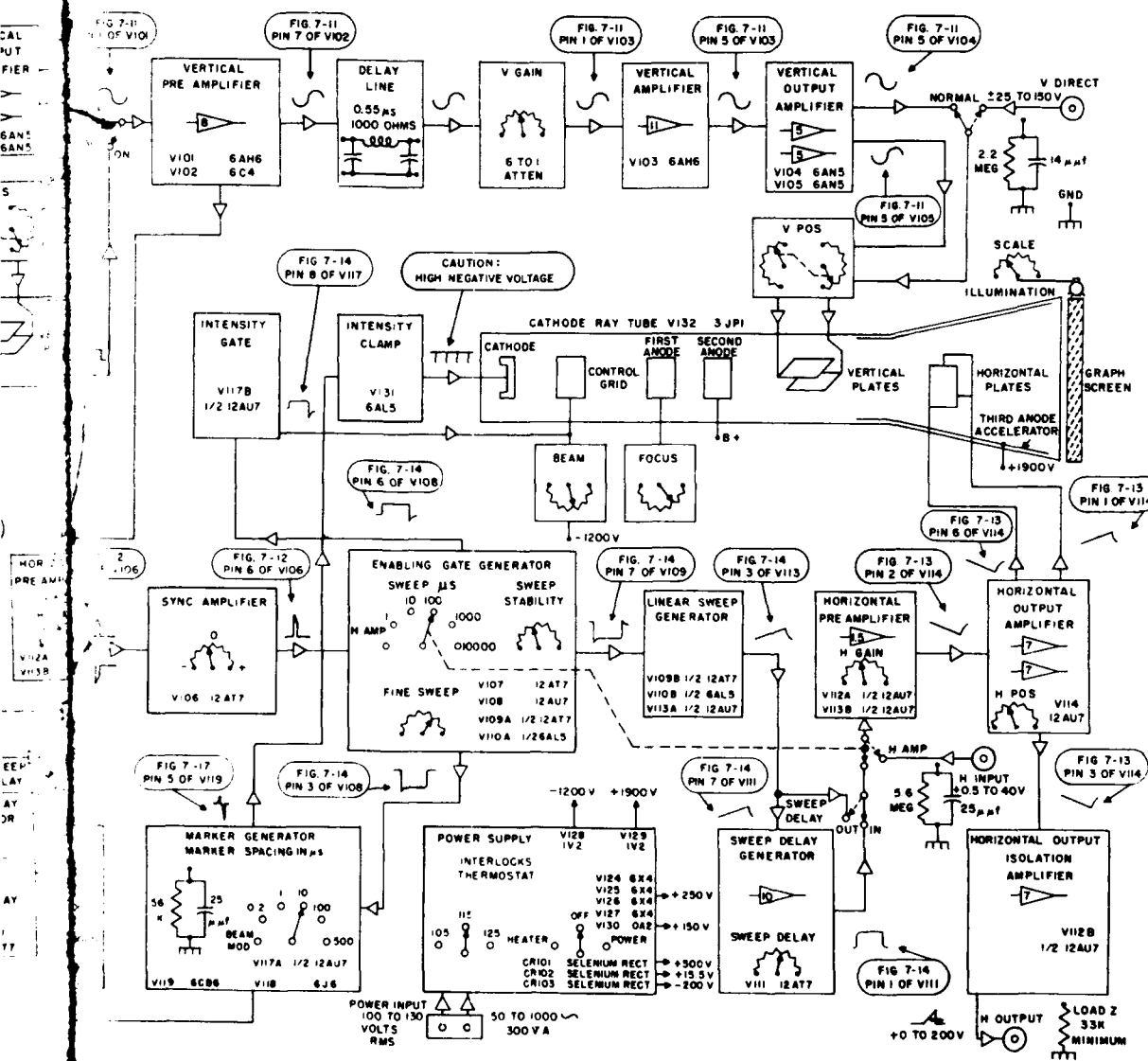


Figure 8-10.—Block diagram of oscilloscope AN/USM-24.

similar to those used in regular test oscilloscopes. The basic principles are discussed in Chapter 13 of *Basic Electronics*, NavPers 10087.

VERTICAL CHANNEL.—The function of the vertical channel is to transmit the signal from the vertical input jack to the vertical plates of the CRT with the desired amplification, but with no appreciable change in its waveform. However, control over the magnitude of the signal is afforded in order to allow the instrument to handle a wide range of signal amplitudes. The signal must also be delayed sufficiently to permit the linear time base, the markers, and the intensification gate to start functioning properly before the signal reaches the vertical plates of the CRT.

Signals from 0.10 to 150 volts can be coupled directly to the input jack; signals from 9 to 300 volts may be connected to the vertical deflection plates of the CRT through the V direct terminal on the back of the oscilloscope. The frequency response curve for the vertical amplifier is essentially flat from about 30 cycles to 2 megacycles.

The R-C network in the V multiplier has a constant impedance equal to 300 k-ohms resistance shunted by 37 μ f capacitance. The voltage divider is frequency compensated so that no distortion of the input signal results within the pass band of the vertical channel. The V multiplier switch has six positions: times 1, 3, 10, 30, 100, and 300. Voltages, as read on the CAL potentiometer (to be discussed later) are multiplied by the associated setting of the V multiplier switch for the purpose of calibrating the incoming signal. When Test Lead CG-883/USM-24 is used, the final reading is multiplied by 10.

The vertical preamplifier and delay circuit consist of a pentode amplifier and triode coupled to a delay line. The gain of the pentode is approximately 16 and the gain through the triode to the delay line (cathode-follower arrangement) is 0.5. Thus, the overall signal gain is 8, as far as the information being supplied to

the vertical amplifier is concerned. The sync signal is tapped off at the plate of the triode and fed to the sync selector. For this signal, the gain of the triode stage is unity, and the gain of the preamplifier is 16.

The delay line is a pi-type filter containing 50 sections and having an overall delay of $0.55 \mu\text{s}$. Terminating the delay line is a wire-wound potentiometer (V gain), the inductance of which provides a constant termination impedance.

The vertical amplifier is so designed that a good frequency response with a gain of approximately 10 is achieved.

The vertical output amplifier is a push-pull stage, feeding into the vertical plates of the CRT through the vertical positioning controls.

HORIZONTAL CHANNEL.—The horizontal channel consists of the horizontal preamplifier, the horizontal output amplifier, and the horizontal output isolation amplifier. Positive-going signals from the time-base channel (composed of the enabling gate generator, the linear sweep generator, and the sweep delay generator) or from the *H* input jack are fed to the horizontal preamplifier.

The horizontal preamplifier is resistance-coupled, with the volume control in the plate circuit. The positive-going input becomes a negative-going output.

The horizontal output amplifier is a cathode-coupled, push-pull stage. By the use of the horizontal output isolation amplifier, signals that have passed through the horizontal preamplifier and the horizontal output amplifier may be fed to an external circuit without affecting the operation of the oscilloscope.

INTENSITY CHANNEL.—The tube in the intensity-gate stage receives at its grid a positive gate pulse from the enabling gate generator. The output (positive going) from the cathode is fed to the control grid of the CRT. In the intensity-gate stage, the circuit constants are such that the tube acts as a limiter and feeds a constant-amplitude, positive-gate pulse to the grid of the CRT.

TIME-BASE CHANNEL.—The time-base channel consists of an enabling gate generator, which produces a gate pulse whose duration may be varied from 1.2 to 120,000 μ s; a linear-sweep generator, which produces a linear sweep as controlled by the enabling gate generator; and a delayed sweep generator, which can be used to take any 10% portion of the linear sweep and magnify it to fill the screen of the CRT. The enabling gate generator can be operated either in a trigger (trigger supplied by the sync amplifier) or in a repetitive condition.

SYNCHRONIZATION CHANNEL.—The synchronization channel consists essentially of a selector switch (sync selector) that permits the selection of an external sync, internal trigger positive pulses from the trigger rate generator, or sync signals as developed in the vertical preamplifier.

MARKER CHANNEL.—The marker channel consists basically of a cathode-driven multivibrator, a gating tube, a marker amplifier, and a means of selecting markers.

TRIGGER CHANNEL.—The trigger channel circuit consists essentially of a free-running multivibrator (in the block marked trigger generator) for determining the repetition rate and a blocking-tube oscillator for producing trigger pulses.

CALIBRATION CHANNEL.—The calibration generator consists of a multivibrator operating at 5 kc and an output system. The potentiometer has a calibrated scale for adjusting voltages from 0.1 to 1 volt. The calibration switch connects either the vertical signal or the calibrated voltage to the vertical preamplifier.

Use of Synchroscope

DETERMINING THE AMPLITUDE AND RISE TIME OF INPUT PULSES WITH THE AN/USM-24.—These two basic measurements, the determination of (1) the amplitude and (2) rise time of a pulse, are given to illustrate the use of the equipment. The steps necessary for checking the amplitude are indicated in figure 8-11 by the circled O

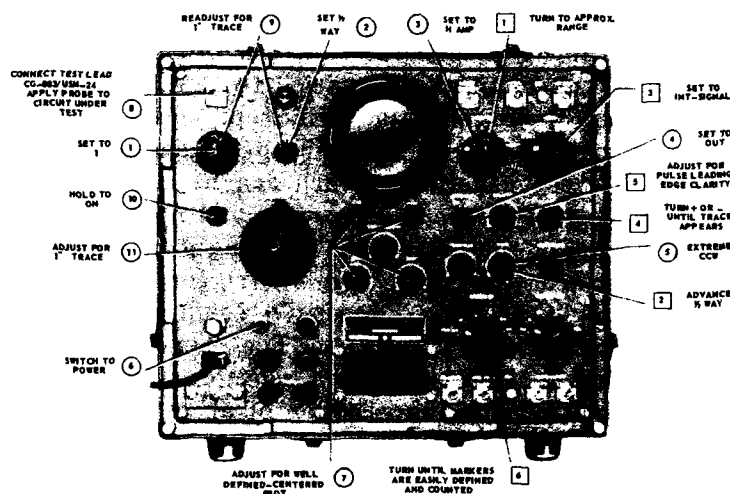


Figure 8-11.—Control settings for basic measurements.

numbers; the numbers enclosed in blocks $\square$ indicate the necessary steps for checking the rise time.

The pulse amplitude may be checked as follows:

1. Set V MULTIPLIER to 1.
2. Set V GAIN half way.
3. Set SWEEP μ s to H AMP.
4. Set SWEEP DELAY to OUT.
5. Set H GAIN to extreme CCW.
6. Turn HEATER-OFF POWER switch to POWER.
7. Adjust BEAM, FOCUS, H POS, and V POS for a well-defined spot located in the center of the screen.
8. Connect Test Lead CG 883/USM-24 to V input and apply to circuit under test.
9. Readjust V MULTIPLIER and V GAIN controls for a 1-inch deflection.
10. Throw and hold the CAL switch to the ON position.
11. Adjust CAL VOLTS control for a 1-inch deflection; release CAL switch.

12. Multiply the CAL VOLTS dial reading by the V MULTIPLIER setting. Multiply the product by 10 (Test Lead CG-883/USM-24 has a 10:1 attenuation factor). The product of these three figures indicates the peak-to-peak voltage of the signal.

The rise time may be checked as follows:

1. Turn SWEEP μs switch to the range most likely to encompass the duration of the signal being viewed. (Test Lead CG-883/USM-24 is applied to the circuit under test.)

2. Advance the H GAIN control half way.

3. Set SYNC switch to INT signal.

4. Advance SYNC control in + or - direction (depending upon polarity of signal being viewed) until horizontal trace appears.

5. Adjust FINE SWEEP control until leading edge of pulse is clearly defined on the screen. At this point it may be necessary to readjust the SYNC control.

6. Turn MARKER μs switch until the markers that appear on the leading edge of the pulse are sufficient in number to be sharply defined and counted between 10% and 90% of the total pulse amplitude.

7. Count the number of markers and multiply by the setting number of the MARKER μs switch. The product will be an indication of the rise time (in microseconds) of the measured pulse. Rise time is illustrated in figure 8-12.

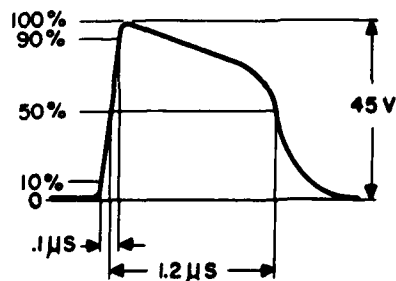


Figure 8-12.—Trigger-generator output pulse.

DETERMINATION OF RADAR ZERO ERROR.—In a radar system there are certain time delays that occur within the radar equipment itself between the time the system is triggered and the time the echo pulse arrives at the indicator. Most of the delay is within the receiver; but some delay occurs in the transmitter and in the transmission line. The total delay may be equivalent to a range of 150 to 350 yards. This means that a target actually at zero range would be erroneously indicated (because of these delays) at a range of 150 to 350 yards. Zero error must be corrected after the time delay in the circuit has been determined. There are several methods of determining zero error. The most reliable is the fixed-target method in which a fixed target at a known range is used.

The synchroscope method, however, is one of the simplest. This method does not require a fixed radar target, and fairly accurate results may be obtained.

The test setup is shown in figure 8-13. In this arrangement the synchroscope horizontal sweep is triggered by the radar system trigger. A fast sweep of about 2 μ s per inch is used, and the sweep must be carefully calibrated so that the number of microseconds each inch represents is known.

Trigger pulses that are used to start the range-marker circuit in the radar indicator are fed to the synchroscope vertical amplifier input. The vertical gain is set to provide a $\frac{1}{2}$ -inch (vertical height) pulse, and the leading edge of the pulse is marked on the scope.

Next, the trigger pulses are removed, and the radar receiver output is fed to the vertical amplifier input. The radar receiver local oscillator is detuned so as not to overload the synchroscope. The radar transmitter pulse will shock-excite the local oscillator at the receiver sufficiently to produce an i-f signal. Thus the pulse from the receiver is delivered to the synchroscope shortly after the trigger pulse is initiated. The vertical gain control is adjusted to provide a $\frac{1}{2}$ -inch pulse from the

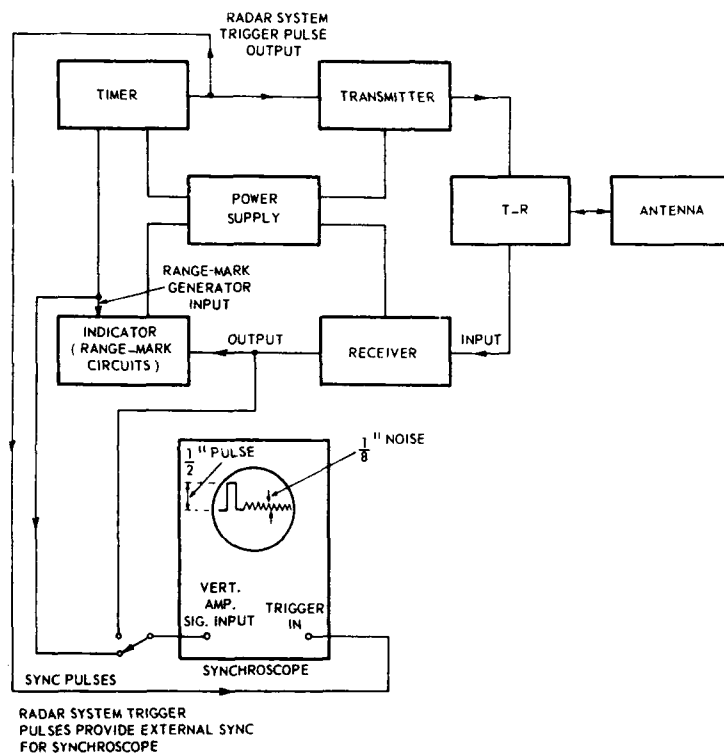


Figure 8-13.—Test setup for zero-error determination.

receiver when the receiver gain is set to produce about $\frac{1}{8}$ inch of noise.

The leading edge of the pulse is again carefully marked on the scope. The distance between the two marks may be converted from microseconds to yards. This interval represents the time delay between the time the system is triggered and the time the receiver pulse arrives at the indicator. This figure is the zero error. This error is corrected for by adjustments in the range-marker circuit.

OTHER MEASUREMENTS MADE WITH THE SYNCHROSCOPE.—Typical measurements made with the synchroscope are included in the Maintenance Check-Off Books for the various radar sets—for example, the AN/SPS-8.

The measurements are made semiannually, or more often if necessary. Typical measurements include the amplitude and time duration of the input trigger pulses.

The amplitude and time duration of the input trigger to the trigger amplifier chassis are determined by applying the trigger to the vertical input of the oscilloscope. The amplitude and time duration of the pulses are determined by observing the waveforms on the screen and the setting of the controls on the synchroscope. The amplitude should be between 15 and 30 v, and the time duration should be between 2.5 and 3.5 μ s.

The same measurements are also made of the amplified trigger. The time duration should be the same, but the amplitude of the trigger pulse should be between 45 and 60 v.

The amplitude and time duration of the modulator pulse are also determined by the synchroscope. The modulator pulse is connected to the vertical input of the synchroscope, and the amplitude and time duration of the waveform determined by observation. The time duration should be between 0.5 and 1.5 μ s and the amplitude between 45 and 60 v.

The amplitude and time duration of the charging waveform (the waveform fed to the pulse network) are likewise, determined. In this case the signal is connected from the charging waveshape jack to the vertical input of the synchroscope. The time duration should be between 950 and 1050 μ s and the amplitude between 15 and 35 v.

Finally, the synchroscope is used to make sensitivity time-control measurements. The function of the sensitivity time-control (STC) circuit is to eliminate saturation effects caused by strong echoes from nearby targets. This circuit reduces receiver gain appreciably for a short time interval immediately after a transmitted pulse and then allows the gain to return gradually to the value normally determined by the setting of the receiver gain control. The waveform of the output signal of the STC

circuit is indicated in figure 8-14. The signal is a negative voltage with a trailing edge that decays exponentially with time. This voltage is superimposed upon the negative gain-control voltage applied to the i-f amplifier portion of the radar receiver in order to control the receiver gain in accordance with the indicated waveform. The signal is obtained between terminal 6 and ground of the sensitivity time control unit (a part of the radar) and applied to the vertical input of the synchroscope. The time duration should be between 140 and 150 μ s and the voltage amplitude between 5 and 10 v.

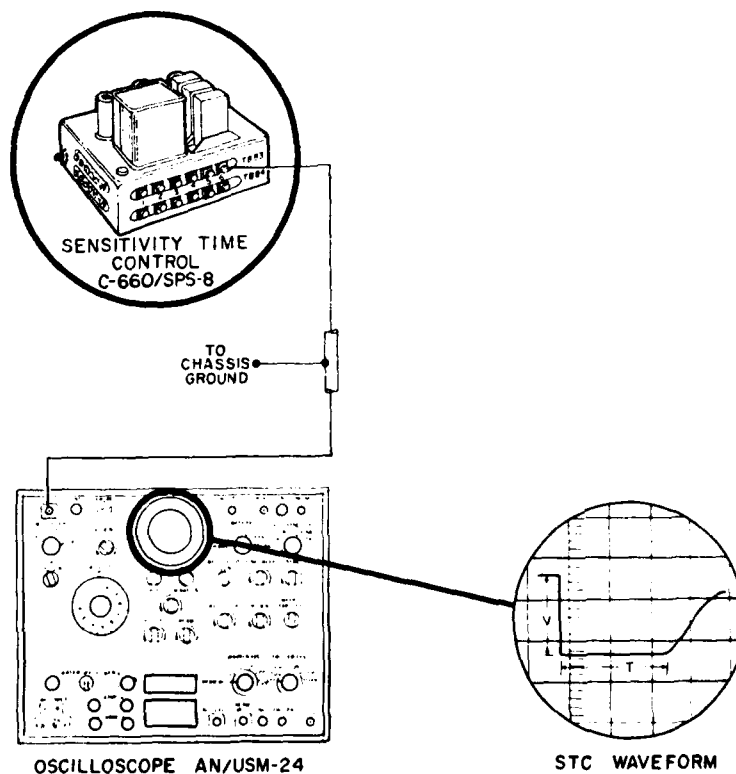


Figure 8-14.—Radar sensitivity time-control measurement.

THE ECHO BOX

Introduction

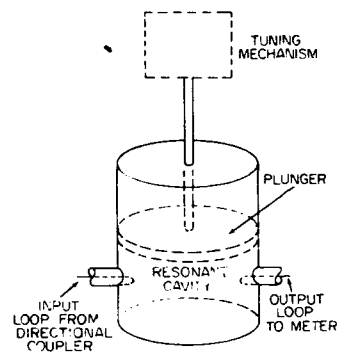
Good radar performance is of vital importance because radar is the eye that the Navy depends on to detect enemy ships and planes long before they are detected by other methods. It has failed to accomplish this purpose if attacking enemy craft are detected too late for effective countermeasures to be taken. It is therefore extremely important that radar installations be maintained so that they always operate close to their maximum efficiency, and technicians should spare no effort in making this possible.

The ECHO BOX is one of the most important single test instruments for indicating the over-all radar system performance. This results from the fact that the echo-box indication reflects the combined relative effectiveness of the transmitter as a transmitter of energy and the receiver as a receiver of energy.

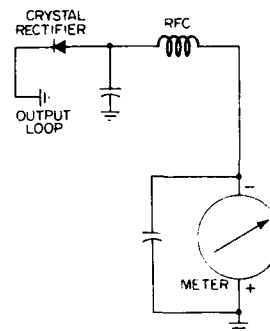
As a matter of fact, the determination of ringtime by the use of an echo box is a daily or weekly requirement in the Maintenance Check-Off Books for the various radar sets. It may be necessary to take these readings oftener than this, if the operation of the radar requires it.

The echo box, or resonance chamber, consists basically of a resonant cavity, as indicated in figure 8-15, A. The resonant frequency of the cavity is determined by the size of the cavity (the larger the cavity, the lower the frequency); and this, in turn, is determined by the position of the plunger. The accurately calibrated tuning mechanism controls the position of the plunger and indicates on a dial the resultant resonant frequency, or data that permits the technician to determine the frequency with great accuracy by consulting a set of curves.

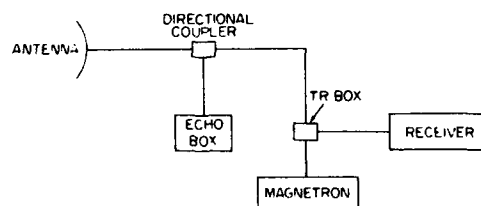
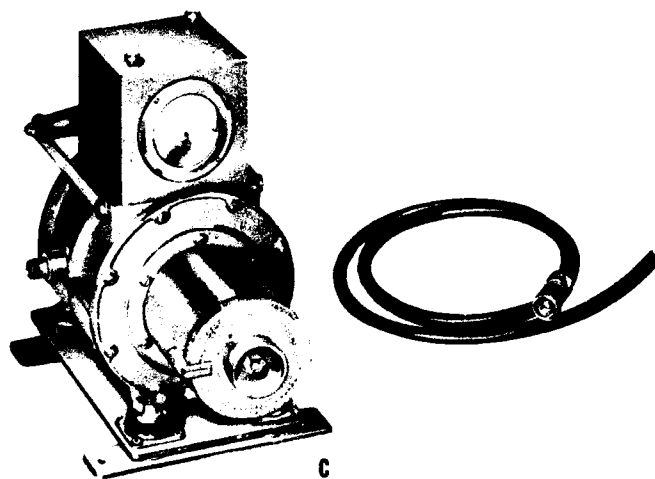
Energy is coupled into the cavity from the directional coupler (or pickup dipole) by means of an r-f cable connected to the input loop. Energy is coupled out of the cavity to the rectifier and the microammeter by means



A SIMPLE ECHO BOX



B OUTPUT CIRCUIT



D LOCATION IN RADAR SYSTEM

Figure 8-15.—Echo box.

of the output loop. The amount of coupling between the echo box and the crystal rectifier can be varied by changing the position of the output loop. A schematic diagram of the output circuit is shown in figure 8-15, B. The energy picked up by the loop is rectified, filtered, and applied to the meter.

A front view of a typical echo box (TS-275/UP) is shown in figure 8-15, C; the method of connecting the echo box in a radar system is shown in figure 8-15, D.

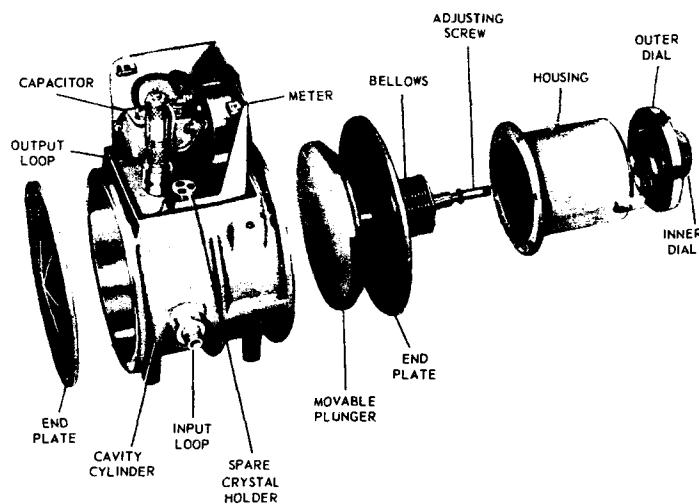


Figure 8-16.—Exploded view of the TS-275/UP echo box.

An exploded view of this echo box is shown in figure 8-16. The box consists of a cast bronze cavity cylinder with removable bronze end plates. The movable plunger is actuated by means of the adjusting screw and the inner dial through the water-tight bellows. The gearing between the inner dial and the outer dial is so arranged that the outer dial travels the amount of one of its divisions while the inner dial makes one revolution (10 major divisions or 100 minor divisions). The gears merely operate the outer dial and have no connection

with the driving of the plunger, and therefore do not cause backlash.

The indicating meter, the filter capacitor, and the spare crystal holder are mounted on top of the cavity cylinder.

The input and the output loop connectors project from the cavity cylinder.

Method of Connecting the Echo Box to the Radar

Either of two methods may be used to connect the echo box to the radar. A pickup dipole may be used, but more generally a directional coupler is used, as in figure 8-15, D. The method of installing the pickup dipole is described in the instruction book (NavShips 900,825).

Much of the information contained in this instruction book is of a general nature and will be very helpful to anyone desiring practical information on the use of echo boxes. As a matter of fact, much of the information contained in this portion of the chapter is condensed from this publication.

A directional coupler is commonly included in the r-f plumbing of radar sets. This echo box is designed to be used with directional couplers having a coupling loss of 20 to 35 decibels on the usual radar in the frequency range covered by this echo box. The exact value depends on the radar.

Frequency Calibration

The echo box dial is read by reading the middle dial number and then the inner dial number. Figure 8-17, A, shows an example in which the reading is three two point six five (32.65). Each major division on the inner dial is one-tenth of a revolution, and each smaller division is one-hundredth of a revolution. Each division of the middle dial represents one complete revolution of the inner dial.

The frequency calibration curve in figure 8-17, B, gives the tuning rate of the echo box with any setting

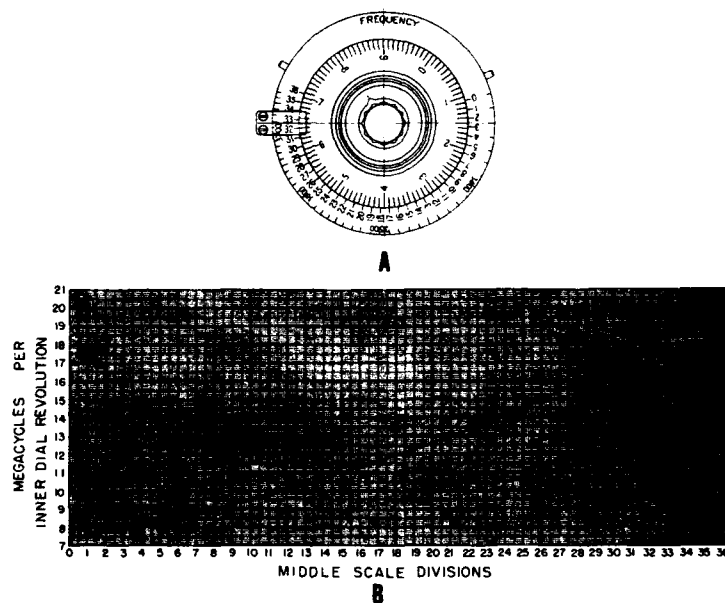


Figure 8-17.—Reading the dial.

of the tuning dial. The method of using the curve may be best explained by giving an example. Assume that a radar under test is supposed to be tuned to a frequency of 3607 mc. (The direct frequency calibration, marked in red on the instrument, is provided on the outer portion of the outer dial.) The echo box is found to be in resonance when the tuning control is at 27.5 (middle dial divisions) rather than the expected 26 (opposite 3607 mc on outer dial). Obviously, the radar is transmitting on a frequency 1.5 inner dial revolutions higher than intended. From figure 8-17, B, the tuning rate is found to be 15.5 megacycles per (inner) dial revolution. The radar is thus transmitting on a frequency 15.5×1.5 , or 23.25 mc too high.

Ringtime

Some of the energy generated by the radar transmitter is picked up by the echo box via the directional coupler.

This energy excites oscillations in the echo box that persist for some time after the end of the radar pulse, much in the fashion of an echo that persists in a large room after a loud noise. As this echo dies down, a part of it is fed back into the radar receiving system, again via the directional coupler. This causes a saturated signal to appear on the radar indicator, which is known as RINGING. The longer this ringing extends the better the performance of the radar—that is, the more powerful the transmitter is and/or the more sensitive the receiver is.

The length of time the echo box SHOULD ring under the particular conditions of the test (called the EXPECTED RINGTIME, or RINGTIME) may be compared with the ringing time observed, to determine whether the radar is performing well or not.

The ringtime to be expected on a good radar depends on the particular type of radar being tested; on the way the echo box is installed—that is, for example, whether a directional coupler or a dipole is used, and on the length and type of cable used; on the individual ringing ability of the particular echo box employed; on the frequency of the radar; and on the temperature of the echo box at the time of the test. Corrections are made for all of these factors according to the procedure given in the instruction book for the echo box being used.

An echo box without correction may be used for the purpose of detecting a CHANGE in the performance of a radar. The ringtime is simply noted and compared from day to day. It should be recognized that these readings do not permit the comparison of a particular radar with a standard of performance, and thus to tell whether more may be expected from a radar than its past performance would indicate.

Ringtime Measurements

Because ringtime measurements constitute the most valuable single feature of the echo box, it is essential that they be carried out properly and with due regard

for the necessary precautions. Ringtime measurements are made on the A scope or on the PPI, both methods of which are discussed later.

In measuring the ringtime, the technician should make sure that it is the echo-box ringtime and not some fixed-target echo or block of echoes that is being received. This condition can be determined by adjusting the radar gain control and noting if there is a back and forth movement of the ringtime on the scope. The echo box echo will change in range; fixed-target echoes, however, will not change in range, only in amplitude.

In order to obtain accurate results, every ringtime measurement should be repeated at least four times, and the readings averaged. Care must be taken to ensure that all readings are accurate. If two or more technicians use the same echo box, they should practice together until their ringtime measurements agree.

Radars have a tendency to drift slightly in frequency. When this occurs, the echo box becomes detuned and accurate ringtime measurement is difficult. Therefore, it is necessary when making ringtime measurements for longer than a very few minutes to retune the echo box from time to time.

The radar antenna should not be pointed at a mast or other nearby obstruction because proximity effect may cause the transmitter to change frequency.

A-scope presentation of ringtime is indicated in figure 8-18, A. The receiver gain should be set so that the "grass" or noise is one-quarter to one-third the total saturated signal height on the A scope. When this is done, a good pattern results, such as either of those shown in the figure. In the event that no "grass" can be seen, the gain of the radar i-f is inadequate and repairs should be undertaken.

The point at which the pattern disappears into the "grass" caused by background noise is independent of the gain setting within fairly wide limits when the ringtime is correctly read. It is advisable to adjust the gain

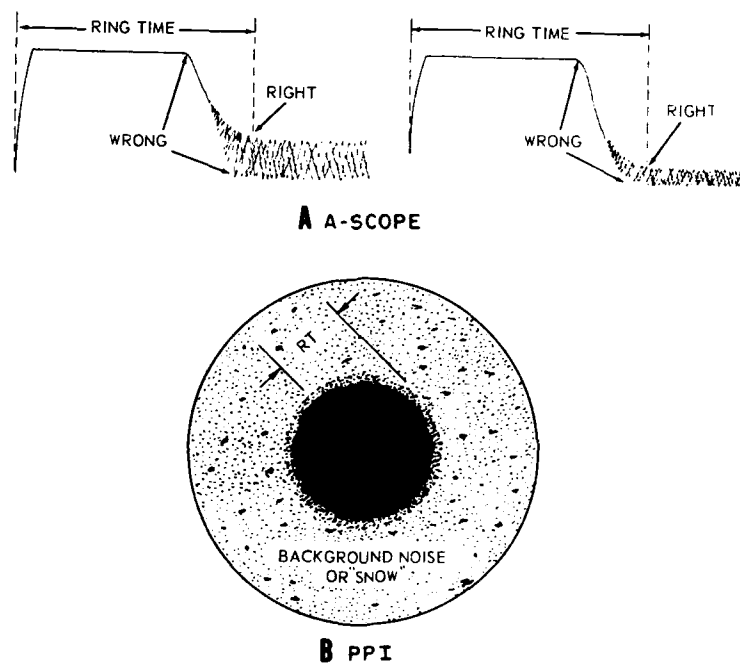


Figure 8-18.—A-scope and PPI presentation of ringtime.

until one-half inch of "grass" is present. (This is roughly the normal gain setting when searching for small targets.)

The exact end of the ringtime occurs at the furthest point to the right at which the TOP of the "grass" is noticeably above the general level of the rest of the "grass." Do NOT judge ringtime by the BOTTOM of the "grass" or by the end of the saturated portion of the ringtime because these items are influenced by the receiver gain setting and other factors.

Setting the gain too high or too low may make it difficult or impossible to read the ringtime with accuracy. (It is essential that "grass" be present.)

An A-scope indicator measurement of ringtime is usually best performed when the radar antenna is stopped.

PPI presentation of ringtime is indicated in figure 8-18, B. In this instance, the same general principles apply as did in the case of the A-scope presentation.

The following procedure should be followed. With the radar antenna rotating, set the receiver gain at a minimum and adjust the intensity (bias) so that there is a very slight radial trace on the PPI indicator. Increase the receiver gain until the PPI-indicator area seems to be just half covered with flecks of snow.

A PPI ringtime pattern, with proper receiver gain adjustment (and the radar antenna rotating), is shown in the figure. In this case, the echo box is used with a directional coupler.

It should be emphasized that the end of the ringtime signal is NOT at the place where the bright or saturated part of the signal ends, but where the fainter portion of the signal disappears into the background noise. Therefore, when reading the ringtime on a PPI indicator, be sure to observe to the extreme edge of the grass and NOT JUST TO THE END OF THE BRIGHT PORTION OF THE PATTERN. Read to the last point at which the "snow" is unusually bright. As indicated in figure 8-18, ringtime (RT) is measured from the center of the pattern to the outer edge.

Radar Spectrum Analysis

Every time a radar transmitter generates an r-f pulse, it produces a certain amount of r-f energy in the form of electromagnetic waves. Not all of these waves, however, are of the same frequency; in fact, only a small portion of them have exactly the same frequency as that to which the transmitter is tuned. The rest of the radiations are at slightly higher or slightly lower frequencies, forming the sideband frequencies. This is the natural result of pulse modulation and cannot be avoided.

Actually, the radar energy is distributed more or less symmetrically over a band of frequencies, as illustrated in figure 8-19, A. This frequency distribution of energy

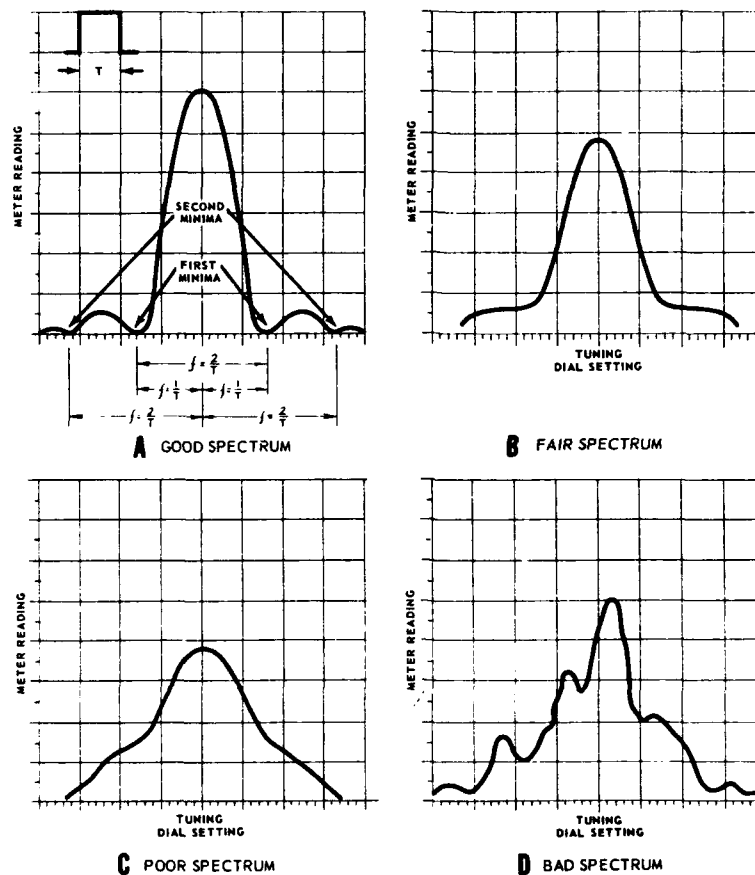


Figure 8-19.—Typical radar spectra.

is known as the SPECTRUM. An analysis of its characteristics may readily be carried out with the aid of the echo box.

When properly performed and interpreted, a spectrum analysis will disclose maladjustments and troubles that would otherwise be difficult to locate. It is important, therefore, that the technician who uses the echo box be able to carry out a spectrum analysis and understand the results.

When a spectrum analysis is to be made, the tuning control of the test set (fig. 8-15, C) is first turned until a maximum output meter deflection is obtained, then the tuning control is turned slowly from a point well below this maximum to a point well above it.

While this is being done, the output meter readings are noted for various settings of the tuning control. It is good practice to cover the frequency range desired by turning the tuning knob slowly in the same direction to each new position, not by turning it back and forth. This is done to minimize any possible error due to backlash. A reading should be taken about every 0.02 revolution of the tuning knob.

Finally, an accurate graph is constructed with the meter readings plotted against the tuning control dial settings. The resulting graph should resemble one of those shown in figure 8-19.

A radar transmitter in satisfactory condition should give a spectrum curve similar to curve A or curve B. Good curves are those in which the two halves are symmetrical and contain deep, well-defined minimum points on both sides of the main peak.

A curve without deep minima, as in curve C, indicates that the transmitter output is frequency modulated during the pulse. This may be due to the application of a negative pulse to the magnetron that does not have sufficiently steep sides or flat extremities. It may also be due to a transmitter tube that is unstable or is operated with improper voltage, current, or magnetic field.

When the spectrum is extremely irregular, as in curve D, it is an indication of severe frequency modulation. This will probably cause trouble in the receiver automatic frequency control as well as general loss of signal strength. When the spectrum has two large peaks, quite far apart, it indicates that the transmitter tube is double moding, perhaps because of unwanted standing waves in the transmission line or a bad transmitter tube. A faulty spectrum can often be improved by adjustment

of the transmission line stubs or by replacement of the transmitter tube. Standing waves may be due to a faulty line connection, a bad antenna rotating joint, or obstructions in the line.

In the case of a good or fair spectrum curve with sharply defined minima on both sides of the main peak, the distance between these two minima is proportional to the duration of the transmitted pulse. Because the duration of the pulse determines the distribution of power in the sideband frequencies, the pulse length may be found from the spectrum graph. The procedure is to determine the distance in megacycles between the minima on either side of the main peak. These minima

are separated by a frequency (in megacycles) equal to $\frac{2}{T}$,

where T is the pulse length in megacycles and $\frac{1}{T}$ is the

number of sideband frequencies contained in either upper or lower sideband (from the carrier frequency to the first minimum on either side of the carrier). Expressed as an equation,

$$\text{pulse length in microseconds} = \frac{2}{\text{distance between minima in megacycles}}$$

Suppose, for example, that the echo box is being used to check the pulse length of a radar. The graph of the spectrum is plotted, and the tuning distance between the minima is from 17 divisions on the middle dial (fig. 8-17, A) to 17.17 divisions (17 divisions on the inner dial). From figure 8-17, B it is found that for the particular frequency range in question (3480-3490 mc) the echo box tunes at a rate of 11.65 mc per revolution (corresponding to 17 divisions on the middle dial). The frequency span between minima is

$$11.65 \times 0.17 = 1.98 \text{ mc.}$$

Applying the equation given in the last paragraph,

$$\text{pulse length in microseconds} = \frac{2}{1.98} = 1.01 \text{ microsecond.}$$

The value thus calculated can be readily compared to the standard value for a radar of the type under test by reference to the radar manual. Any great change in the test value compared to the standard value indicates an improper pulse length.

The shorter the pulse length, the wider will be the frequency band that the signals occupy. This effect will appear on the graph as a wide span between the first minima of the spectrum curve.

An abnormally narrow spectrum shows that the transmitted pulse is too long. Such a pulse could result in a long ringtime and high power reading on the echo box output meter, thus falsely indicating superior system performance.

Power Output

At the time of installation, the meter reading on the echo box, TS-275/UP, should have been set between 40 and 80 divisions (by adjusting the orientation of the output loop) while the echo box was tuned to resonance with the radar transmitter.

The output meter reading is closely proportional to the average radar power picked up by the echo box and to the transmitter pulse length, when the echo box is tuned to the maximum output signal of the spectrum. If the pulse length is long, the spectrum curve is consequently high and narrow, and the meter reading is high. Where the pulse length is shorter, the spectrum curve is flatter and the meter reading will be lower.

The power output of a radar is generally good if the transmitter current is normal. Loss in the transmission line may cause loss of power, and in the event that low power is observed at the antenna of the radar by means of a pickup dipole and echo box, the transmission line may be suspected. Because of the high initial cost of radar transmitting tubes, the echo box and its accessories should be checked carefully before discarding such a tube. Transmitter tuning stubs are NEVER adjusted for

maximum power output, as indicated at the echo box. These stubs provide a transmitter frequency adjustment, the net effect of which is observed at the receiver indicator rather than at the echo box. The correct procedure for checking the radar frequency is described in chapter 7.

Other Test Procedures

GENERAL PROCEDURE.—A variety of radar equipment checks can be carried out with the aid of the echo box. The exact nature of these tests, as well as the detailed methods of procedure, may vary to some extent between different types and models of radar equipment. The typical procedures given in the following paragraphs will be useful in establishing test routines to be followed in radar maintenance. Practice and experience may suggest variations as the technician becomes more familiar with the use of the echo box.

In the testing procedures outlined in the following paragraphs it is assumed that the echo box is properly installed, and that the expected ringtime and output meter reading are known for the particular radar under test.

All measurements should be recorded in the radar log and/or on forms provided for this purpose. One such form for ringtime, from the *Maintenance Check-Off Book for Radar Set AN/SPS-3*, NavShips 91522.41, is included in figure 8-20. The figure includes complete instructions for making the test. Another form for listing echo box meter reading from the same publication is included in figure 8-21.

As a preliminary step in all tests, the radar equipment should be allowed to warm up fully to the normal operating temperature. The directional (or bidirectional) coupler or the pickup dipole (when used) should be correctly coupled to the echo box. All antijamming provisions (provisions to reduce the effects of the enemy jamming the radar) and the sensitivity time control, if provided, should be turned off.

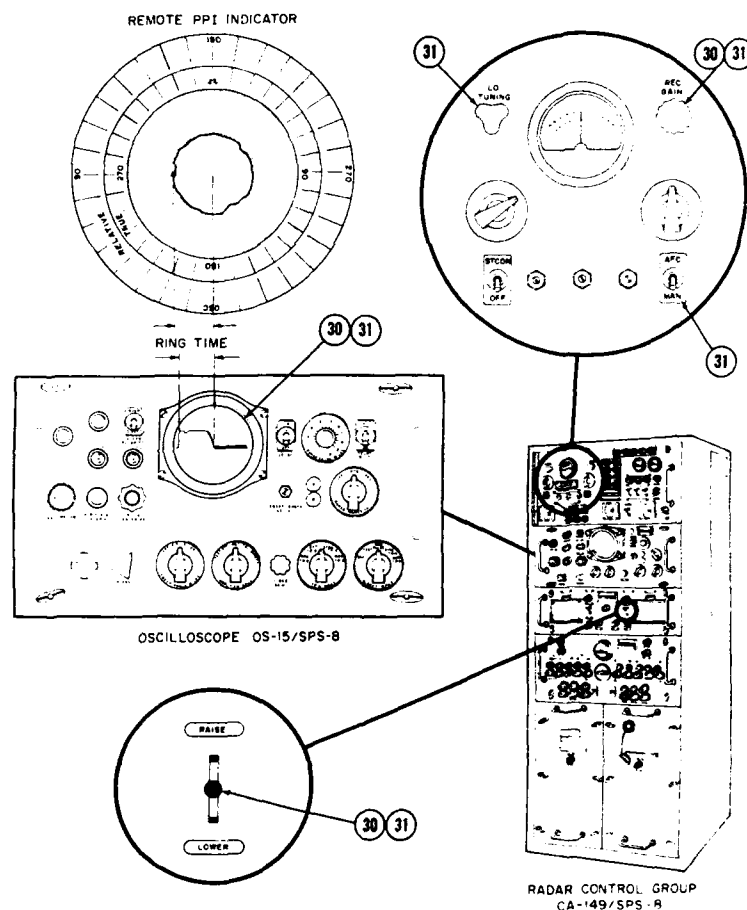


Figure 8-20.—Steps for recording ringtime.

OVER-ALL PERFORMANCE.—Adjust the echo box tuning knob for a maximum reading of the output meter, indicating that the echo box is tuned to resonance with the radar. Then adjust the radar receiver local oscillator frequency for maximum ringtime on the indicator. Measure the ringtime as accurately as possible, preferably by taking advantage of at least four readings. Ringtime is most conveniently measured on an A scope with the

STEP NO.	ACTION REQUIRED	PRELIMINARY ACTION	READ INDICATION ON	PERFORMANCE STANDARD
30	Record radar ring time with AFC.	Set REC GAIN (R7142) for one-half inch of grass on Oscilloscope screen. Tune Echo Box with RAISE-LOWER switch (S7404) for maximum ring time indication of Oscilloscope screen. The ring time is obtained directly in yards on the remote PPI indicator. Rotate Antenna and set the range ring slightly beyond the solid echo portion of pattern as shown on illustration page.	Range Dial Remote PPI Indicator.	YDS (3200 or more)
31	Record radar ring time in manual tuning position.	Same as Step 30 except AFC-MANUAL switch (S7104) in MANUAL position, and LO TUNING (R7138) varied for maximum ring time.	Range Dial Remote PPI Indicator.	YDS (3200 or more)

STEP NO.	30	31	30	31	30	31	30	31	30	31	30	31
Month	JAN 19__		FEB 19__		MARCH 19__		APRIL 19__		MAY 19__		JUNE 19__	
Week	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init
1												
2												
3												
4												
5												
Month	JULY 19__		AUG 19__		SEPT 19__		OCT 19__		NOV 19__		DEC 19__	
Week	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init
1												
2												
3												
4												
5												

Figure 8-20.—Continued.

antenna stopped, and on a PPI scope with the radar antenna rotating. Record the ringtime on the forms provided. Compare this figure with the corresponding value of the performance standard.

If the output meter and ringtime measurements are both satisfactory (compared with the expected values), the radar transmitter and receiver are both functioning well. If the meter reading is satisfactory but the ringtime is low, the radar receiver is the probable source of the trouble. Service the receiver, consulting the appropriate instruction book for the detailed procedure.

TRANSMITTER POWER.—The echo-box output meter reading is closely proportional to the average energy radiated from the radar on a particular frequency. The

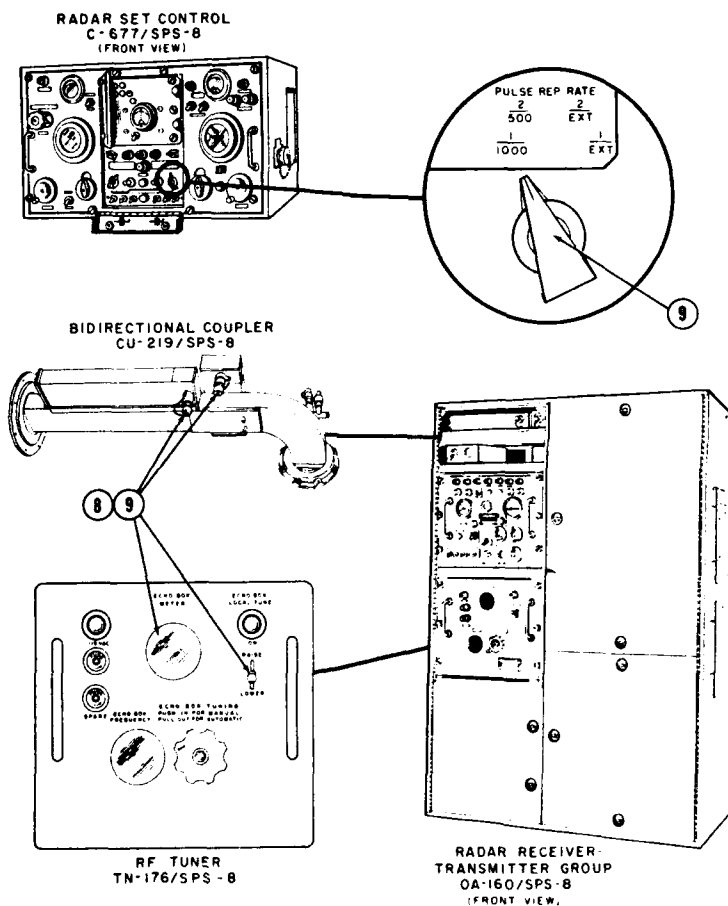


Figure 8-21.—Steps for recording transmit/receive ratio.

measurement of relative transmitter power is, therefore, a direct and simple procedure. Tune the echo box to resonance and then stop the radar antenna. Record the maximum reading on the output meter. This measurement, compared with the corresponding value on previous tests, gives an index of transmitter power. If the meter reading is satisfactory, the radar power output is good. If the meter reading and ringtime are low, the

STEP NO.	ACTION REQUIRED	PRELIMINARY ACTION	READ INDICATION ON	PERFORMANCE STANDARD								
⑧	Record Echo Box ratio as an indication of transmission line voltage standing wave ratio (VSWR) with a 1-microsecond pulse. (These ratios are inversely proportional; if actual VSWR is desired see interpolation curves in Section 6 of NAVSHIPS 91522 (A)).	Connect echo box to J3007 on transmitter arm of bidirectional coupler. Vary RAISE-LOWER switch (S3501) for maximum reading on Echo Box Meter. Note reading. Connect echo box cable to J3008 on receiver arm of bidirectional coupler. Vary RAISE-LOWER switch (S3501) for maximum reading on Echo Box Meter. Note reading. Divide the first reading by the second reading and record the ratio.	Echo Box Meter <u>First reading</u> <u>Second reading</u>	Ratio (1.1 or larger)								
⑨	Record Echo Box ratio as an indication of transmission line voltage standing wave ratio (VSWR) with a 2-microsecond pulse. (These ratios are inversely proportional; if actual VSWR is desired see interpolation curves in Section 6 of NAVSHIPS 91522 (A)).	Throw PULSE REP RATE switch (S6205) to 2/500 and repeat Step ⑧.	Echo Box Meter <u>First reading</u> <u>Second reading</u>	Ratio (1.1 or larger)								
STEP NO.	1st QUARTER 19__			2nd QUARTER 19__	3rd QUARTER 19__	4th QUARTER 19__						
	Ratio	Initial	Date	Ratio	Initial	Date	Ratio	Initial	Date	Ratio	Initial	Date
⑧												
⑨												

Figure 8-21.—Continued.

transmitter power output is low, and a spectrum analysis should be made, as previously described.

RADAR FREQUENCY.—To check the TRANSMITTER FREQUENCY, adjust the echo-box tuning knob for maximum deflection of the output meter, and stop the antenna. Read the tuning-knob scale and determine the transmitter frequency by reading the red calibration on the outer portion of the face of the outer dial, or by referring to the echo-box frequency calibration curve (fig. 8-17, B). If the transmitter frequency is found to be different from the frequency intended, the cause may be the trans-

mitter tube or the transmitter tuning adjustments. Reference should be made to the appropriate instruction book.

To check the LOCAL OSCILLATOR FREQUENCY, the echo box is disconnected from the directional coupler (or pickup dipole). It is then coupled directly to the local oscillator output. (A special connector may have to be improvised to fit the local oscillator output of certain radars. It is desirable to insert 10 to 20 db of attenuation between the local oscillator and the echo box.) Adjust the echo-box tuning control for maximum deflection of the output meter. Read the tuning-control scale and, referring again to the echo box calibration data, record the local oscillator frequency. The echo box meter reading is likely to be excessive if attenuation is not inserted, and the output loop (fig. 8-15, A) should be adjusted to protect the meter (the loop may be adjusted with a wrench).

THE DIFFERENCE BETWEEN THE TRANSMITTER AND THE LOCAL OSCILLATOR FREQUENCIES is easily checked by the curve in figure 8-17, B. It is necessary to have not only the correct frequency difference but also to have the local oscillator operating on the proper side (above or below) the transmitter frequency. This frequency difference is, in each case, identical with the frequency of the radar i-f amplifier. Using the tuning curve in figure 8-17, B, the technician can readily check the frequencies and determine whether the difference between them is correct.

To TUNE THE LOCAL OSCILLATOR, couple the echo box to the local oscillator. From the echo-box calibration data, find the echo-box setting for the correct local oscillator frequency, and adjust the echo-box tuning control accordingly. Then adjust the local oscillator, referring to the radar manual for the correct procedure, until the echo box output meter shows maximum deflection. The oscillator is then approximately tuned to the correct frequency. Final tuning of the oscillator should be such as to produce maximum ringtime and proper radar crystal current.

ERRATIC TRANSMITTER OPERATION.—Adjust the echo-box tuning control for maximum deflection of the output meter with the echo box connected to the directional coupler, and stop the antenna. If the transmitter is operating normally, a good ringtime pattern will be displayed on the A scope (fig. 8-18). If the ringtime is erratic, or extra background noise traces appear in the pattern, then the transmitter may be multiple moding (transmitting on two or more distinct frequencies) or failing to fire on every pulse. This may be due to faulty pulsing; transmission-line troubles, especially arcing; or other causes. Examine the spectrum in order to help localize the trouble. Refer to the appropriate instruction book for help in correcting the trouble.

TRANSMITTER PULLING.—Magnetron frequency pulling results from a change in the loading as the antenna is rotated. As a check for magnetron pulling, turn off the automatic frequency control on the radar receiver. Adjust the echo-box tuning control for maximum deflection of the output meter. With the radar antenna rotating, observe the pattern on the PPI indicator. If the transmitter is operating normally, a good ringing pattern will be seen, as in figure 8-22, A. If there are blank spaces on the PPI indicator or if the ringtime is reduced on certain azimuths, as a part B, then the transmitter is being frequency pulled. In such a case, the output meter reading will also fluctuate as the radar antenna is rotated slowly. Transmitter frequency measurements at several azimuths may also be used to confirm this difficulty. The pulling may be caused by a bad rotating joint or by a reflecting surface near the antenna. Refer to the appropriate instruction book for corrective measures.

AUTOMATIC FREQUENCY CONTROL.—To determine whether the local oscillator is following the transmitter when it is pulled, first stop the antenna on an azimuth where the ringtime pattern is broken, and then retune the echo box to resonance. Rotate the radar antenna and again examine the PPI pattern. If the ringtime is

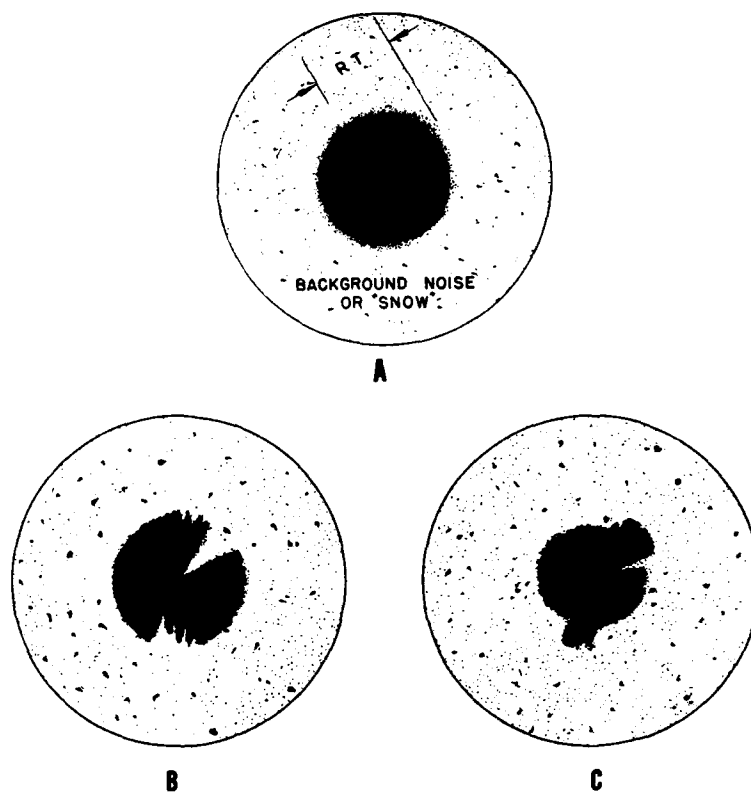


Figure 8-22.—Indication of magnetron pulling.

now good on the azimuth at which the echo box was retuned (fig. 8-22, C), the AFC is in operation on that azimuth and the local oscillator is following when the transmitter is pulled. As may be seen in part C, the ringtime may have now decreased in those azimuths where it was originally good. If the AFC does not follow, the pulling may be excessive or the AFC may be at fault. If the ringtime is greatly decreased at certain azimuths and the AFC does not follow, the radar must be considered inoperative at those azimuths and should be so reported.

A simple procedure will show whether the AFC is locked on the proper frequency. Stop the radar antenna and tune the echo box for maximum meter reading. Turn off the AFC switch and tune the local oscillator for maximum ringtime, thus putting the local oscillator in proper tune. Turn the AFC switch on again. If the ringtime decreases, even slightly, the AFC is locking on the wrong frequency, or is failing to lock. The proper instruction book should be consulted for corrective procedure. The probable cause of the AFC failure is a bad spectrum or the fact that the local oscillator is tuned to a frequency on the wrong side of the transmitter frequency. It is usually not advisable to tune the AFC circuit.

T-R BOX RECOVERY.—The time required to permit T-R (transmit-receiver switch) recovery is determined by the time it takes the T-R switch to deionize after each transmitter pulse. It is usually defined as the time required for the receiver to return to within 6 db of normal sensitivity after the end of the transmitter pulse. T-R recovery time is the factor that limits the minimum range of a radar because the radar receiver is unable to receive signals until the T-R switch is deionized. In various radar sets, the recovery time may vary from about 3 to 20 μ s.

To test for T-R box recovery, adjust the echo-box tuning control for maximum deflection of the output meter, and stop the radar antenna. Adjust the A scope for a good ringtime pattern, such as curve E in figure 8-23. Slowly and gradually reduce the radar receiver gain setting, or better, detune the local oscillator. A pattern will result, such as curve D in figure 8-23, having the same relative shape as curve E. Further slight reduction in gain setting will produce another pattern, such as curve C, again similar in shape to curve E. Continue until a change occurs in the slope of the curve, as in curve B. This point of change marks the T-R box recovery time of the radar, as indicated in the figure.

For a good radar, the T-R recovery time should correspond to a range of one mile or less.

If the gain control is reduced still further, a greatly distorted pattern will appear, such as curve A in figure 8-23. This curve shows that the T-R box has not recovered. Refer to the appropriate instruction book for corrective procedures. If the above procedure does not produce a series of curves (as indicated) giving a T-R recovery point, and if the ringtime is short, then it is probable that the T-R recovery time is much too high (greater than the ringtime) and a new T-R tube is needed. Check the keep-alive current. The keep-alive should be negative, and current between 0.1 and 0.2 ma.

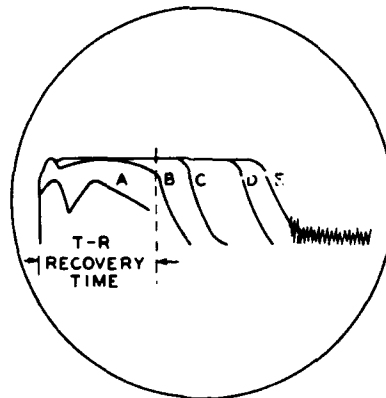


Figure 8-23.—Checking T-R box recovery.

RECEIVER RECOVERY.—Adjust the echo-box tuning control for maximum deflection of the output meter, and stop the radar antenna. Then detune the echo box, and adjust the radar receiver gain control until the indicator shows a pattern similar to one of those illustrated at the left of figure 8-24. Now retune the echo box to resonance and again observe the indicator pattern. If the receiver recovery time is normal, the background noise will reappear immediately after the end of the ringtime pattern, and this noise will be approximately as strong

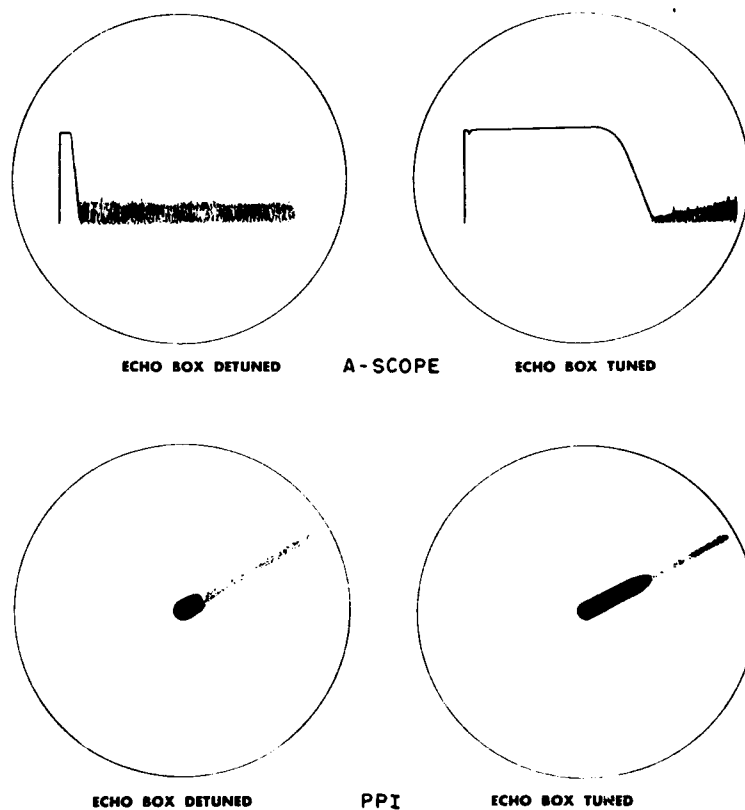


Figure 8-24.—Receiver nonrecovery.

as the noise previously observed with the echo box detuned. If the receiver recovery is slow, the noise will be weak and will not reappear for some time after the end of the ringtime pattern (see the right-hand portion of figure 8-24). In extreme cases of receiver nonrecovery, normal background noise may not reappear on the indicator at all. Receiver nonrecovery is usually an i-f tube or video defect, and one which will make the radar susceptible to enemy jamming.

TRANSMISSION LINE LOSS.—Using the directional coupler, tune the echo box to resonance. Record the ring-

time and the output meter reading. Disconnect the echo box from the coupler and connect it to the dipole (the proper location of the dipole is given in the instruction book; it is located at a position somewhere in the antenna radiation field). Again tune the echo box to resonance and again record the ringtime and the output reading. Comparing these measurements, while allowing for the normal difference due to the difference between the coupler attenuation and the antenna space loss (losses are

EFFECT	APPEARANCE ON		PROBABLE CAUSE
	RADAR INDICATOR	ECHO BOX METER	
RINGTIME — NORMAL ECHO BOX METER — NORMAL			RADAR PERFORMANCE SATISFACTORY.
RINGTIME — LOW ECHO BOX METER — NORMAL			RECEIVING TROUBLE: DETUNED MIXER OR LOCAL OSCILLATOR, BAD CRYSTALS, EXCESSIVE I-F NOISE, ADJUSTMENT OF PROBES IN MIXER CAVITY, DETUNED T/R BOX
RINGTIME — LOW ECHO BOX METER — VERY LOW			LOW POWER OUTPUT—CHECK SPECTRUM.
RINGTIME — LOW ECHO BOX METER — LOW			TROUBLE PROBABLY IN TRANSMITTER AND RECEIVER AND/OR TROUBLE IN TRANSMISSION LINE
RINGTIME — ERRATIC ECHO BOX METER — STEADY			ECHO BOX DETUNED, BAD PULSING, DOUBLE MODING TRANSMITTER, OR LOCAL OSCILLATOR POWER SUPPLY TROUBLE. CHECK SPECTRUM.
RINGTIME — ERRATIC ECHO BOX METER — ERRATIC			FAULTY TRANSMISSION LINE OR CONNECTION — CONDITION WORSE WHEN LINE IS VIBRATED.
END OF RINGTIME SLOPES GRADUALLY, POSSIBLY EXCESSIVE RINGING GRASS APPEARS COARSE. ECHO BOX METER—STEADY AND SATISFACTORY.			OSCILLATING I-F STAGE
PRONOUNCED DIP IN RINGTIME AT END OF PULSE.			FAULTY T/R TUBE
RINGTIME—SLIGHTLY LOW POOR OR BAD SPECTRUM.			TRANSMITTING TROUBLE
BLANK SPACES OR ROUGH PATTERN ON PPI RINGTIME INDICATOR. ECHO BOX METER READING VARIES AS ANTENNA IS ROTATED			FREQUENCY PULLING OF TRANSMITTER DUE TO BAD ROTATING JOINT OR TO REFLECTING OBJECT NEAR RADAR ANTENNA

Figure 8-25.—Troubleshooting chart.

$$\text{pulse length in microseconds} = \frac{2}{1.98} = 1.01 \text{ microsecond.}$$

indicated in tables in the echo box instruction book), an indication can be obtained of the loss in the radar r-f transmission line. If there is unusual loss in the radar transmission line, there will be greater differences than usual in the ringtime and also in the output meter reading. Repair or adjustments may then be undertaken.

Intermittent defects in the transmission line can often be found by rapping on the line while observing the echo box meter reading.

RAPID TROUBLESHOOTING CHART.—When the technician has become familiar with the test procedures and measurements, the echo box may be used for rapid troubleshooting. Radar troubles may be more readily checked with the aid of the cause-and-effect chart of figure 8-25, which is essentially a summary of the information given on the use of the echo box as a test instrument.

RADAR PERFORMANCE FIGURE

Although ringtime measurements are valuable in indicating the over-all performance of a radar system, they are not as precise as Radar Performance Figure (RPF) measurements. However, neither of these measurements indicates much about how efficient the waveguide or antenna is in performing its function. Ringtime measurements are relatively easy to make; RPF measurements are more difficult to make.

The maximum range of a radar system depends on several factors—for example, (a) transmitter power, (b) receiver sensitivity, (c) the performance of the waveguide and antenna, (d) the effectiveness of the target in reflecting radar energy, and (e) atmospheric conditions.

The first two of the factors listed are especially significant in so far as equipment performance is concerned and are used in determining the RPF of a radar system. The RPF of a radar system is the ratio of the peak (pulse) power, P_p , of the radar transmitter to the power of the minimum discernible signal (P_{mds}), expressed in

decibels (db) or in decibels with a reference of 1 mw (that is, dbm). Expressed mathematically,

$$RPF \text{ (db)} = 10 \log \frac{P_p}{P_{mds}}$$

Because P_{mds} is a very small fraction, its log has a negative sign, and therefore

$$RPF \text{ (db)} = 10 [\log P_p - (-\log P_{mds})]$$

$$RPF \text{ (db)} = 10 \log P_p + 10 \log P_{mds}$$

If the power reference is 1 mw, the equation becomes

$$RPF \text{ (dbm)} = P_p \text{ (dbm)} + P_{mds} \text{ (dbm)}.$$

To determine the RPF of a radar system it is necessary first to determine the transmitter average power by means of a power meter (discussed in chapter 7) and to convert the average power in dbm to peak power in dbm. As explained in chapter 7, the various losses must be taken into consideration in determining the power output. It is also necessary to determine the power of the minimum discernible signal.

The measurement of the minimum discernible signal in dbm involves the use of a signal generator and an oscilloscope. The exact method of making the measurement depends on the radar set being tested. For example, the procedure for making MDS measurements on Radar Set AN/SPS-6 is given in the *Performance Standards Book* (NavShips 91081.31) and in the *Maintenance Check-Off Book* (NavShips 91081.41).

An external pulse-modulated signal and a method of viewing this signal is required. These requirements are satisfied by the use of Signal Generator TS-419 U and Oscilloscope OS-8/U or equivalents. The test equipment is connected as shown in figure 8-26, and the correct procedures are as follows:

1. Deenergize the radar equipment (depress S102) and apply power to the signal generator and the oscilloscope.
2. Adjust the signal generator to the assigned transmitter frequency, set the FUNCTION switch to ZERO SET and adjust the ZERO SET control until the meter indication is zero.

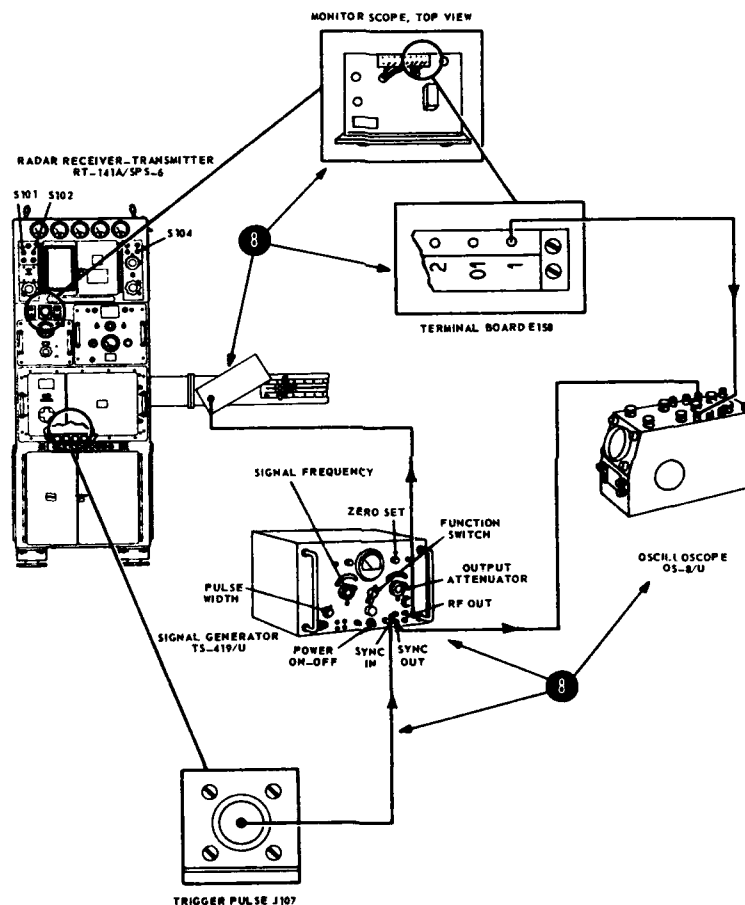


Figure 8-26.—Test setup for making MDS measurements.

3. Set the FUNCTION switch to CW and adjust the POWER SET control until the meter pointer is at the power set marker.

4. Set the FUNCTION SELECTOR switch to the RATE x 10 position, the PULSE WIDTH control to 2 and the PULSE RATE control to 30.

5. Make certain that all connections to the test equipment are correct, and that the oscilloscope is adjusted for maximum clarity of presentation.

6. Depress MAIN POWER ON switch (S101) on the radar set, and set MANUAL-AFC switch to MANUAL (Radar Set AN/SPS-6C). The RADIATION switch (S104) is OFF.

7. While observing the pulse-modulated signal on the oscilloscope, slowly decrease the output of the signal generator with the OUTPUT ATTENUATOR control until the signal is barely visible in the "grass" on the oscilloscope. Read the indication on the attenuator dial in dbm.

The minimum discernible signal is the sum of the test set reading in dbm, the cable attenuation in db, and the waveguide connector in dbm. For this equipment, the power of the MDS is normally between 100 and 115 dbm.

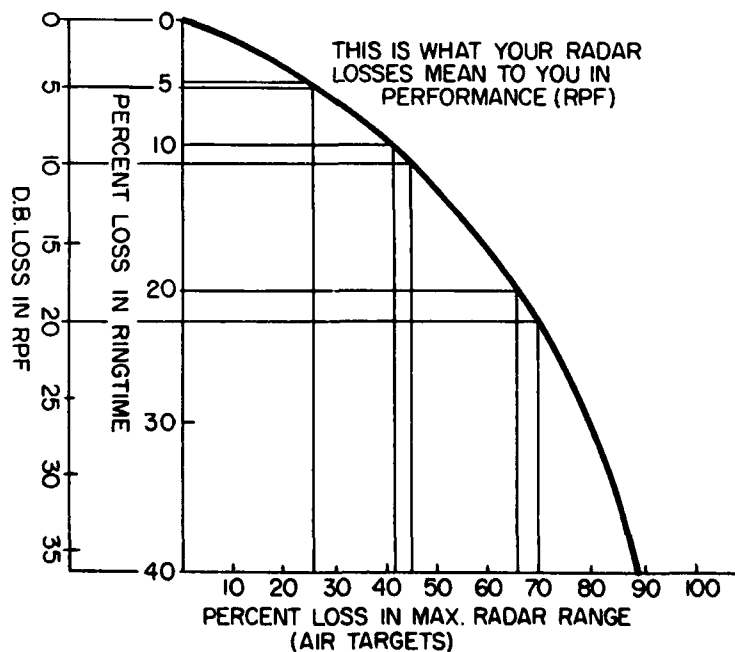


Figure 8-27.—Effects of loss in RPF and ringtime on radar range.

Thus, if the peak power (P_p) output is assumed to be 90 dbm and the power of the MDS (that is P_{mfs}) assumed to be 105 dbm, the radar performance figure (RPF) is

$$\text{RPF (dbm)} = P_p \text{ (dbm)} + P_{mfs} \text{ (dbm)}$$

$$\text{RPF (dbm)} = 90 + 105 = 195.$$

A graph showing the percentage loss in maximum radar range for various db losses in RPF and for various percentages of loss in ringtime is shown in figure 8-27. This graph was published in EIB No. 459 (27 May 1957).

QUIZ

1. What is the purpose of the vertical attenuator in the OS-8A/U Oscilloscope?
2. What are the three sources of synchronizing voltage that may be selected by the sync selector switch?
3. Which control on the OS-8A/U Oscilloscope regulates the bias on the CRT grid?
4. What device may be used with an oscilloscope to reduce to safe value a voltage that is too high to be applied directly to the input?
5. What is the vertical deflection sensitivity (in mm per volt) of an oscilloscope when 10 volts applied to the vertical deflecting plates cause the spot to move 5 mm?
6. Why should the test leads from the circuit under test to the oscilloscope be kept as short as possible?
7. What is the principal disadvantage of using the CRO for measuring a-c voltages?
8. What are three advantages of using the CRO as an a-c voltmeter?
9. What is the Lissajous figure?
10. In figure 8-5, A, it is assumed that a 1000-cycle signal is applied between the horizontal deflecting plates, what is the frequency applied between the vertical deflecting plates?
11. What is the pattern indicated on the screen of the CRO when sine-wave voltages of the same frequency and amplitude but 90° out of phase are applied to the deflecting plates?
12. What are the two basic modulation patterns employed in obtaining modulation measurements by the use of the oscilloscope?

13. The modulation percentage of a radio transmitter is to be determined by observing the wave-envelope pattern. Assuming that the peak-to-peak height of the unmodulated carrier is four units and the peak-to-peak height of the modulated carrier is 6 units, what is the modulation percentage?
14. What is the purpose of the marker pips displayed on the CRT of a synchroscope?
15. What is the purpose of the delay line in the vertical channel of the AN/USM-24 Oscilloscope?
16. In what part of the radar set does most of the delay occur?
17. Why is the echo box one of the most important single-test instruments for indicating over-all radar system performance?
18. What are the two methods by which an echo box is connected to a radar?
19. If the observed ringtime is less than the expected ringtime, what conclusions may be drawn with respect to the transmitter power and/or the receiver sensitivity?
20. How many ringtime measurements should be averaged to obtain accurate results?
21. Why may it be necessary to retune the echo box from time to time during ringtime measurements?
22. What trouble is indicated by a radar spectrum that does not have deep minima on each side of the main peak?
23. What trouble is indicated when the radar spectrum has two large peaks quite far apart?
24. What is the pulse length of a radar pulse (in microseconds) if the distance between the minima on the spectrum is 2 mc?
25. If the echo box meter reading is satisfactory but the ringtime is low, in what unit is the trouble most likely to be found?
26. If the transmitter frequency (by the use of the echo box) is found to differ from the intended frequency, what are two probable causes?
27. In checking the radar local oscillator frequency by means of the echo box, why is it desirable to insert 10 to 20 db of attenuation between the local oscillator and the echo box?
28. When final tuning of the local oscillator is accomplished by means of the echo box, what should the indications be with respect to ringtime and crystal current?
29. What causes magnetron frequency pulling?

30. What is the probable cause of AFC failure?
31. For a properly operating radar, what should be the maximum TR recovery time (fig. 8-22) in terms of miles?
32. What is the probable cause of a pronounced dip in the ringtime at the end of the pulse?
33. The radar performance figure (RPF) of a radar system is expressed in db as the ratio of what two quantities?

CHAPTER

9

SWITCHES, SWITCHBOARDS, AND AND SWITCHING SYSTEMS

INTRODUCTION

A basic understanding of switches and the functional use of switchboards and switching systems is a necessity for the Electronics Technician. In some instances, the switching systems used with electronic equipment are more difficult to understand than the operation of the equipment itself. In general, however, although switching systems are becoming more complex, the methods of operation are being simplified.

The Navy uses hundreds of different types of switches in (and associated with) electronic equipment. They are listed in the *Catalog of Navy Material*, part II (class 17, sections SW 1-1 and SW 1-2). The operation of most of them is not difficult to understand, however, and only a few representative examples are given in this chapter.

Switchboards make use of multisection switches that are not difficult in themselves to understand, but the entire switching function performed by switchboards, or by combinations of switchboards, may be somewhat involved. In this chapter a typical receiver switchboard and a typical transmitter switchboard are treated. These switchboards are replacing the old-style plugboards (more commonly known as patch panels).

Simplified diagrams, showing how switchboards are connected to receivers, transmitters, radiophone units, and accessory equipment, are included. For completeness, block diagrams of the switching circuits between Radio Central, Radio II, and Radio III in one type of installation, are also included.

Another portion of the chapter includes a brief treatment of antenna switching systems.

Finally, the more complex radar data switching system is described with the aid of block diagrams and simplified switching circuits.

The Electronics Technician should bear in mind that in many of the switching systems described there are a large number of possible circuit arrangements. In this chapter a great deal of simplification is employed; and, in general, only the less complex arrangements are included. However, enough basic information is included to give the prospective ET 3 the necessary background for further study in the subject.

TYPES OF SWITCHES

Some of the more common types of switches used with electronic equipment are illustrated and described briefly in this portion of the chapter. There are many variations of each type of switch; however, only a few representative examples are included here. For additional information the *Catalog of Navy Material*, class 17, may be consulted.

Toggle Switches

Representative examples of toggle switches are shown in figure 9-1. In part A is shown a single-pole, single-throw (SPST) toggle switch, rated at 20 v and 20 amperes, and having 2 screw terminals. The schematic diagram is shown beneath the switch. This switch is used to open or close an electric circuit.

Part B shows a single-pole, double-throw (SPDT) switch, rated at 250 v and 1 ampere, and having 3 screw

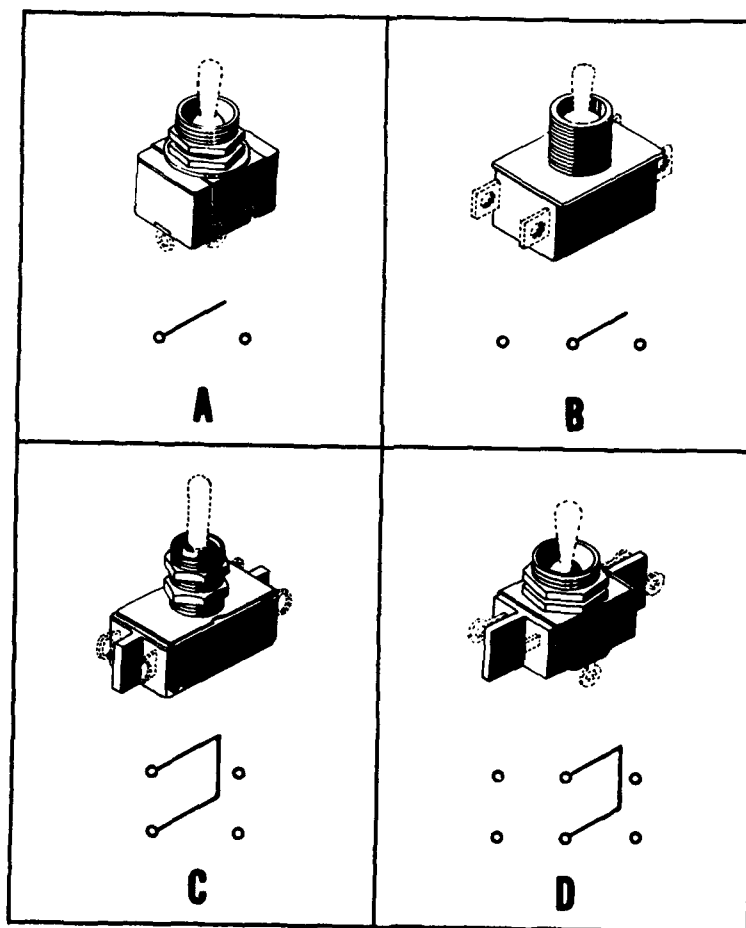


Figure 9-1.—Toggle switches.

terminals. One of the uses of this switch is to turn a circuit on at one place and to turn it off at another place. It is sometimes called a 3-way switch.

A double-pole, single-throw (DPST) switch is shown in part C. It has 4 solder terminals and is rated at 250 v and 1 ampere.

A double-pole, double-throw (DPDT) switch is shown

in part D. It has 6 solder terminals and is rated at 125 v and 3 amperes.

The following types of switches are also used: 3-pole, single-throw (3PST); 3-pole, double-throw (3PDT); 4-pole, single-throw (4PST); and 4-pole, double-throw (4PDT) switches. The voltage ratings range from 20 v to 600 v, and the amperage ratings range from 1 ampere to 30 amperes.

Push Switches

The contact arrangement of push switches is shown in figure 9-2, A, and an example of a typical contact arrangement is shown in part B. The type and quantity of each basic form used to make up the contact assembly are determined from part A. Part B illustrates how the

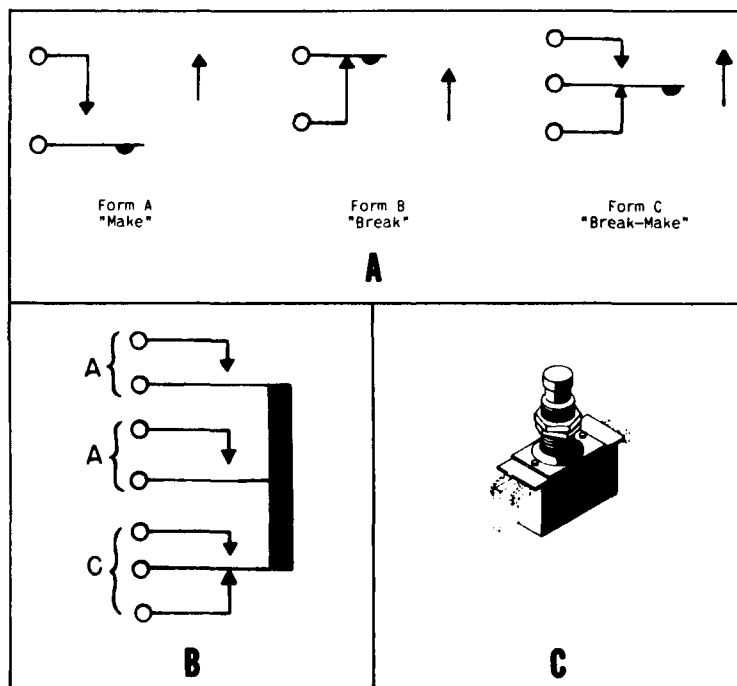


Figure 9-2.—Push switches.

illustrations in part A may be used in a practical switch assembly. Thus, in part B the switch contains a total of three separate basic forms: two forms A, and one form C. The contact arrangement for this switch is therefore 2A1C. Obviously, there are many possible contact arrangements. For example, 1A, 1A1A, 1A1B, 2A, 2A1B, 1B, etc., are common.

A push switch employing a 2A contact arrangement is shown in figure 9-2, C. It is rated at 250 v and 3 amperes.

Wafer Lever Switches

A wafer lever switch is shown in figure 9-3. It is a double-pole, triple-throw (DP3T) type of switch rated at 110 v and 0.150 ampere. A schematic diagram is shown beneath the switch. It locks in position and is

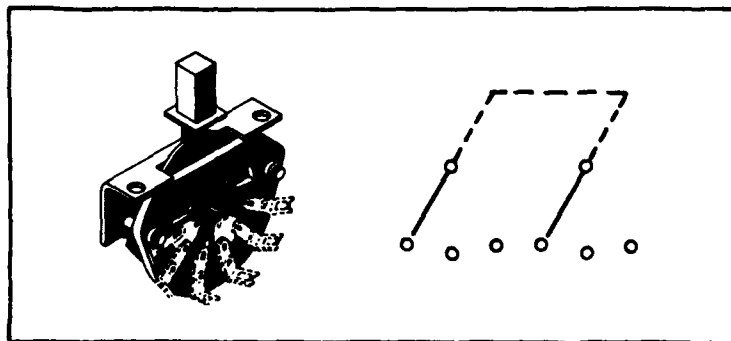


Figure 9-3.—Wafer lever switch.

nonshorting; that is, one circuit is opened before the next circuit is closed. In switches of this type the action may be locking or momentary, and the contacts may be shorting (for example, one circuit remains closed until an instant after the next circuit is closed; then it is opened) or nonshorting. Other contact arrangements are DPDT, 4PDT, and 6P3T.

Lever Pileup Switches

One type of lever pileup switch is shown in figure 9-4, A. As may be seen in the schematic illustration, it is a 2-position switch. There are 9 solder terminals, and the switch is rated at 48 v and 1 ampere. In the schematic diagrams the downstroke of the switch is designated by 2, the upstroke by 1, and OFF position by zero. The No. 2 position is momentary.

A 3-position, 21-terminal switch is shown in part B, and a 2-position, 9-terminal switch is shown in part C.

Nearly a hundred types of lever pileup switches are available for various uses. They may have up to 75 terminals, and the associated switch contacts may be arranged in various ways.

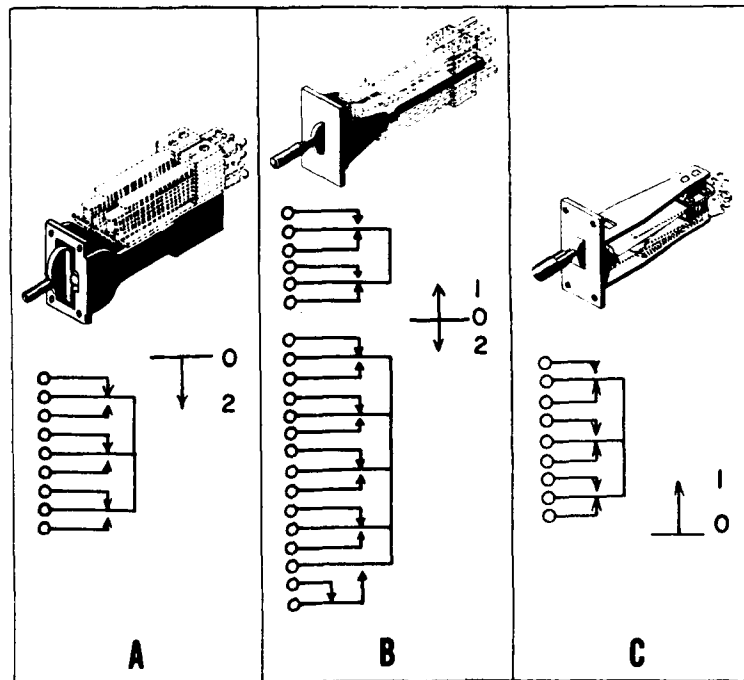


Figure 9-4.—Lever pileup switches.

In addition to lever pileup switches, rotary pileup switches (activated by a rotary motion) and the jack-type pileup switches (activated by the thrust of the plug) are used in automatic telephone systems.

Knife Switches

Knife switches are essentially power switches; they will handle up to 500 amperes and up to 15,000 v. Figure 9-5, A, shows a double-pole, single-throw (DPST) knife switch rated at 125 v and 30 amperes.

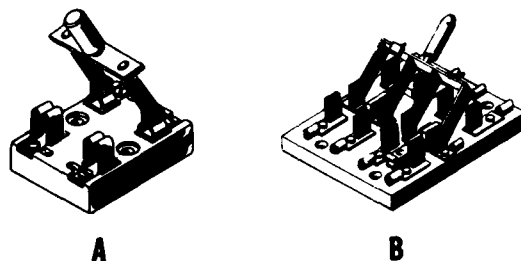


Figure 9-5.—Knife switches.

Part B shows a 4-pole, double-throw (4PDT) knife switch rated at 125 v and 100 amperes.

Thermostatic Switches

Thermostatic switches are designed to either open or close when the temperature reaches a certain value. A large number of different types of thermostatic switches are used by the Navy to control the temperatures in compartments and rooms, to regulate dampers, to maintain constant crystal temperatures in some radio transmitters; they are also used in many other heating and cooling applications. The *Catalog of Navy Material* lists nearly 50 different types of thermostatic switches. Switches of a given type may have different contact arrangements, be operated at different temperature ranges, or have different voltage or current ratings.

A large number of thermostatic switches employ a bimetallic strip as the active element. The basic operating principle is illustrated in figure 9-6, A. One side of the bimetallic strip is brass and the other side is iron (other metals may also be used) welded to the brass. When the strip is heated, the brass expands more than the iron and the strip bends downward to open the switch contacts. Thus, power is removed from the load when a certain temperature is reached. Of course, the switch action may be reversed so that power is applied to the load when a certain temperature is exceeded. Although not shown in the figure, various refinements such as adjustments and snap action may be incorporated in the switch.

In mercury thermostatic switches the mercury itself completes the circuit as it expands upward between two metallic contacts. The basic operating principle is illustrated in figure 9-6, B. When the temperature decreases, the mercury contracts and opens the circuit.

The principle of operation of gas thermostatic switches is illustrated in figure 9-6, C. When the gas is heated, it expands the bellows and closes the switch; when it is cooled, it contracts the bellows and opens the switch.

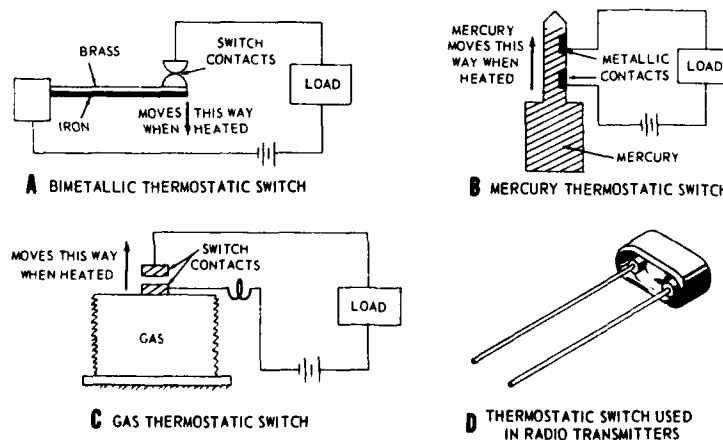


Figure 9-6.—Thermostatic switches.

In each of the illustrations, only the basic principle of operation is shown. Certain refinements are generally added.

Figure 9-6, D, shows the thermostatic switch used in the crystal oven of one type of radio transmitter. The contact arrangement is for a single-pole, single-throw operation, and the switch is rated at 115 v and 0.75 ampere. The operating temperature is 170.6° F to 179.6° F, the temperature differential being 9°.

Rotary Pileup Switches

Rotary pileup switches are so constructed that they open and/or close one or more electrical circuits; the contacts are arranged in a leaf, or pileup, fashion and they are actuated by a rotary motion.

One type of rotary pileup switch is illustrated in figure 9-7. As may be seen in the figure, there are six terminals. When the armature is moved upward by the rotary motion of the switch knob, two circuits are opened and two other circuits are closed.

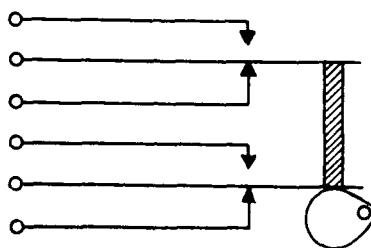


Figure 9-7.—Rotary pileup switch.

This type of switch has numerous applications in low-voltage signal circuits.

Rotary Selector Switches

Rotary selector switches are used in a large number of electronic equipments. They are commonly made up of a number of sections, or decks, the number used depending on the complexity of the switching functions.

One deck of a rotary selector switch is shown in figure 9-8. The code letters are also included at the leads extending from the various terminals. Short clips are indicated by the letter, X. Dummy lugs are indicated by the letter, D. Nonshorting rotary teeth (or blades) are indicated by crossed lines. The word, nonshorting, means that the width of the rotor tooth is less than the distance between adjacent contact clips. This means that as the rotor is turned, one circuit will be opened before the next one is closed. The shorting type is shown without the crossed lines. In this case the rotary tooth is wider than the distance between adjacent clips, and therefore as the rotor is turned, one circuit is closed

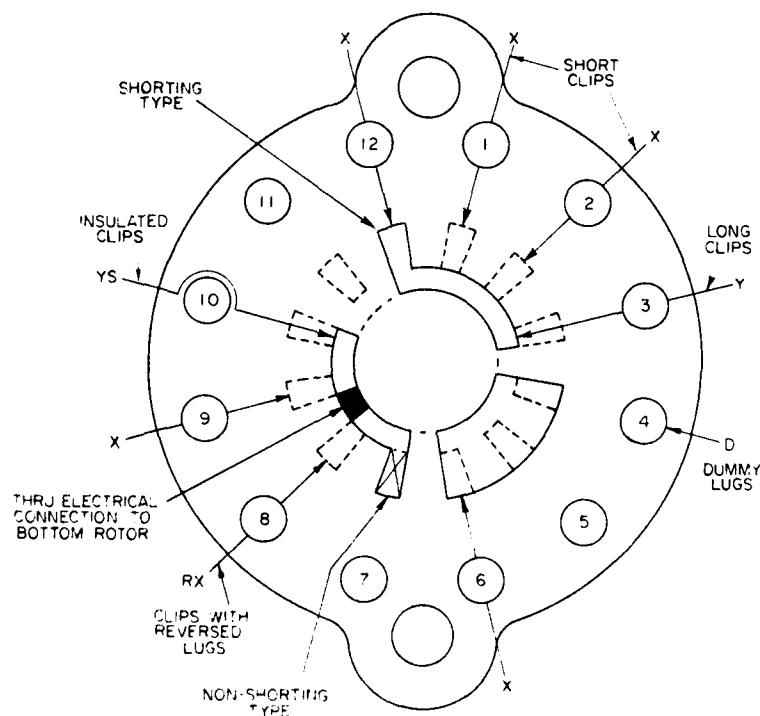


Figure 9-8.—Deck of rotary selector switch, showing contact arrangement and code letters.

before the preceding one is opened. Clips that are insulated from their associated lugs are indicated by the letter, S; long clips thus insulated are indicated by the letters, YS. When a clip is thus insulated, the lug may be connected to a clip on the reverse side. A through electrical connection is indicated when the rotor (or a portion of it) is shown in black. This means that the section of the rotor so marked in the figure is connected through to a bottom rotor, not shown.

There are hundreds of possible contact arrangements. The technician will have to find his way through whichever arrangement is used in the particular piece of equipment on which he is working. Some typical arrangements are used in the switching circuits covered later in this chapter.

Telephone-Type Jacks

The contact assemblies on telephone-type jacks are divided into two categories: (1) the plug contact assembly and (2) the pileup contact assembly. The plug contact assembly includes the contact springs (and all others making electrical connection with them) that make direct contact with the plug when it is inserted. Both categories are illustrated in figure 9-9, A.

Figure 9-9, C, illustrates the common varieties of plug contact assemblies used on jacks and indicates the code designation for each.

The proper contact arrangement for jacks is determined with the aid of figure 9-9, B. The plug contact assembly (J7) is distinguished from the pileup contact assembly (B), and the code designation for the plug contact assembly is determined from figure 9-9, C. The type and quantity of each basic form used to make up the pileup contact assembly are determined. In the case of part B of the figure the proper contact arrangement designation for the jack is "J7-1B."

Jacks are used in plug panels, teletype panels, phone units, and in many other applications.

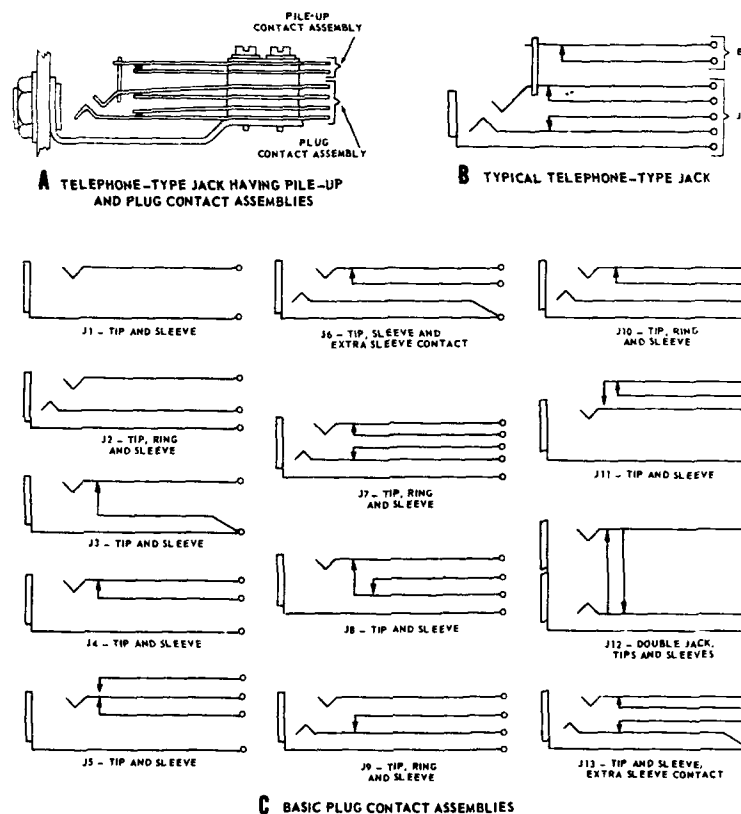


Figure 9-9.—Telephone-type jacks.

RADIO RECEIVER BAND-SWITCHING CIRCUITS

Band-switching circuits in radio receivers commonly employ rotary selector switches. In order to trace the various circuits through these switches, it is necessary to pay careful attention to the schematic diagrams. The band-switching circuit of the RCK receiver is relatively easy to follow, and is included in figure 9-10.

The 4-position switch, *S101B*, in the input grid circuit of the oscillator tube, *V105*, selects 1 of 4 crystals. An additional set of contacts on *S101B* provides for ground-

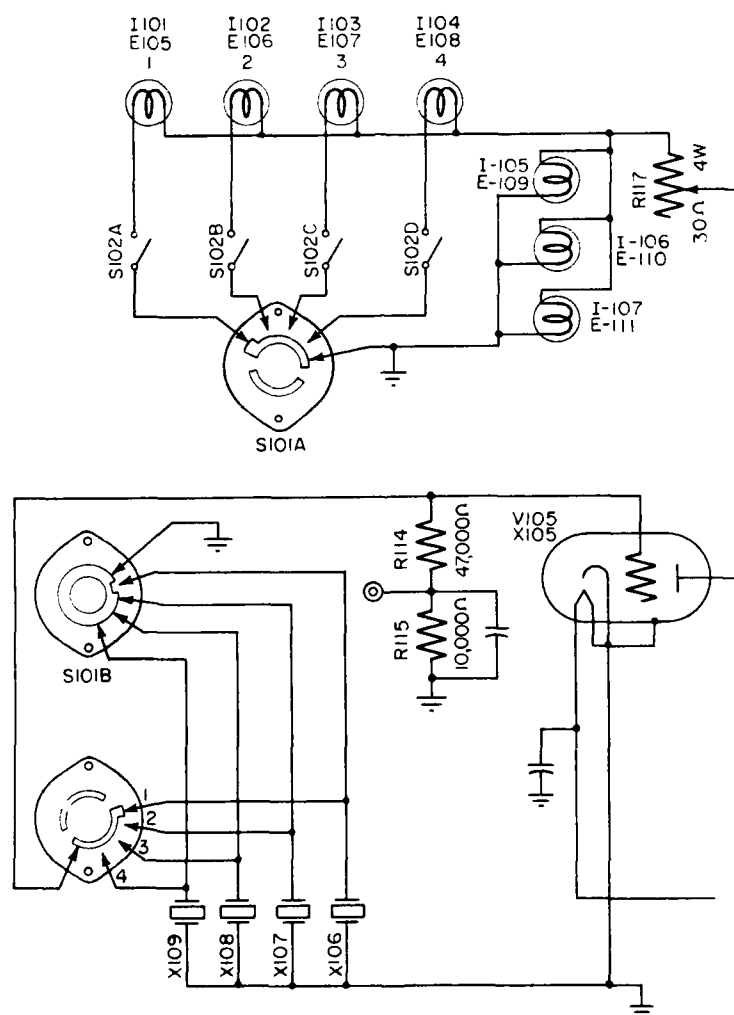
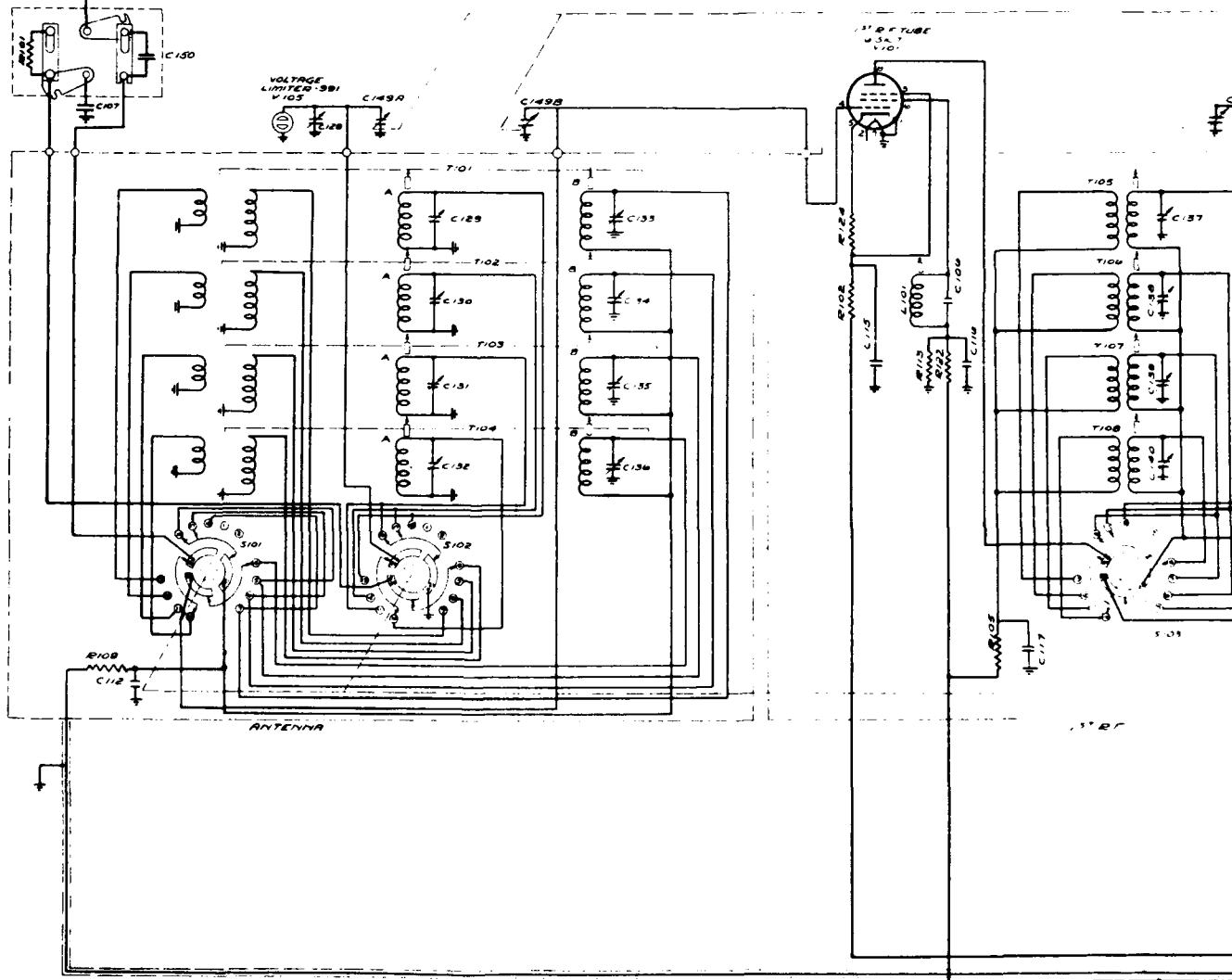


Figure 9-10.—Band-switching circuit of the RCK receiver.

ILLUSTRATIONS



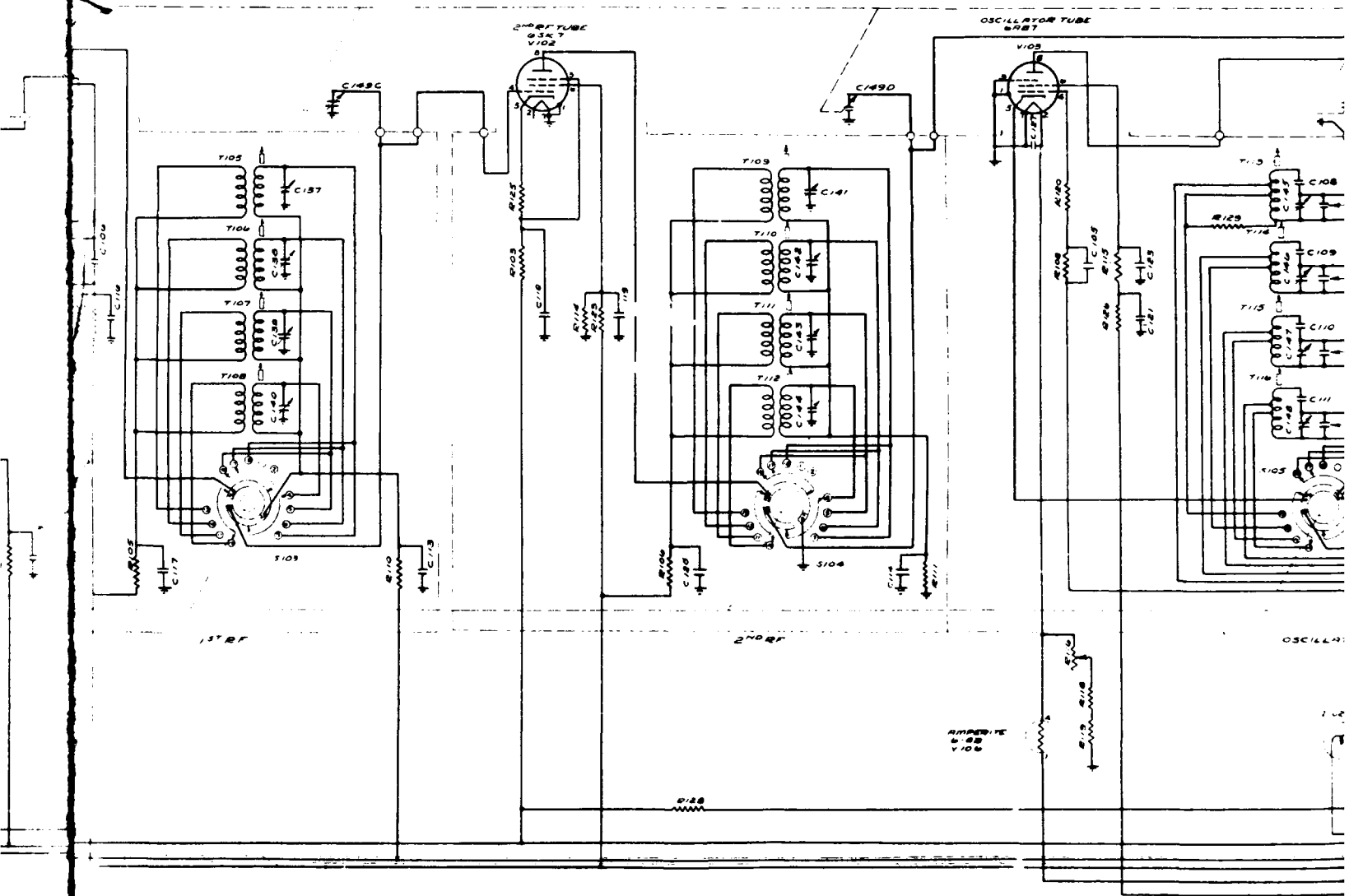
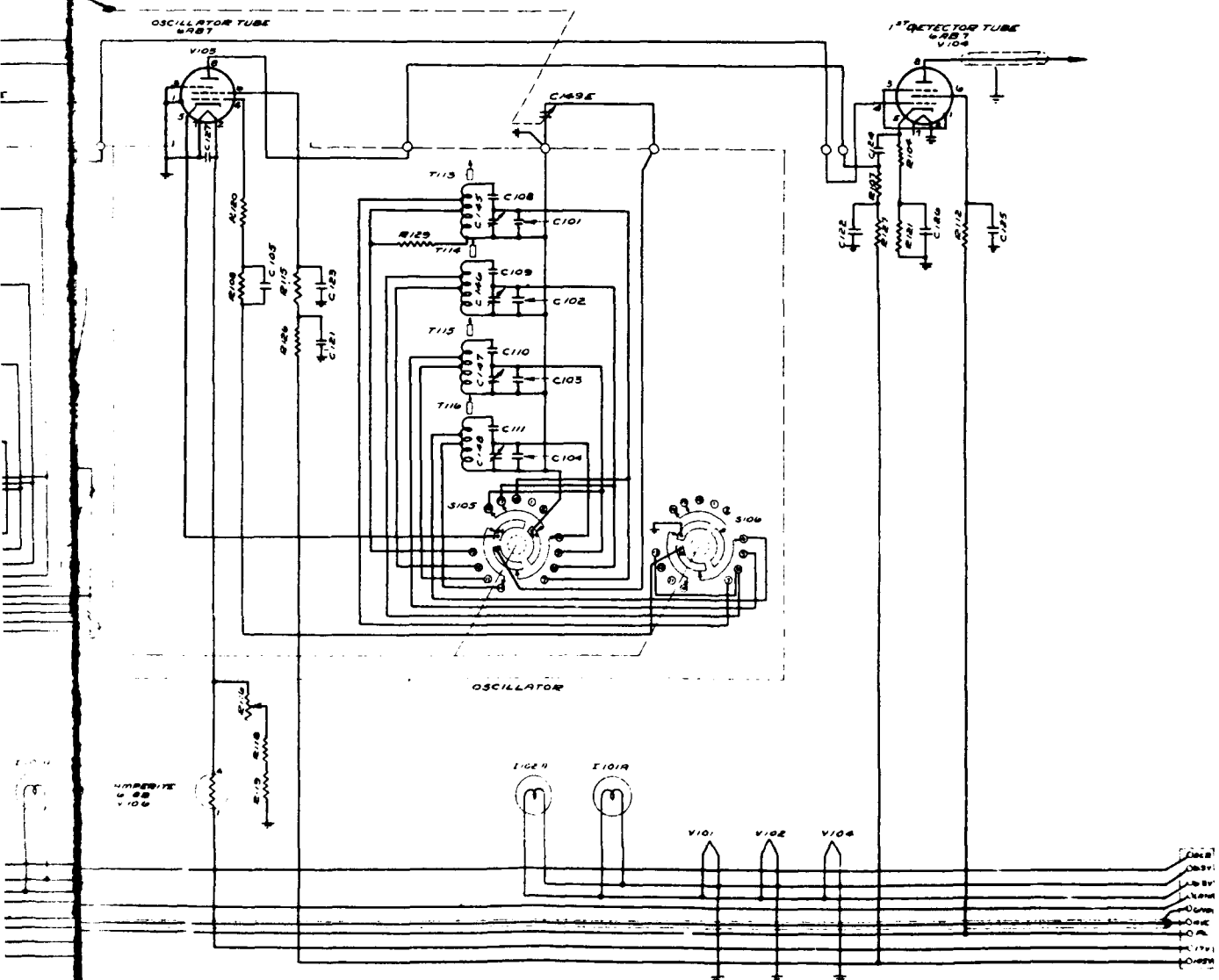


Figure 9-11.—Schematic diagram of preselector unit of the RBB receiver.



ing the three crystals that are not in use at any given time. The operating crystal is connected directly to the grid of V105. In the switch position, 1, shown in the figure, crystal X106 is connected between the grid of V105 and ground; the other three crystals are shorted to ground. In position 2, X107 is connected to the grid, and crystals X106, X108, and X109 are grounded.

The 4-position switch, S101A, mounted on the same shaft as crystal-selector switch S101B, connects filament potential to the proper channel-indicating lamp through S102. In the position shown in the figure, S101A provides circuit continuity for lamp (1); the other three lamps are open at the switch contacts.

Rheostat R117 enables the operator to control the brilliancy of the channel-indicator lamp and the dial lamps, E109, E110, and E111.

The band-switching circuits of the RBB receiver are somewhat more involved than those of the RCK receiver. However, careful circuit tracing through the preselector unit of this receiver will enable one to follow the signal path. A schematic diagram of the preselector unit is given in figure 9-11.

The input circuit from the antenna or transmission line is adjusted by means of the links to accommodate the various methods of feed. When the RBB receiver is connected for transmission-line operation, C107 is used to shunt the unused antenna input system in order to maintain alignment of the circuit. For common operation of more than one RBB equipment on the same antenna, decoupling resistor R101 is inserted in series with the input to each equipment. For operation of the RBB equipment in common with other low-frequency receivers for a transmission-line input, decoupling capacitor C150 is employed.

The setting of the links for the operating condition connects the proper set of coupling coils for antenna or transmission-line input. These coupling coils are part of transformers T101, T102, T103, and T104. They make

up the two vertical rows of coils at the extreme left in the diagram.

For transmission-line input, the coupling system for this equipment consists of separate coils (vertical row at the extreme left in the figure) for each of the four bands. The coils are designed to match the receiver input to an average of 70 ohms resistance over each frequency band. The coil for a particular band is selected by a section of band switch *S101*.

For antenna input, the coupling coils (second vertical row from extreme left in figure) are designed to resonate in conjunction with the antenna at a frequency below the low limit of the band being received. They are also designed to match the receiver input to impedances varying from approximately 300 ohms resistance at the high-frequency end of the equipment range to 1500 ohms reactance at the low-frequency end.

The input circuit is coupled to the first r-f tube through two tuned circuits for each band. These two circuits consist of coils "A" and "B" and the associated trimmer capacitors of transformers *T101* to *T104*. An additional trimmer capacitor, *C128*, is employed for the first circuit. This capacitor permits the circuit to be tuned to resonance for antennas varying from 80 to 500 mmf capacity.

The voltage limiter, *V105*, protects the input circuit from damage by high r-f voltages induced by local transmitters. Ionization in this tube bypasses excessive r-f currents to ground.

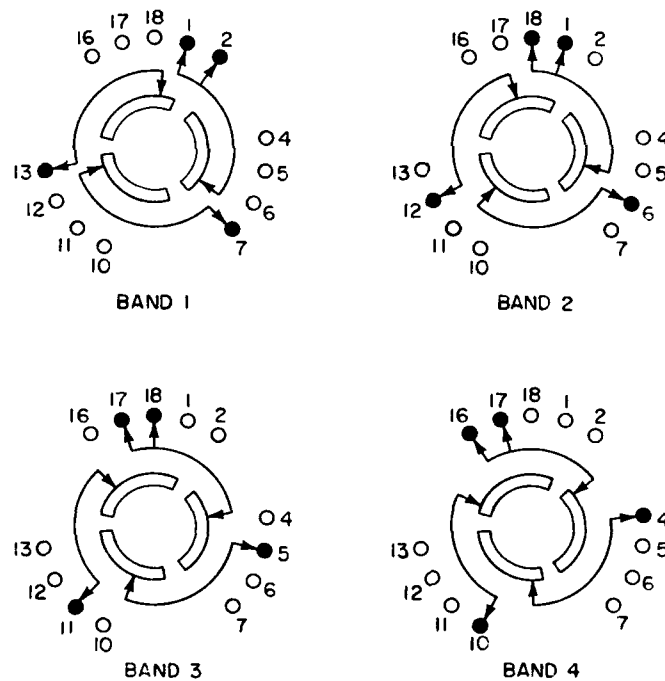
The four tuning bands are selected by the ganged switches, *S101* to *S105*. These switches not only select the appropriate transformers (*T101* to *T116*), but also short out certain portions of those unused circuits that would otherwise introduce spurious resonance effects. In the switch position shown in the figure, the RBB receiver operates on band No. 4.

These switches are 3-pole, 4-position switches employing shorting type contacts and detent action. The positions of the moving parts of the switch are shown properly oriented with respect to the stationary num-

bered terminals and also with respect to the 3 stationary poles (sectors) for each of the 4 bands (fig. 9-12, A).

The 5-section capacitor, C149, serves as the tuning capacitor for all bands.

To make circuit tracing easier, the transformer and switch contacts associated with each band are listed in figure 9-12, B.



A SCHEMATIC DIAGRAM

FREQUENCY (mc)	BAND	TRANSFORMERS	SWITCH CONTACTS CLOSED
0.50 - 0.84	1	T101, T105, T109, T113	1, 2, 7, 13
0.84 - 1.41	2	T102, T106, T110, T114	1, 6, 12, 18
1.41 - 2.37	3	T103, T107, T111, T115	5, 11, 17, 18
2.37 - 4.00	4	T104, T108, T112, T116	4, 10, 16, 17

B TABLE

Figure 9-12.—The 3-pole, 4-position switch used in RBB receiver.

As an exercise in signal tracing, assume that the receiver is being fed from a transmission line and that the switches are connected for band-four operation.

The signal passes through the link that shorts C150 (fig. 9-11), through S101 contact (10), and through the extreme left-hand coil of T104 to ground. The signal is coupled by mutual induction to T104A and applied across C149A through S102 contact (10).

The signal voltage developed in T104A is coupled by mutual induction to T104B. From the top of T104B the signal voltage is applied through S101 contact (4) to the grid of V101. The return path of the r-f signal is from the bottom of T104B through C112 to ground.

The signal voltages are amplified in the plate circuit of V101 and applied to the primary (left coil) of T108 through S103 contact (10), and returned to ground through C117. The signal voltages in the primary of T108 are inductively coupled to the secondary and fed through S103 contact (4) and C113 to the input of V102.

The signal voltage is amplified in the plate circuit of V102 and coupled to the primary (left coil) of T112 through S104 contact (10) and C120. These signals are inductively coupled to the secondary (right coil) and fed to the grid of V104 through S104 contact (4), and returned to ground by way of C114.

The oscillator signals are generated in V103 and the circuits of T116. The top of C148 and the top of C149E are connected together through S105 contact (4). The cathode of V10C is connected to the lower tap on T116 through S105 contact (10), and the grid of V103 is connected to the upper tap on T116 through S106 contact (4).

It should be noted that S102 contacts (16) and (17) provide a short to ground for T103A and T102A, respectively. Also, S104 contacts (16) and (17) provide a short to ground for T111 and T110, respectively. The grounding of these unused circuits (during band-four operation) avoids spurious resonance effects.

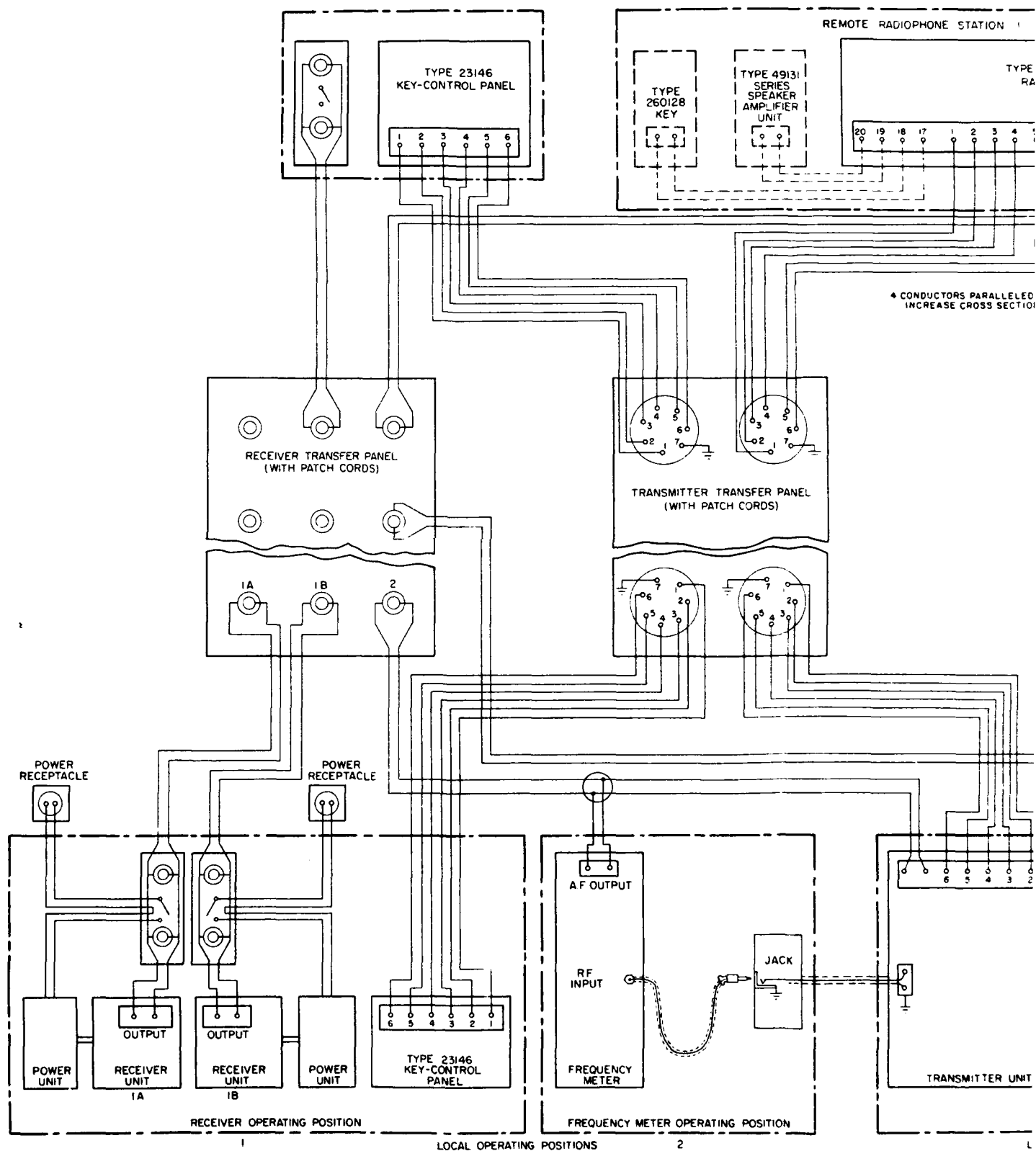
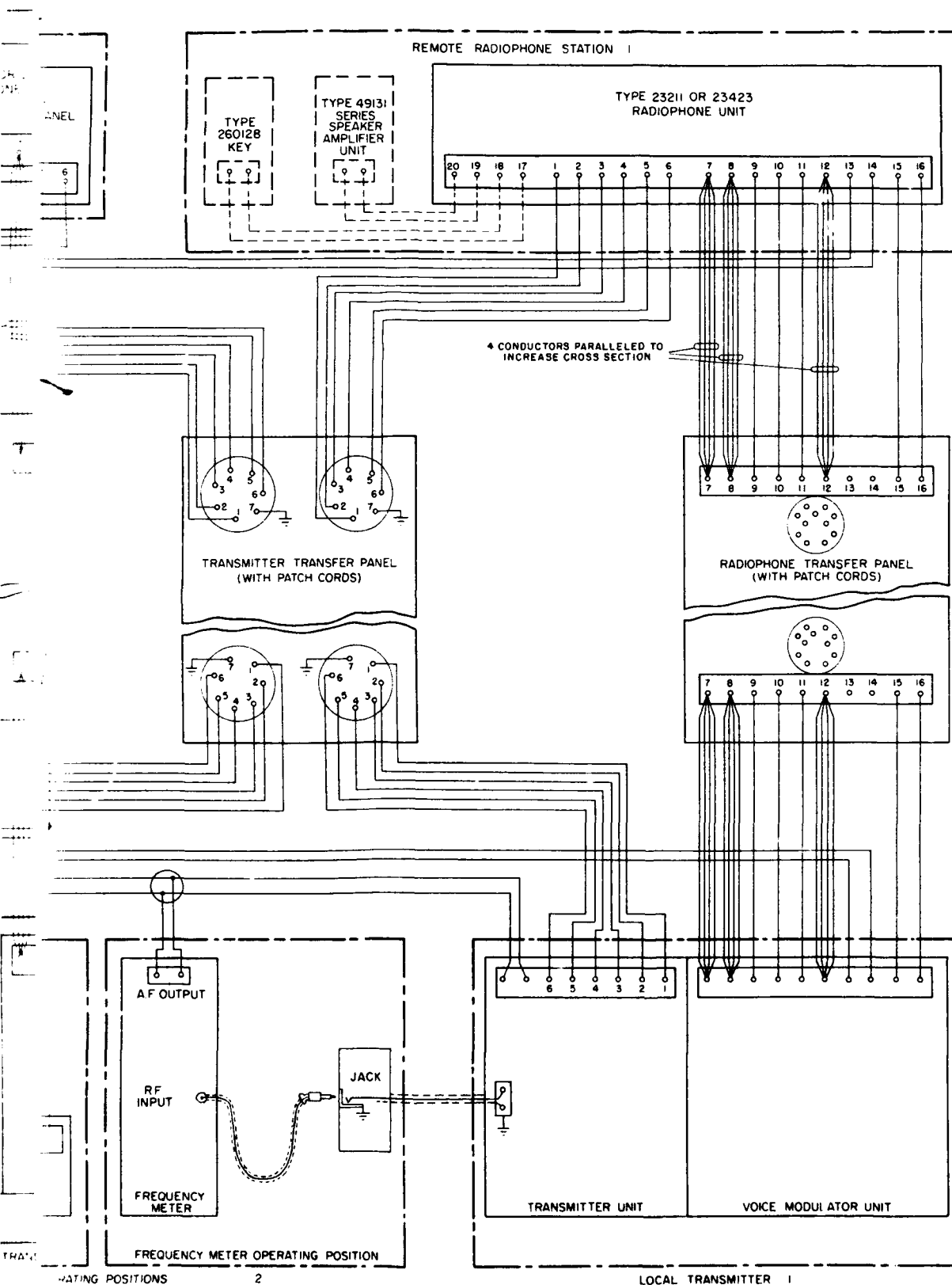


Figure 9-13.—Radio remote-control system showing interconnecting wiring.



3.—Radio remote-control system showing interconnecting wiring.

The same type of circuit-tracing procedure may be followed for each of the remaining three bands.

RADIO RECEIVER AND TRANSMITTER REMOTE-CONTROL TRANSFER SWITCHBOARDS

Radio remote-control transfer plug panels have become too cumbersome to be used in the vastly expanded shipboard radio installations on modern Navy vessels. Therefore, control panels utilizing switches instead of plugs and patchboards are being installed in new construction and in conversion jobs. Two unit-constructed panels (one for receivers and one for transmitters) now provide all of the facilities that were available in three types of plug panels (the receiver transfer panel, the transmitter transfer panel, and the radiophone transfer panel), and in addition afford greater flexibility in the remote-control system. The old-style radio remote-control system, with interconnecting wiring system, is shown schematically in figure 9-13.

Receiver Transfer Switchboard, Type SB-82/SRR, and Transmitter Transfer Switchboard, Type SB-83/SRT, are both highly flexible in the method of operation. These two types are described under separate headings.

Receiver Transfer Switchboard

An external view of the Receiver Transfer Switchboard, Type SB-82/SRR, is shown in figure 9-14. A simplified schematic diagram of a portion of the internal switching arrangement is shown in figure 9-15.

The receiver switchboard has 5 vertical rows of 10 double-pole, single-throw (ON-OFF) switches that are continuously rotatable in either direction. However, for simplicity, the latter feature is not shown in the simplified diagram of figure 9-15. As may be seen in the figure, one side of each switch within a vertical row is wired in parallel with the same sides of the other nine switches within that row. Similarly, the other

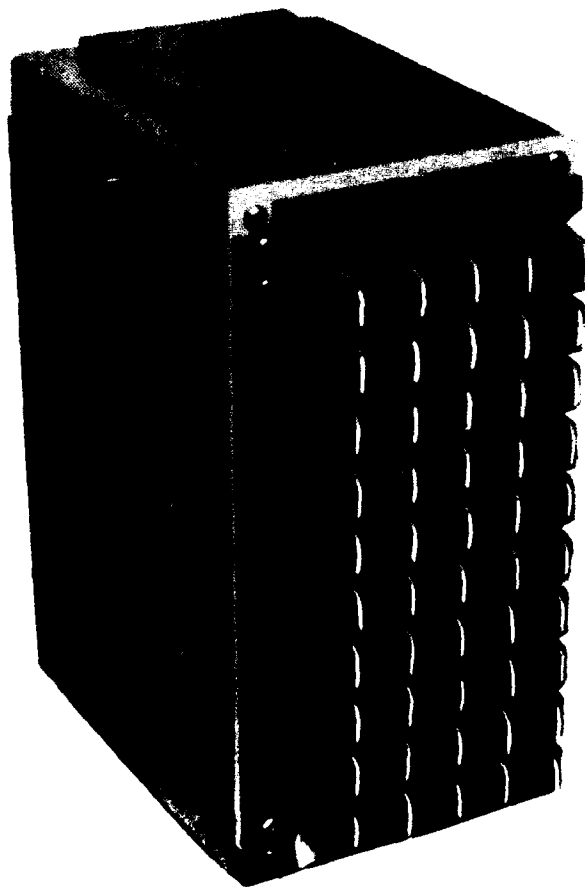


Figure 9-14.—External view of the Receiver Transfer Switchboard, Type SB-82/SRR.

side of each switch is wired in parallel horizontally with the corresponding sides of each of the other four switches in a horizontal row. This method of connecting the switches gives rise to the term CROSS-MAT PARALLELING, and permits a high degree of flexibility.

It may be seen in the figure that the audio output from the receiving equipments, connected to the five vertical rows of switches, may be fed to any or all of the remote stations by closing the proper switch or switches. For

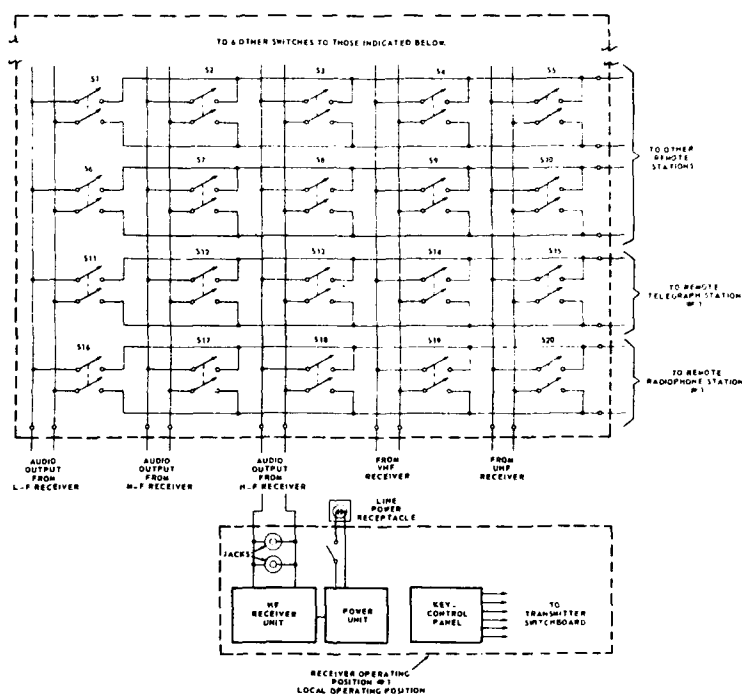


Figure 9-15.—Simplified schematic diagram of the Receiver Transfer Switchboard, Type SB-82/SRR.

example, the audio output from the L-F receiver may be fed to remote radiophone station No. 1 by closing switch 16; it may be fed to all of the remote stations by closing all of the switches in the left-hand vertical column.

Shielded leads are used for the audio circuits.

The knob of each switch is marked with a heavy white line to provide visual indication of the communication setup. In general, there are more remote stations than there are receivers, and therefore the switchboards are normally mounted in a vertical position (as in fig. 9-14). This arrangement permits the outputs from 5 receivers to be fed to the 5 vertical rows and up to 10 remote stations to be fed from the 10 horizontal rows of switches.

Switchboards are furnished with the knobs in the OFF position when the white line is vertical.

If it becomes necessary to employ a system where there are 10 receivers and 5 remote stations, the switchboard may be mounted in a horizontal position and each switch knob rotated 90° with respect to the shaft. All shafts have two flat sides for set screws so that this change can be made if desired. The purpose of rotating the switch knobs with respect to the shaft is to standardize the setup so that the switches will be in the OFF position when the white line is vertical. To further standardize all installations, receivers are always connected to the vertical rows of switches, and remote stations are always connected to the horizontal rows of switches after the orientation (vertical or horizontal) of the switchboard has been determined.

It should be noted that only the receiver audio output circuit is connected to the switchboard. This is true also of the receiver transfer plug panel used in earlier installations. Transmitter transfer switchboards, however, handle several other types of circuits in addition to audio circuits.

Transmitter Transfer Switchboard

An external view of the Transmitter Transfer Switchboard, Type SB-83/SRT, is shown in figure 9-16. A simplified schematic diagram of a portion of the internal switching arrangement is shown in figure 9-17. The same cross-mat parallel wiring of the switches is employed as is employed in the receiver switchboard. The method of mounting and indication are also the same.

The transmitter switchboard has 5 vertical rows of ten 12-pole, single-throw switches continuously rotatable in either direction (this feature is not shown in the figure).

As has been stated, the receiver switch panel carries the receiver audio output circuit only; in this respect, it is similar to the older receiver transfer plug panel. In the transmitter switch panel, however, each switch

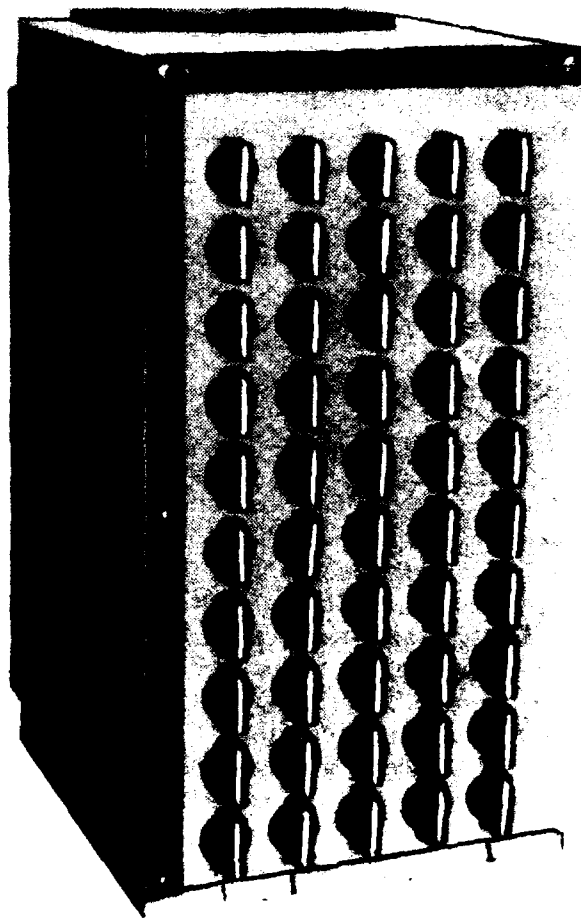


Figure 9-16.—External view of the Transmitter Transfer Switchboard, Type SB-83/SRT.

carries the START-STOP INDICATOR, and KEYING circuits (6 conductors), as in the transmitter transfer plug panel. In addition, the transmitter switch panel carries the 12-VOLT D-C MICROPHONE, CARRIER CONTROL, and CARRIER INDICATOR CIRCUITS that were formerly carried in the radiophone transfer plug panel. Thus, the transmitter switch panel takes the place of two transfer plug

panels (the transmitter plug panel and radiophone transfer plug panel).

As an example of the operation of the switchboard, assume that the local transmitter control is to be transferred to remote radiophone No. 1. This is accomplished by closing switch *S3*. A mechanical interlock arrangement between *S3* and *S4* prevents the closure of *S4* when *S3* is closed. This arrangement prevents two or more transmitters from feeding a single radiophone station at the same time.

Installation

Although the ET is primarily interested in repair, it is helpful in certain instances if he understands the method of installation and the problems involved. This is especially true of transfer switchboards.

All external wiring is brought into both types of transfer panels through terminal tubes and is connected to a terminal block located at the back of the cabinet. The panels themselves are designed as units, and as many units as are required for a particular installation may be mounted together on a common bracket. To make interconnections easier for group installations, the Bureau of Ships provides two types of cable harness for each type of panel, one for vertical and one for horizontal interconnection.

The following installation procedures are condensed from the *Electronics Installation Bulletin*, NavShips 900,002A.

The number of panels of each type required for a particular installation should be determined by judicious choice of equipments and remote stations. Proper grouping of equipments and remote stations will reduce considerably the number of panels required in the larger vessels. For example, where a vessel requires three radiophone units (RPU's) in the pilot house, these may be grouped as shown in figure 9-18. In this illustration it is assumed that the vessel's allowance is three each, LF, MF, HF, and UHF transmitters with appropriate

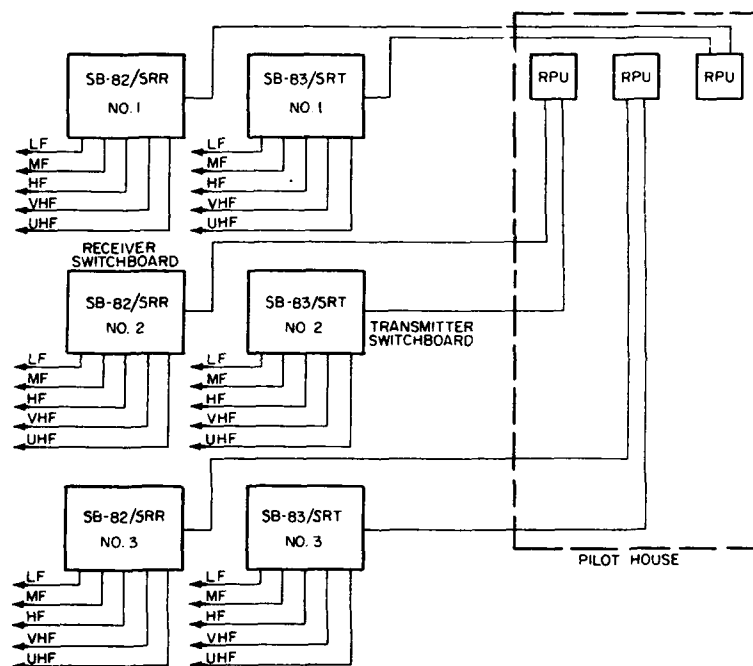


Figure 9-18.—Grouping of equipments and remote stations on transfer switchboards.

receivers. With this grouping, the pilot house can select any of the 12 transmitters or receivers aboard ship for immediate use. The Bureau of Ships provides sketches showing the desired grouping. For installations on small vessels, such groupings will not be required.

The fabrication of grouped panels is accomplished in the shop (at the yard). The proper number of panels are bolted to an appropriate frame and the panels electrically wired together, using the cable harness that is furnished.

The proper operation of these panels is dependent upon good soldered connections, and extreme care should be exercised in making these connections.

Whenever possible, at least one spare vertical and one spare horizontal row of switches in both the receiver and transmitter switchboard installation are provided to allow for an increase in the number of transmitters and receivers at some future time, or for some other switching function.

Maintenance Problems Resulting From Improper Installation

The following information obtained from *Electronics Information Bulletin*, No. 416, indicates some of the possible causes for crosstalk in the Radio Receiver Transfer Switchboard, Type SB-82/SRR. Although not mentioned in this issue of EIB, it is possible that certain malfunctions of the SB-83/SRT may be due to similar causes.

Based on an engineer's work report describing the inspection of the SB-82/SRR at one installation, the following statements reveal certain conditions that may prevail when the equipment is not properly installed.

1. Conditions found: numerous conditions that could cause crosstalk.

2. Cause: numerous loose metal objects (such as bolts, nuts, lock washers, and solder) inside the switchboard, many of them directly across terminals; knobs incorrectly mounted, or missing; and no cable clamps were used for external cables coming into the panel.

3. Corrective measures: all vertical and horizontal rows of switches on this panel were checked for grounds and shorts between switch rows running in either direction. All metal parts (such as loose nuts, bolts, washers, and solder) found in the panels were cleaned out. The knobs on the switches were readjusted, as required, to prevent shorts between adjacent circuits. The missing knobs were replaced. Different combinations were tried to see if crosstalk still persisted; none could be found.

4. Remarks: most of the troubles listed could have been prevented if the panels had been cleaned out when they were installed. Because no cable clamps were used

to bring the external cable into the panel, it is recommended that these clamps be put on as soon as possible to prevent possible fraying and future trouble. The exercise of greater care during installation of the equipment and a thorough inspection after the job is completed will reduce or eliminate the conditions reported. The use of a small drop cloth to cover the wiring mat when the front panel is open during installation should prevent solder and small parts from entering the wiring mat. Inspection of existing installations during routine maintenance may also prove of value in reducing cross-talk and malfunctioning of equipment.

Interconnections Between Transfer Switchboards

Figure 9-19 illustrates possible interconnections between the various switchboards located in Radio Central, Radio II, and Radio III.

It is easy to see how increased flexibility may be obtained by the use of the arrangement shown in the figure. This flexibility is achieved by the use of a large number of switchboards in Radio Central and a smaller number of switchboards (two for transmitters and four for receivers) in Radio II and Radio III. Most of the space on two bulkheads may be taken up by the switchboards in Radio Central.

Switch Connections Between Radiophone Unit and Transmitter

Generally, a radio transmitter connects through the transmitter transfer switchboard to a radiophone unit. However, in figure 9-20 the transmitter transfer switchboard has been omitted; and only a simplified diagram of the transmitter (Navy Model TED-8), showing the control circuits, is included.

The line power switch, S1, is a 2-pole, single-throw switch in the 60-cycle, single-phase, power-line circuit and must be closed before the equipment can be started with the start-stop switch at the transmitter or RPU.

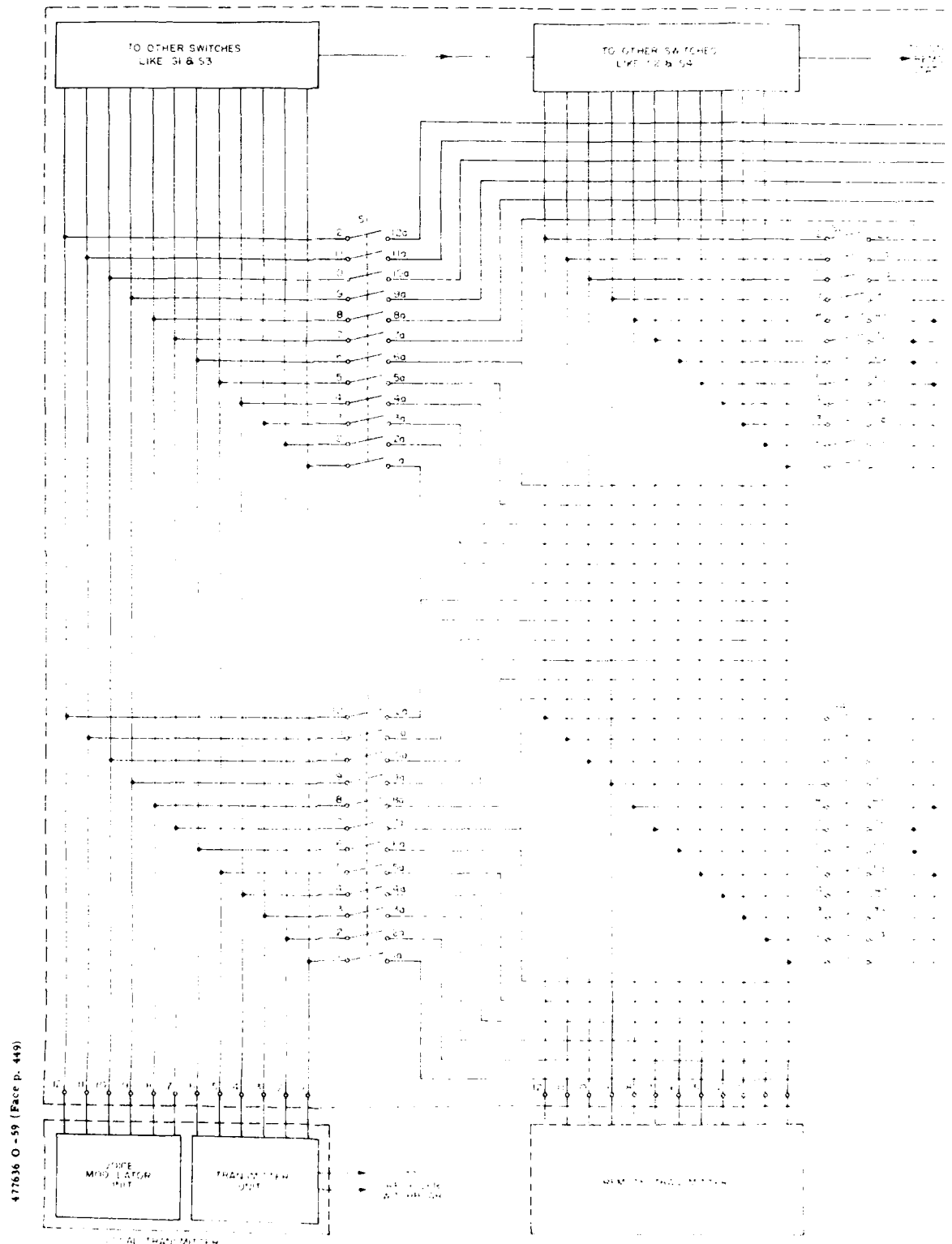


Figure 9-17.—Simplified schematic diagram of the Transmitter Transfer Switchboard, Type SB-83/SRT.

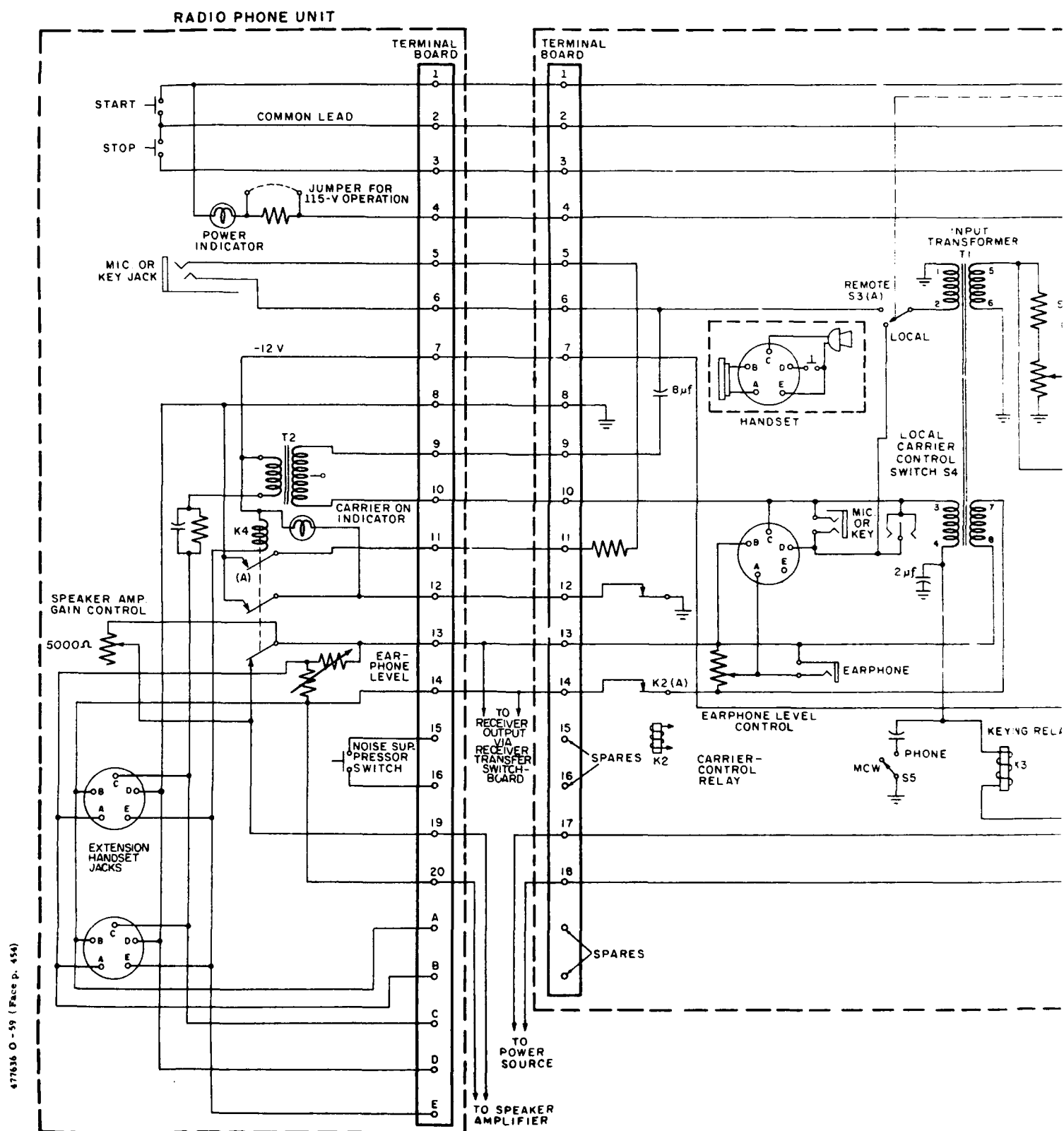
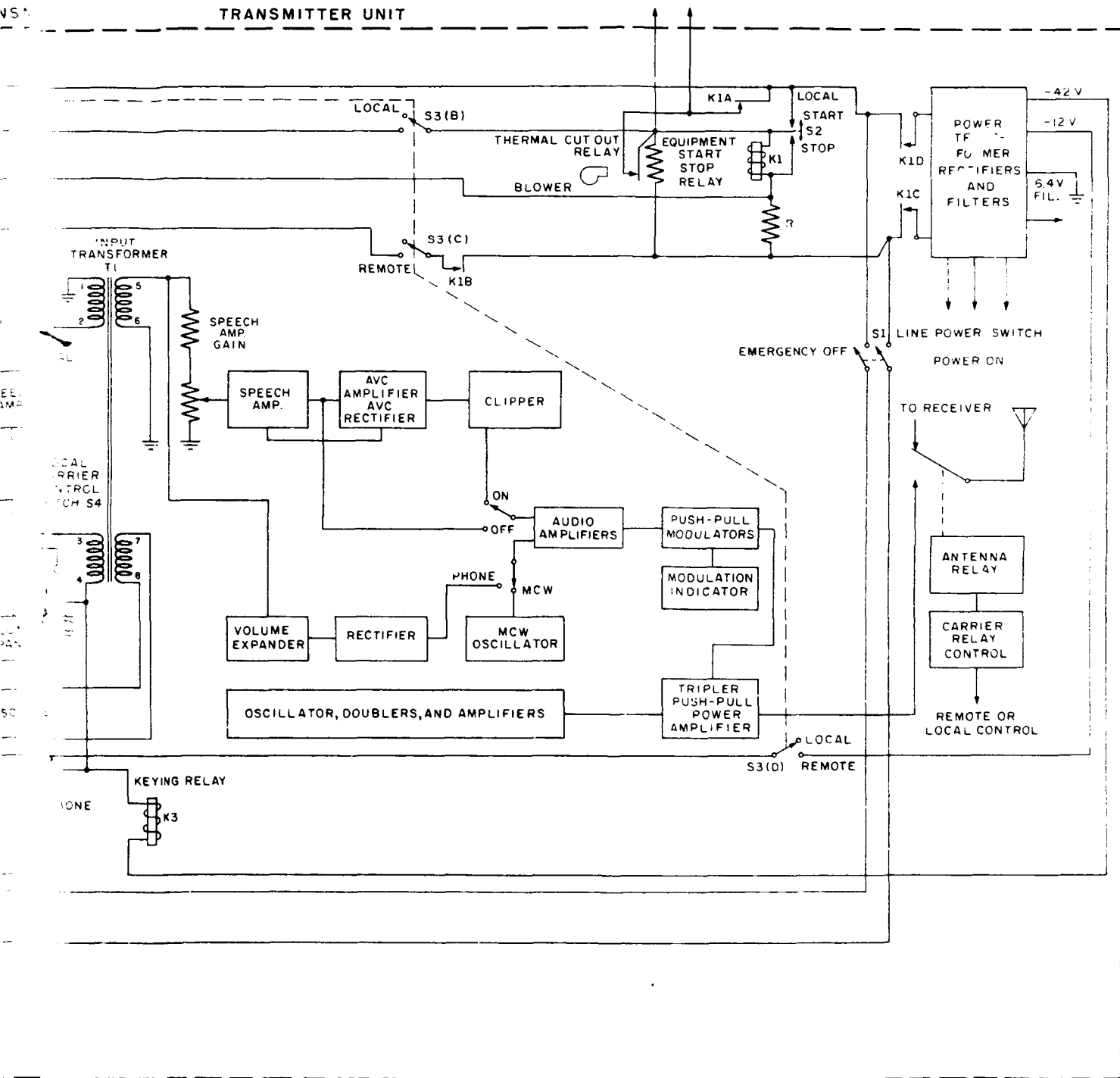


Figure 9-20.—Switch connections between radiop



In an emergency, power can be quickly removed from the entire equipment by throwing the line power switch to the EMERGENCY OFF position.

The local start-stop switch, *S2*, in the transmitter is a momentary contact (nonlocking) switch used to start or stop the equipment after *S1* has been closed. Momentary closure of *S2* on the START side energizes the equipment start-stop relay, *K1*, which locks itself in the closed position through contacts *K1A*, the thermal cutout relay contacts, and resistor *R*. Relay *K1* remains energized until its coil is shorted when *S2* is moved to the STOP position.

The local remote switch, *S3*, affords local or remote control of the operation of the transmitter. When *S3* is set to LOCAL, *S3(a)* connects the parallel combination of the local handset, the microphone jack, and the local carrier-control switch in series with the input windings of the input transformer, *T1* (winding 1-2 in series with winding 3-4), thus providing local control of the carrier. Indicating and control functions are disconnected from all remote units by operation of *S3(a)*, *S3(b)*, *S3(c)*, and *S3(d)*.

When *S3* is turned to the REMOTE position, the following sequence of events takes place:

1. Switch *S3(a)* connects the *T2* secondary and the microphone or key jack in the RPU as a parallel combination across the transmitter *T1* primary (1-2 winding in series with the 3-4 winding) and disables the local carrier-control circuits. The circuits through the handset microphone in the RPU are from the -12 v supply (terminal 7), the *T2* primary, terminals *C* and *D* of the handset extension jacks by way of the push-to-talk switch (not shown in the RPU), and ground return at terminal 8. The circuits through the handset receiver in the RPU are from terminals *A* and *B* of the handset extension jacks, the earphone-level potentiometer, and terminals 13-14 to the associated receiver via the receiver transfer switchboard (not shown).

2. Switch *S3(b)* connects the common lead to the start-stop circuit to the stop switch in the RPU.

3. Switch *S3(c)* connects one side of the 115-volt, a-c line to the RPU power indicator by way of terminal 4. The other side of the 115-volt line is always connected directly to the other side of the power indicator.

4. By means of *S3(d)*, -12 v is applied to the RPU for microphone current.

The audio monitoring circuit involves the circuits connected to terminals 5, 6, 10, 13, and 14 on the terminal board. The audio monitoring circuit enables the operator to listen to the output of the receiver when the transmitter is off and to listen to speech "sidetone" when the transmitter is being used. Circuits are provided so that this may be done either locally or at a remote location. The audio signal from the receiver is brought into terminals 13 and 14.

When the transmitter carrier is off, relay contacts *K2(a)* are closed (*K2* is deenergized), and the audio signal from the receiver is fed via *K2(a)* to the earphone-level volume control at the transmitter and to the 7-8 winding of *T1*. The receiver may be monitored locally by plugging the earphones into the earphone jack at the transmitter, because this jack is connected across a part of the earphone-level volume control.

When the transmitter carrier is on, relay *K2* is energized and contacts *K2(a)* are open. This condition disconnects the receiver audio signal circuit from the earphone-level control at the transmitter, the associated earphone jack, the receiver handset plug terminals *A* and *B*, and the 7-8 winding of *T1*. The transmitter sidetone signal is picked up by the secondary, 7-8, winding of *T1* and impressed across the earphone-level control for local monitoring. The remote monitoring signal is picked up from the control lines on which the signal is normally present during voice operation.

When *S5* is in the PHONE position and the local microphone handset press-to-talk switch is operated, keying relay *K3* is energized. This action indirectly energizes

carrier control relay *K2*, which disconnects the receiver from *T1*, as previously described. Thus, the receiver is disconnected when the transmitter carrier is on. The same action takes place in remote operation, except that relay *K4* in the RPU energizes *K3* by applying ground to terminal 3 of the 3-4 winding of *T1* via terminals 8 and 11 and contacts *K4(a)*.

TRANSMITTER-STATION ANTENNA SWITCHING

An array of switches used for connecting the several transmitters of a shore-station radio facility to the various antenna systems is shown in figure 9-21. The stacking arrangement is illustrated in figure 9-21, A. A rear view showing the arrangement of the movable and stationary blades is illustrated in figure 9-21, B. The arrangement of the switches makes for great flexibility; that is, any transmitter may be connected to any antenna. Electrical and mechanical interlock features incorporated in each switch unit and the method of wiring the array make the operation practically foolproof. Such errors as "hot switching" (the connection of more than one transmitter to the same antenna, and/or the connection of one transmitter to more than one antenna) are avoided.

Each switch (Rotary Switch SA-160/U) is a 2-section, double-pole, double-throw, air-break knife switch having a capacity of 50 kw at frequencies up to 21 mc. Each switch will carry a maximum current of 15 amperes (rms) and will withstand a maximum peak potential of 40 kv, balanced to ground. The nominal characteristic impedance of each section of the switch is 424 ohms. This switch is designed to be operated from one position to another only when the circuits are deenergized.

The primary purpose of this type of rotary switch (when used in an array) is to provide a means of selectively connecting the individual transmitters employed in a radio facility to the various antenna systems avail-

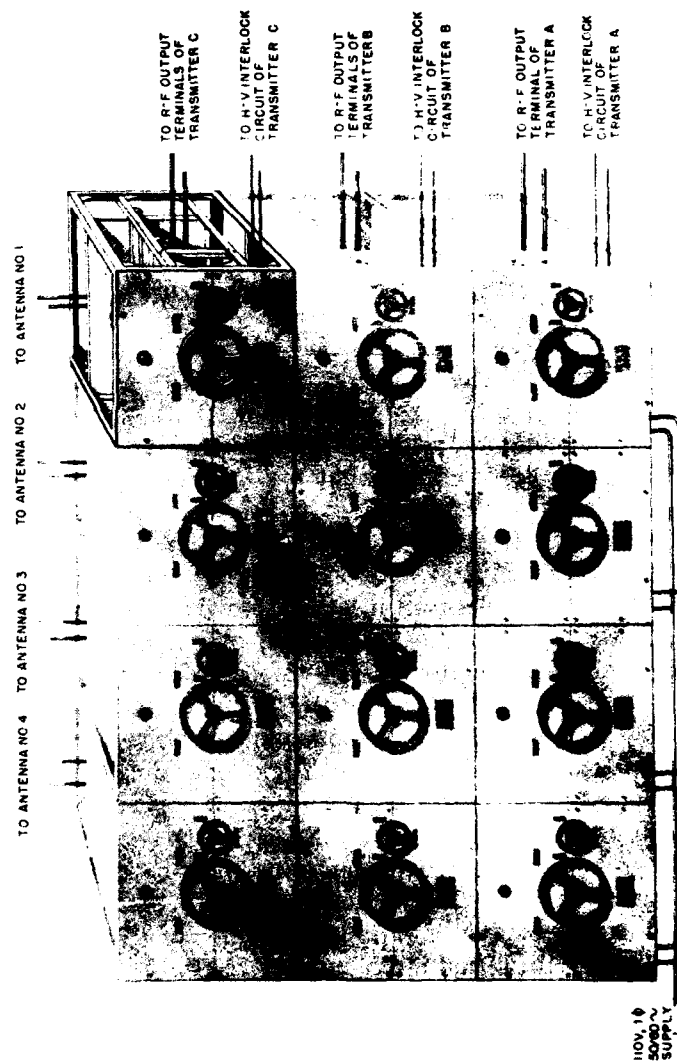


Figure 9-21.—Transmitter-station antenna switching array.

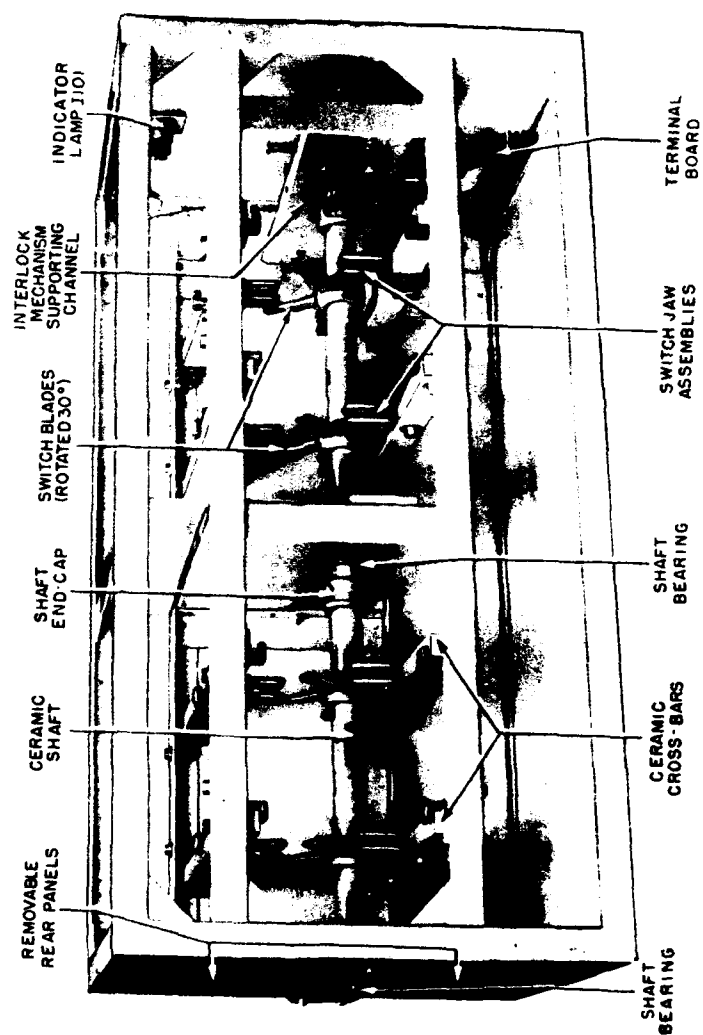


Figure 9-21.—Continued.

able. To accomplish this, a separate rotary switch must be provided for each transmitter-antenna combination to be connected together. That is, for each transmitter used, a separate switch will be required for each antenna system to which that transmitter may have to be connected.

The switches associated with each transmitter are arranged in horizontal rows, and those associated with each antenna system are arranged in vertical columns as indicated in figure 9-22. This relationship of units permits the shortest and simplest interunit wiring arrangement.

The transmission line from a transmitter, or from a preceding switch in a horizontal row, connects to the common terminals (upper terminals in the diagram) in

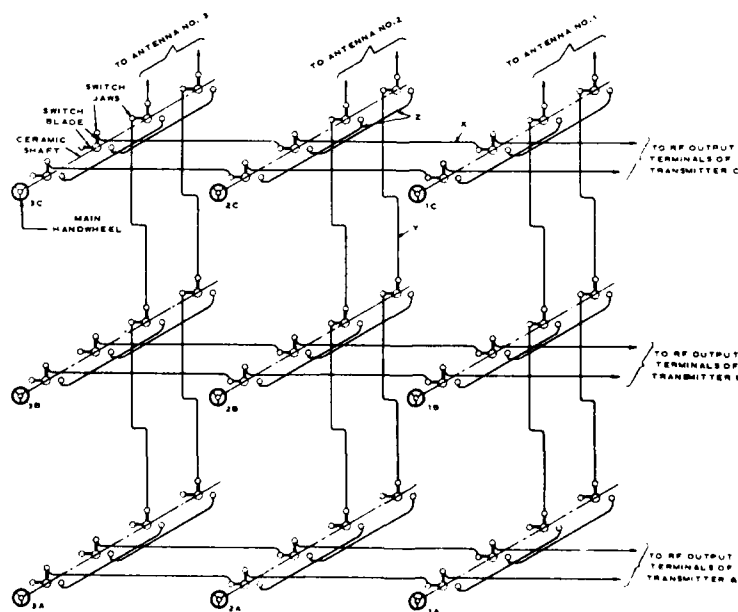


Figure 9-22.—Interconnections between switch units in an antenna switching array.

the front section of the switch; and the transmission line from an antenna, or from an upper switch in a vertical column, connects to the common terminals in the rear section of the switch. Thus, the front section of each switch performs the function of transmitter switching, and the rear section performs the function of antenna switching. In the switch positions shown in figure 9-21, the three transmitter circuits are not connected to the three antenna circuits.

The switching functions are performed as follows:

1. When a rotary switch (for example, an upper switch in a vertical column) is turned to its ANTENNA ON position (clockwise 90°), the transmission line from the transmitter, or from a preceding switch in the same horizontal row, is connected to the antenna via the common terminals (the upper pair of terminals in each switch) in the front section, the lower right terminals in the front section, the lower right terminals in the rear section, and the common terminals in the rear section. If there is another switch in the equipment above the one being discussed, the circuit continues to the upper switch and then, via the common terminals on the same switch section, to the antenna.

2. When a rotary switch is in its ANTENNA OFF position, the transmission line from the transmitter, or from the preceding switch in the same horizontal row, is connected to other switches that follow in the same row via the common terminals and the lower left terminals, and so on to the last switch, or to a switch that is not in its ANTENNA OFF position.

From figure 9-22 it may be seen that with all switches in the ANTENNA OFF positions, the transmission line from each transmitter will be connected through the first switch in the horizontal row associated with that transmitter to the next switch in the row, and through that switch to the next, and so on. Also, the transmission line from the antenna associated with each column of switches will be connected through the top switch in the

column to the next lower one, and through that to the next switch, and so on.

When any switch is rotated to its ANTENNA ON position, its two pairs of knife blades swing to their alternate positions and complete a double-pole, double-break circuit from the associated transmitter to the associated antenna. After one switch has been so operated, it will be noted that in connecting the associated antenna to the associated transmitter the following situation is established:

1. The antenna automatically becomes disconnected from the circuit, feeding other switches lower down in the antenna column.

2. The transmission line from the transmitter involved is automatically disconnected from the circuit that feeds the switches further to the left in the transmitter row.

These features alone make it impossible to connect one transmitter to more than one antenna, or more than one transmitter to the same antenna. However, in order to make the system more nearly foolproof, the mechanisms that control the various switches are mechanically and electrically interlocked to prevent more than one switch in any vertical column from being operated at the same time.

The interlock system associated with this switching arrangement is not discussed in this chapter. It is best understood by the use of the instruction book and a visual inspection of the equipment itself.

RECEIVING-ANTENNA DISTRIBUTION SYSTEMS

Various types of shipboard receiver-antenna distribution systems are in use. Some systems are for small vessels and special applications only. Information about distribution systems is contained in Chapter 2 of *Shipboard Antenna Details*, NavShips 900121(A); filter-type multicouplers are treated in chapter 3 of this publication.

System Employing Transfer Panels

A receiving-antenna distribution system, using antenna transfer panels, is shown in figure 9-23. The transfer panels are interconnected so that a receiver in any radio

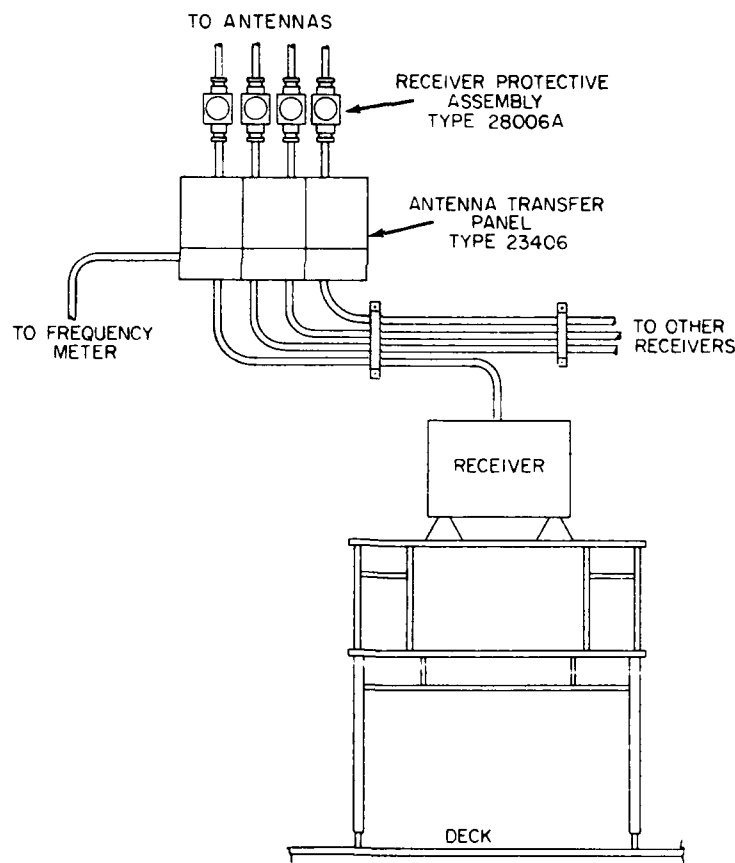


Figure 9-23.—Receiving-antenna distribution system, using antenna transfer panels.

space may be connected to any receiving antenna, regardless of its topside location.

Two different views of the antenna transfer panel, Navy type-23406, are shown in figure 9-24 (A and B

parts); a simplified schematic diagram is shown in figure 9-24, C. These transfer panels provide the means by which as many as four radio receivers may be operated simultaneously from one antenna. At the transfer

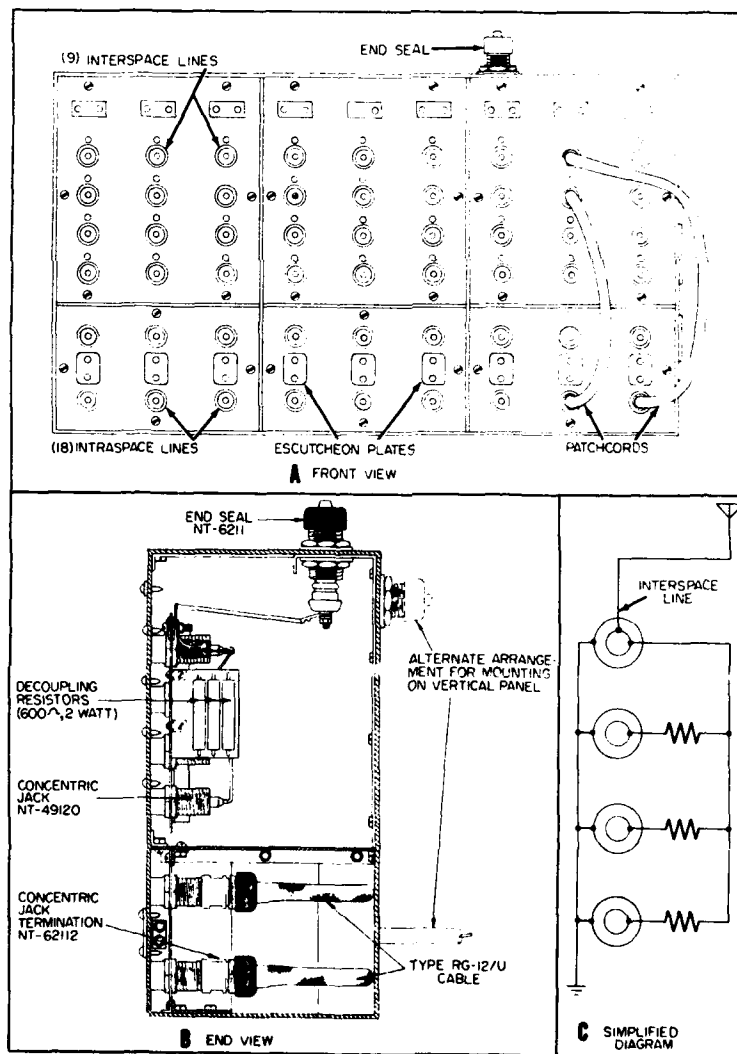


Figure 9-24.—Antenna transfer panel, Navy type-23406.

panel, each antenna is connected to a vertical row of four jacks. One jack is connected directly to the antenna; the other jacks are connected in parallel through 600-ohm decoupling resistors. Of course, the receivers connected to the three decoupled jacks will operate at reduced efficiency.

There are nine interspace lines (one for each vertical row of four jacks) that connect to the various antennas (fig. 9-24, C). These lines connect to the vertical rows composed of four jacks (fig. 9-24, A). The escutcheon plate at the top of each line of four jacks is marked to indicate the remote termination of that line.

The 18 intraspace lines (lower 2 rows of jacks) connect to terminal boxes located at the various receiver, frequency meter, or other equipment positions. White escutcheon plates are mounted between each pair of jacks to enable the operator to mark the respective communications channel, frequencies, or schedules thereon. Patch cords are provided to complete the connections between the various jacks on the front of the panels.

System Employing Filter Assembly

A receiving-antenna distribution system, using a filter assembly, is shown in figure 9-25. This type of distribution system makes possible the multiple operation of a maximum of 28 radio receivers from a single antenna. However, it is generally preferable to limit the total number of receivers to 7.

This filter assembly or "multicoupler" provides 7 r-f channels in the frequency range from 14 kc to 32 mc. Any or all of these channels may be used independently of, or simultaneously with, any of the other channels. Connections to the receivers are made by means of coaxial patch cords and a patch panel.

An external view of the filter assembly is shown in figure 9-25, A. Separation of the frequency range into channels is accomplished by combinations of filter sub-assemblies, which plug into the main chassis. Each filter

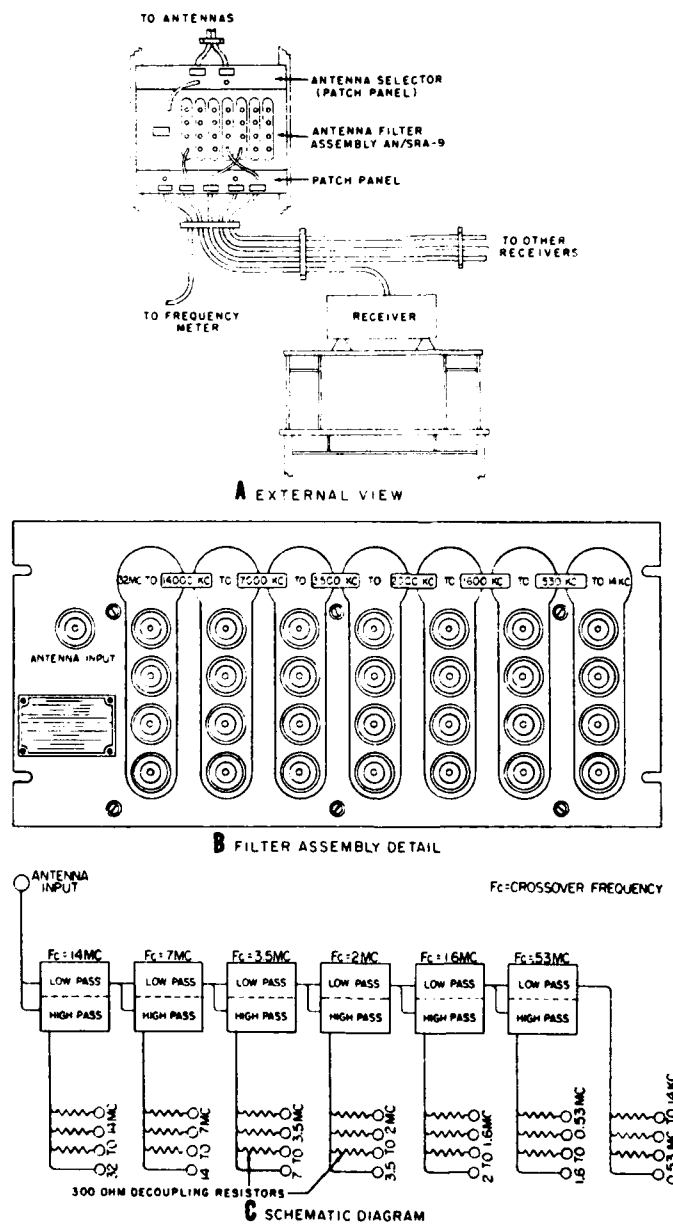


Figure 9-25.—Receiving-antenna distribution system, using antenna filter assembly.

subassembly consists of complementary high-pass and low-pass filter sections, the common crossover frequency (F_c) of which marks the division between channels.

The filters not only guard against interference at frequencies falling outside the channel being used, but also prevent receivers connected to alternate rows of jacks from interacting with each other when their tuning and trimming adjustments are made.

A set of nine filter subassemblies is available, any six of which may be used at one time. The filter subassemblies are sealed units consisting of inductors and capacitors and are terminated in 4-terminal plugs, which are designed to engage octal receptacles on the main chassis. The subassemblies have numbers stamped on them that indicate their crossover frequencies. These numbers can be viewed through windows in the front panel. The six subassemblies that are used are assembled in the order of decreasing frequencies from left to right, as viewed from the front of the panel.

The filter panel (fig. 9-25, B) contains 1 antenna input jack, 28 output jacks, 21 decoupling resistors, and 6 octal sockets. The antenna input jack and the 28 output jacks are all Navy type-49120 r-f connectors. [In the AN/SRA-12 Receiving Filter Assembly, these connectors have been changed to receptacle connectors UG-1111/U (and plug connectors UG-968/U) which are improved quick-disconnect type r-f connectors.] The filter subassemblies plug into octal sockets in the rear of the main chassis (not shown in the figure).

The bottom jack in each vertical row of output jacks is painted red to indicate that it is connected directly to its subassembly. The other three output jacks in each row are unpainted to denote that they are decoupled from their corresponding subassemblies by 300-ohm resistors (fig. 9-25, C).

To keep the losses to a minimum, the input and output of the filter assembly should be terminated in 180 ohms. However, only a slight reflection loss (of the order of 1.0 db) results when the input is terminated in 70 ohms,

a value typical of the impedance of r-f cables used in receiving-antenna installations aboard ship.

Because Navy communications receivers generally operate throughout frequency bands that exceed the widths of the channels normally provided by the filter subassemblies, a given receiver must be connected to the particular row of output jacks that provides the signals of the desired frequency. For example, if a receiver is tuned from some frequency in the 7- to 14-mc band to some frequency in the 14- to 32-mc band, the patch cord would have to be moved from the output of the 14- to 7-mc subassembly unit to the output of the 32- to 14-mc subassembly unit.

When necessary, the bands of frequencies available in a given row of output jacks may be changed either by using different combinations of filter subassemblies or by removing various subassemblies and inserting "shorting plugs," which are provided with the equipment. These shorting plugs provide continuity between successive subassemblies, as required when testing or when a subassembly is removed for any reason, without the necessity for changing the position of the remaining subassemblies.

The red-painted jacks at the bottom of each row are directly connected to the subassemblies and should be used whenever maximum signal strength is desired. The other 3 jacks in each row are decoupled by 300-ohm resistors and are best suited for use with relatively strong signals. In the ideal arrangement, only one receiver is connected to each vertical row of jacks, and that receiver is connected to the bottom jack in each row. This means that seven receivers are fed from each antenna. At frequencies somewhat removed from the crossover points, the performance of each of these seven receivers should be comparable with that obtained if a given one of the receivers were connected directly to an antenna. Likewise, the performance of 21 receivers connected to the "decoupled jacks" should be comparable with the performance of 3 receivers decoupled in like

manner, using conventional patch panels with a given antenna.

DISTRIBUTION OF RADAR INFORMATION

Introduction

The distribution of radar information is somewhat involved, and complex switching equipment is needed. There are various types of switching gear and various combinations of radar equipments and radar repeaters. Therefore, it is difficult to pick any one system that might be considered typical.

For the purpose of this chapter, a brief discussion of Data Switching Group OA-496/SSA is included. Included with this switching group is Video Amplifier Assembly AM-518/SSA, Rotary Switch SA-243/SSA, and Rotary Switch SA-247/SSA. For remote servo operation, Rotary Switch SA-243/U is also needed at other repeaters. These units are indicated in the block diagram in figure 9-26.

As indicated in the block diagram, the purpose of the equipment is to distribute radar information to remote indicators throughout the ship. The number of data switching groups actually required in any particular installation depends on the number of signal sources and the number of repeaters to be served. Only a relatively simple system is shown in this figure.

Each of the 10 radar selector switch units in the data switching group provides for the selection (remote or local) of any one of seven radar-data inputs (only 2 are shown in the figure), as selected by the operator at any one of ten remote radar repeaters. The assembly data switching group consists of 10 radar selector switches (A through K), 10 video and trigger cathode follower subassemblies, and 2 power supplies.

Each selector switch has 25 data sections (decks), the 8 positions (7 active positions; the eighth is OFF) of which are selected automatically by a commutator-

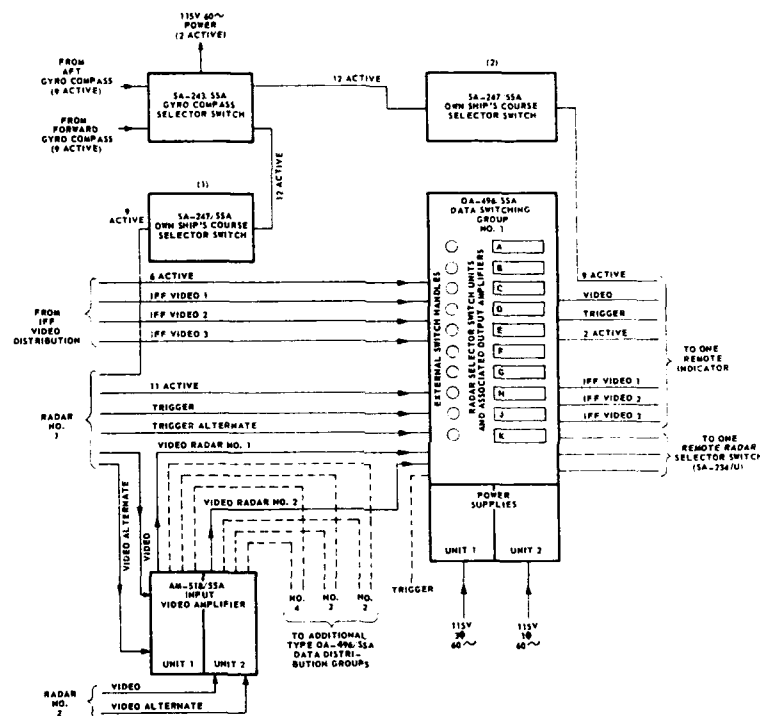


Figure 9-26.—Block diagram of Data Switching Group OA-496/SSA and associated units.

type switch used in connection with the remote-control servo system. The switch may be manually operated locally by means of the external switch handle or remotely by means of the remote selector switches. Each switch section has seven input circuit contacts and one output contact from the common arm.

A 3-section video and trigger switch is installed on the back end of the 25-section switch.

Video signals from the radar receivers are fed through Video Amplifier Assembly AM-518/SSA to the data switching group. This amplifier is capable of providing an essentially flat frequency response for any input signal over a range from 100 cycles through 10 mc. The as-

sembly consists of two amplifiers, each providing for one regular and one alternate input, and four outputs so that the input signal may be delivered to four data switching groups, one of which is shown in the block diagram of figure 9-26.

Trigger voltages and IFF video signals are fed directly to the data switching group where they are distributed to the desired remote location.

Switching-Control Servo System

A simplified schematic diagram of the switching-control servo system is shown in figure 9-27. The system consists of a 3-phase motor, which drives the 8-position, rotary-type switch through a gear train; and a split phase motor, which controls the operation and direction of rotation of the 3-phase motor by means of switch S502.

Two multitapped, single-phase autotransformers, one in the data switch selector servo unit and one in the remote selector switch unit, provide the required control power to the split-phase motor. These transformers are energized from 1 phase of the 3-phase supply. At the remote selector switch unit, the operator turns the switch to the position that will bring in the desired radar information. The transformer in the switch unit develops an opposing voltage to that developed by the transformer in the servo unit. The voltage contributed by the transformer in the servo unit is zero when S503 is in the *H*, or OFF position. The potential difference (the potential not balanced out by the action of the two transformers) is applied to the control winding of the split-phase motor and causes it to develop a torque in one direction or the other, depending on the condition of unbalance. A vane on the shaft of the control motor actuates the sensitive switches, S502 (upward or downward against spring action), depending upon the direction in which the torque is developed. The switches apply 3-phase power to the 3 windings of the 3-phase drive motor. The drive motor, M2, drives S503 to zero the voltage on

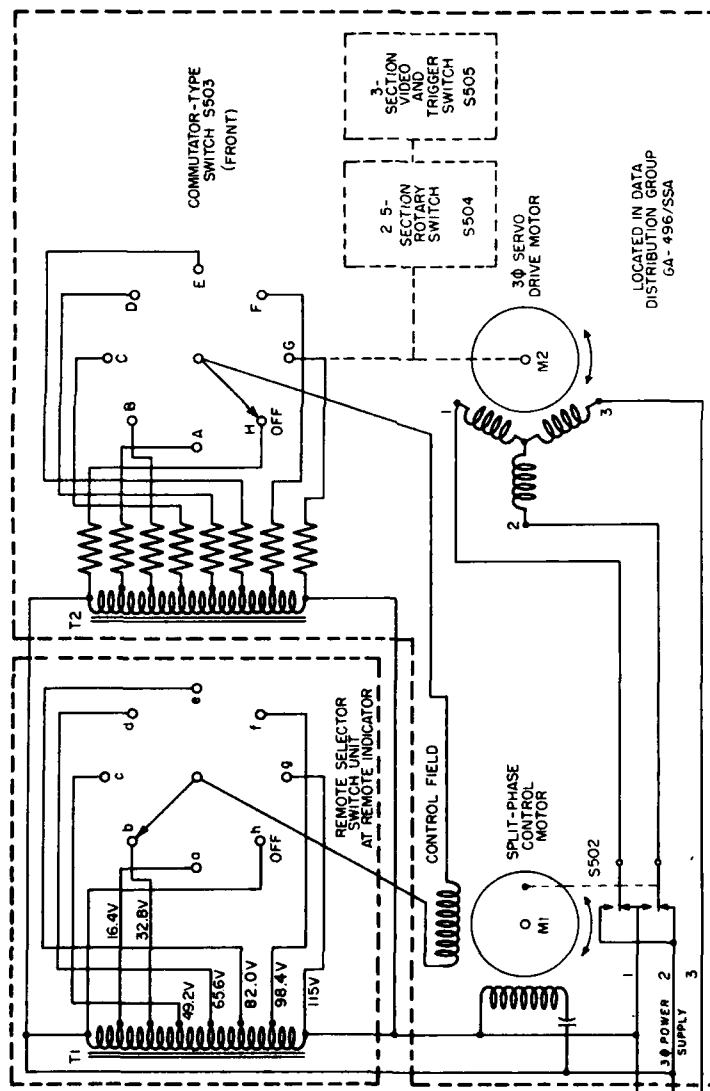


Figure 9-27.—Switching-control servo system.

the control field of *M1*, thereby removing the torque developed by *M1* and opening *S502* to stop the drive motor.

The drive motor is reversed by reversing the torque on *M1* to operate *S502* in the opposite direction. This action interchanges two line leads to *M2* to reverse its direction of rotation. The reversal of torque on *M1* is brought about by the reversal of the control field of *M1* with respect to the constant field of *M1*. The relative phase of the control field depends upon the relative magnitudes of the voltages at *T1* and *T2* that are applied to the control field.

The 3-phase drive motor drives the commutator switch, *S503*; the 25-section rotary switch, *S504*; and the 3-section video and trigger switch, *S505*. As the commutator switch arm contacts the tap that corresponds to the one selected at the remote selector switch unit, the unbalanced potential is reduced to zero. The control field of the control motor is then deenergized, switch *S502* returns to the neutral position, the drive motor is deenergized, and the switch arm of *S503* remains in the desired position. Of course, the 25-section rotary switch and the 3-section video and trigger switch, both of which are on the same shaft with *S503*, remain in the desired position also.

Rotation of the commutator switch in the opposite direction is accomplished in the same manner, except that the polarity of the unbalanced difference voltage applied to the control field of the control motor is opposite, and the direction of rotation of both motors is opposite.

As an example of automatic operation, assume that the operator at the remote selector switch unit (located at a repeater) desires to receive radar information that will be available if he moves his switch to position *b*. Assume also that his switch and the one in the data switching group are in the OFF position.

The operator turns his switch to position *b*, and a potential of 32.8 v developed by *T1* is applied to the control field. The opposing voltage in *T2* is zero. The control

motor turns (for example, clockwise) because of the phase relationship of the control and the constant fields. The motion of the control motor moves *S502* downward (for example) and applies phase 1 to terminal 1 and phase 2 to terminal 2 of the 3-phase drive motor. The drive motor rotates switch *S503* through position *A*. The 16.4 v developed by *T2* at position *A* oppose the 32.8 v developed by *T1*, but a net potential difference of 16.4 v is still applied to the control field of *M1*. Motor *M1* continues to rotate clockwise and *M2* moves the contact of *S503* to position *B*. In this position, the voltages developed by *T1* and *T2* are equal and opposite and no voltage is applied to the control field of *M1*. Motor *M1* stops, *S502* springs open, power is removed from *M2*, and the contact of *S503* remains in position *B*.

The example just given applies to all cases where the remote controller calls for higher position in the alphabet than the initial position of the setting at the data switching group.

For the opposite case, where the remote controller calls for a dial setting lower in the alphabet than the one at the data switching group, a similar analysis will show that the unbalanced control field voltage will produce a current opposite in direction to that of the example given. This results from the fact that the higher voltage now comes from the taps on *T2*. Accordingly, *S502* will be moved upward by the movement of *M1* in a counterclockwise direction because of the reversal in phase of the control field with respect to the constant field. Phase 2 will be applied to terminal 1 of the drive motor *M1* and phase 1 of the line to terminal 2 of *M2*, and the contact arm of *S503* will be rotated in a direction opposite to that given in the previous example. Again, when the two voltages (from *T1* and *T2*) are equal, the switch positions are matched and both motors stop.

Gyrocompass Selector Switch

This switch is used in conjunction with Data Switching Group OA-496/SSA to select either the forward or

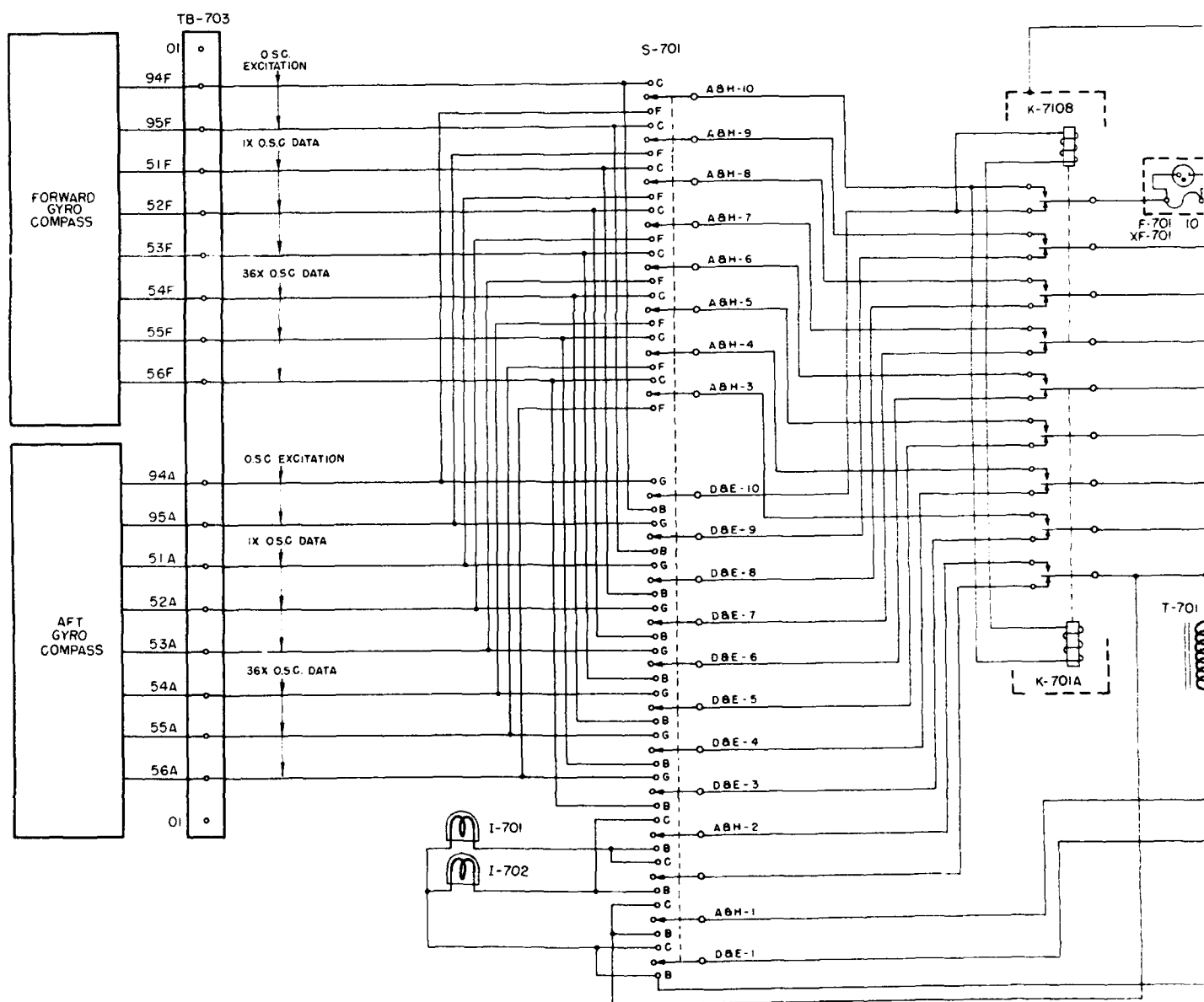


Figure 9-28.—Gyrocompass selector switch.

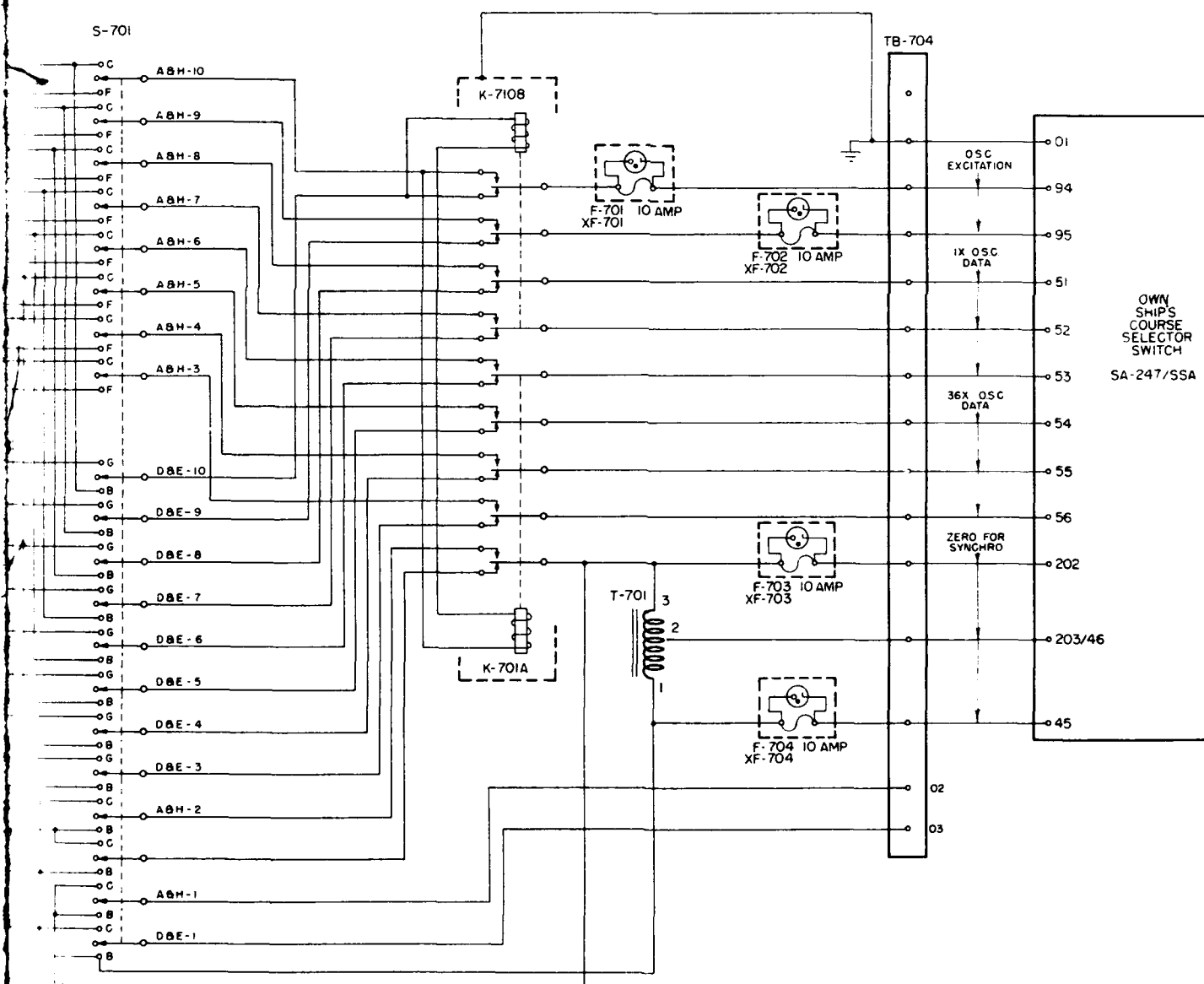


Figure 9-28.—Gyrocompass selector switch.

aft gyrocompass synchro output (both 1X and 36X speed) and to provide a 78-volt synchro electrical zero reference voltage. The switch consists of a 20-pole, 3-position type switch controlled by a relay. A schematic diagram of the Gyrocompass Selector Switch SA-243/SSA is shown in figure 9-28. Electrical zero reference voltage is provided by autotransformer T701 when the switch is turned to either the forward or aft gyro position. In case of a power failure of the selected gyro source, relay K701 (A and B) is deenergized, providing a signal from the alternate source. Indicator lights inform the operator which gyro output is appearing on the switch position selected.

Own Ship's Course Selector Switch

This switch is capable of selecting either a gyro output signal (from the fore or aft gyro, as selected by the gyrocompass selector switch) or the electrical zero reference voltage from the rotary gyrocompass selector switch. A schematic diagram of this switch is shown in figure 9-29. A relay in the unit automatically selects the electrical zero supply voltage and applies it to the synchro in the repeater on failure of the gyro output from the gyrocompass selector switch. A flashing light on the front of the own ship's course selector switch indicates gyro failure.

Radar Selector Switches

The ten 25-section switches (one of which is shown as S504 in fig. 9-30) in the data switching group, transfer the incoming information (except video and trigger) from any one of the seven radars and the information from the IFF video distribution system to any or all of the 10 remote indicators. A wiring diagram of a typical radar selector switch is shown in figure 9-30. Each switch includes two units, S504 and S505. Unit S504 has 25 data sections and 8 positions referred to previously in the introduction to the distribution of radar information.

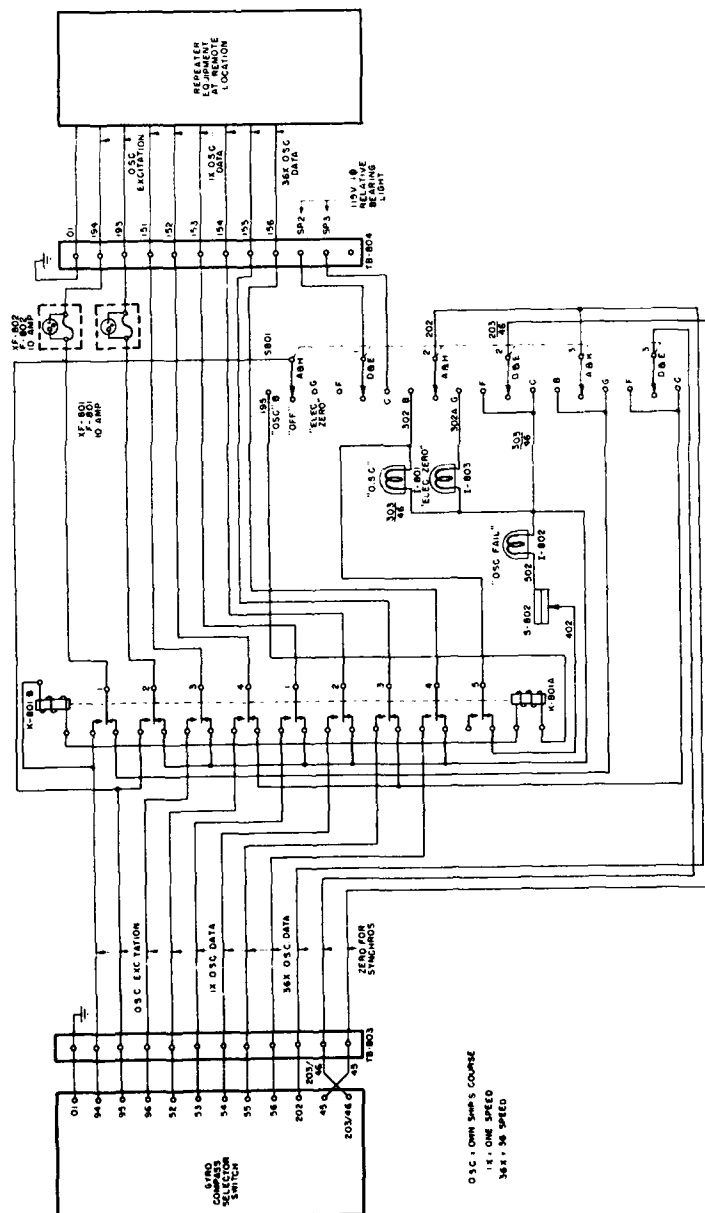


Figure 9-29.—Own ship's course selector switch.

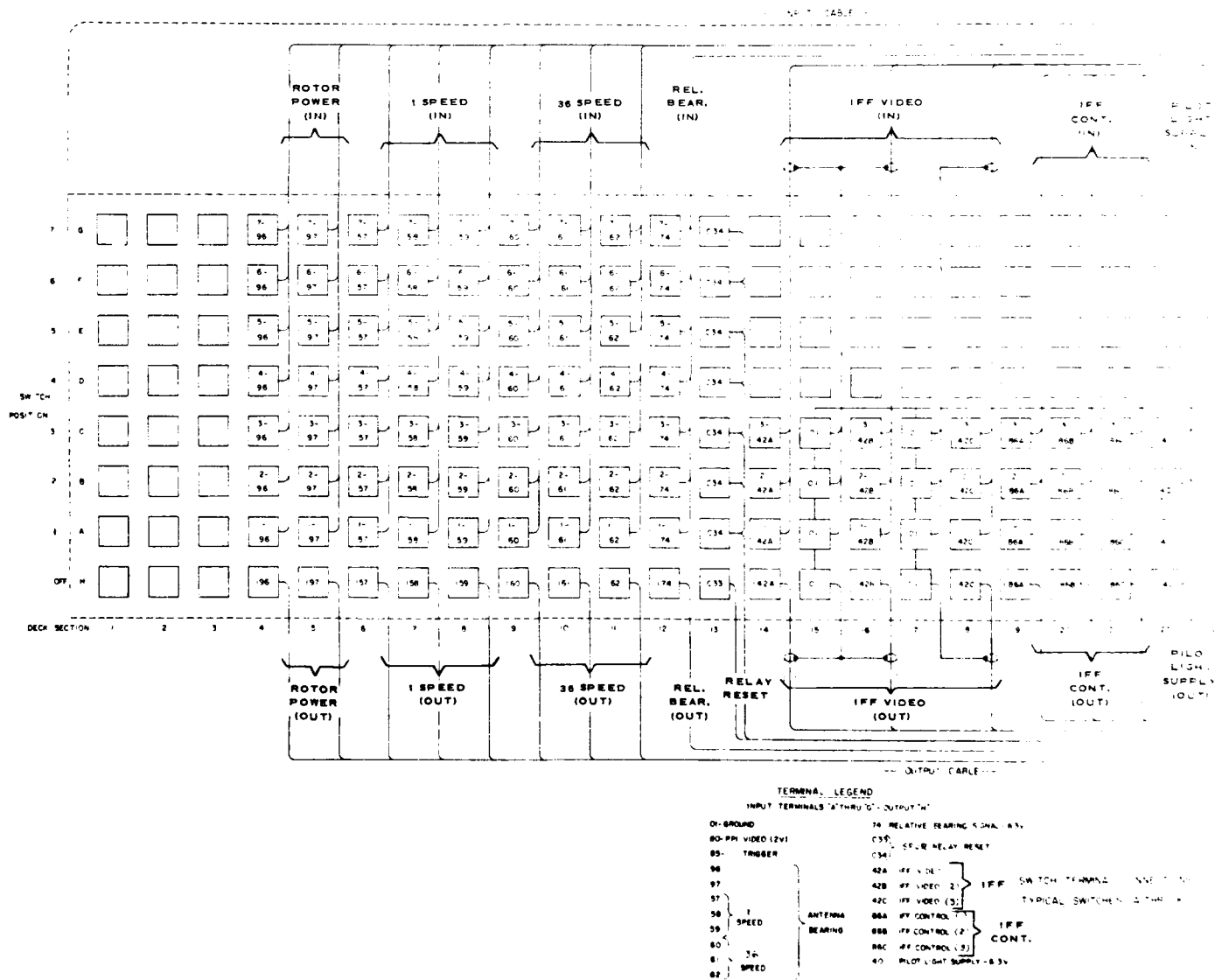
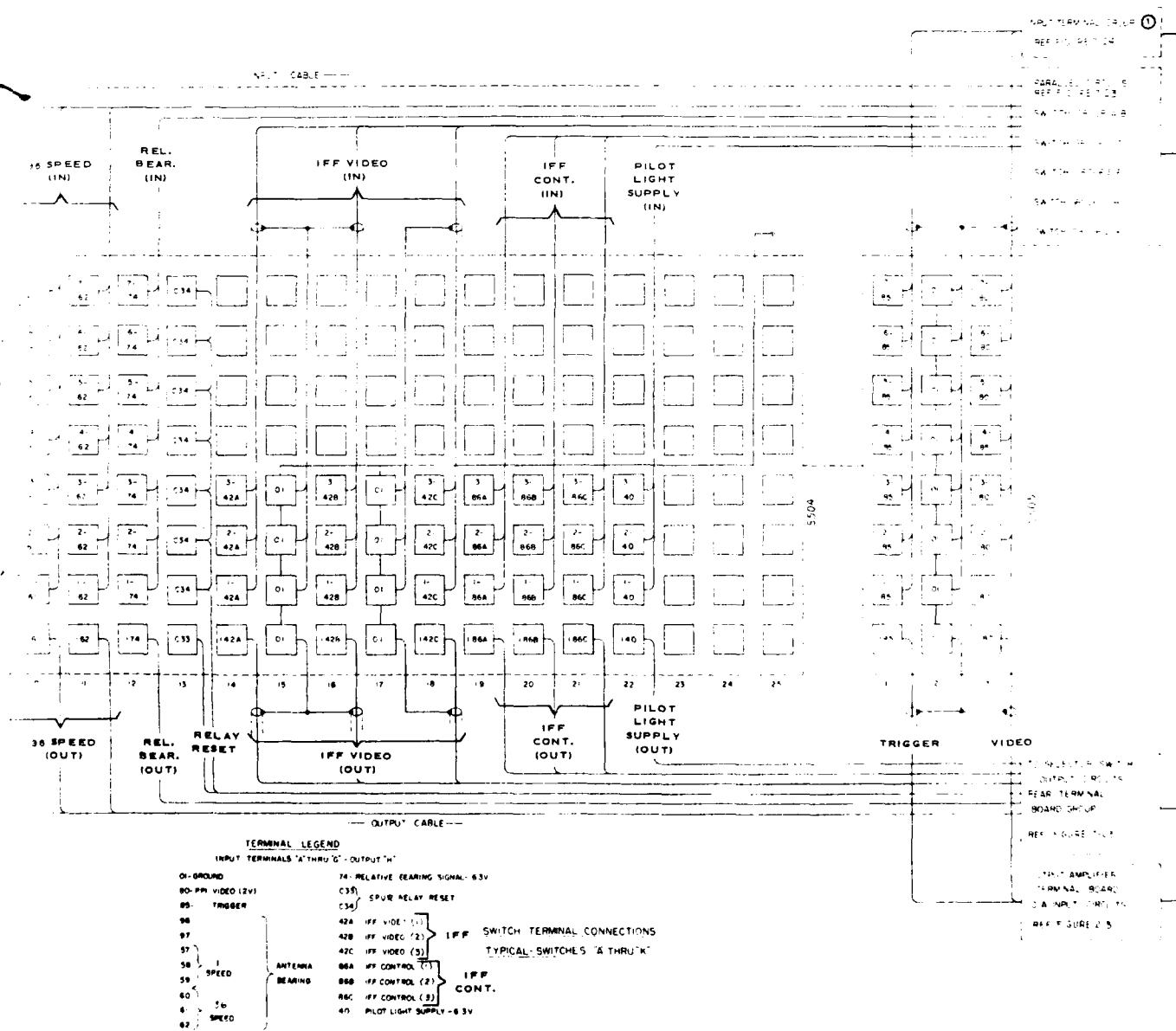


Figure 9-30.—Typical radar selector switch in the data switching group.



Unit S505 has three sections and eight positions and is mounted on the same shaft as S504. Both S504 and S505 turn as a single unit and may be operated by an external handle or automatically by a servo unit, as previously described. The video and trigger signals are fed into S505 from the input terminal group, indicated as a block in figure 9-30.

TRIGGER AND VIDEO SWITCHING.—Trigger and video signals from the various radars (up to seven) connected to the switching group are fed to the input terminal group. From the input terminal group, trigger voltages are fed to seven sections of deck section 1 of S505. Video signals from the seven radars are likewise fed to seven sections of deck section 3. Deck section 2 serves as ground.

Although only one switch (made up of S504 and S505) is shown in figure 9-30, it should be recalled that 10 of these switches are wired into the system.

For example, assume that after being amplified in video amplifier AM-518/SSA, the video signal from radar 1 is fed through the input terminal group to switch terminal 1-80 of S505 (fig. 9-30). The same signal is also fed to terminals 1-80 of S505 in the nine remaining switches. The outputs (from terminal 180) of the 10 switches are fed independently through the output amplifier associated with each switch to the repeater associated with each amplifier. Any or all of the repeaters may be switched to radar 1. The radars connected to the other terminals of the radar selector switch may likewise be selected at the repeater.

Trigger switching follows the same general pattern as video switching, except that the trigger voltage is not amplified before it is fed to the input of the data switching group.

The detailed connections of one switch unit is shown in figure 9-31.

SWITCHING OF IFF AND OTHER DATA.—Whereas S505 handles video and trigger switching, S504 handles such

additional data as antenna bearing, relative bearing IFF video signals, IFF control functions, etc.

The various circuits feeding into and out of a typical switch (S504) are illustrated in figure 9-32. The type of data passing through the various terminals are written

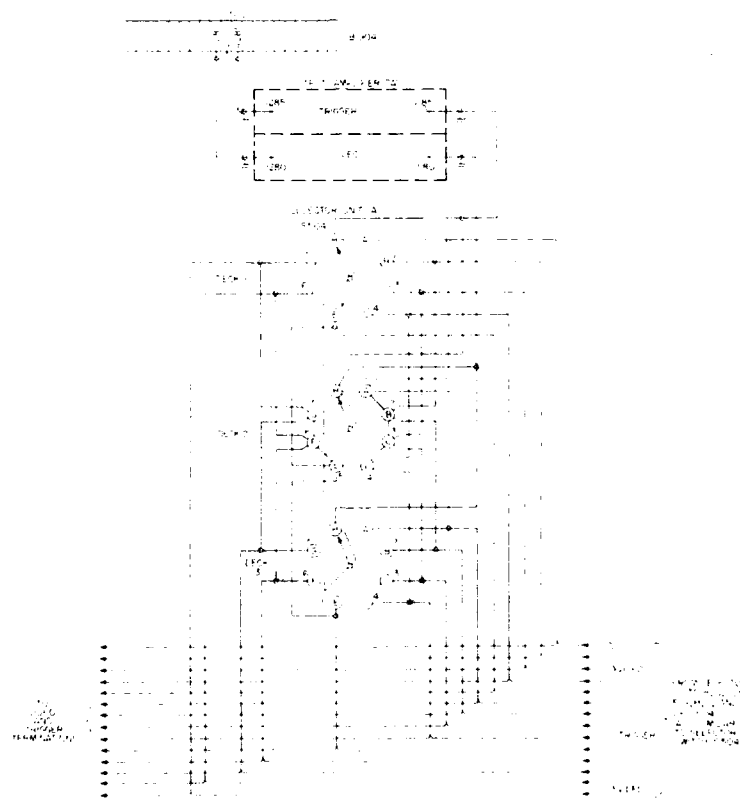
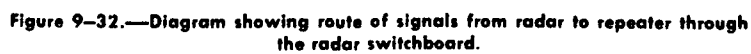


Figure 9-31.—Wiring diagram of video and trigger switching circuits.

on the terminals to simplify signal tracing. The parallel nature of the circuit connections should be kept in mind, and the same reasoning that was employed in video and trigger switching may be employed here.



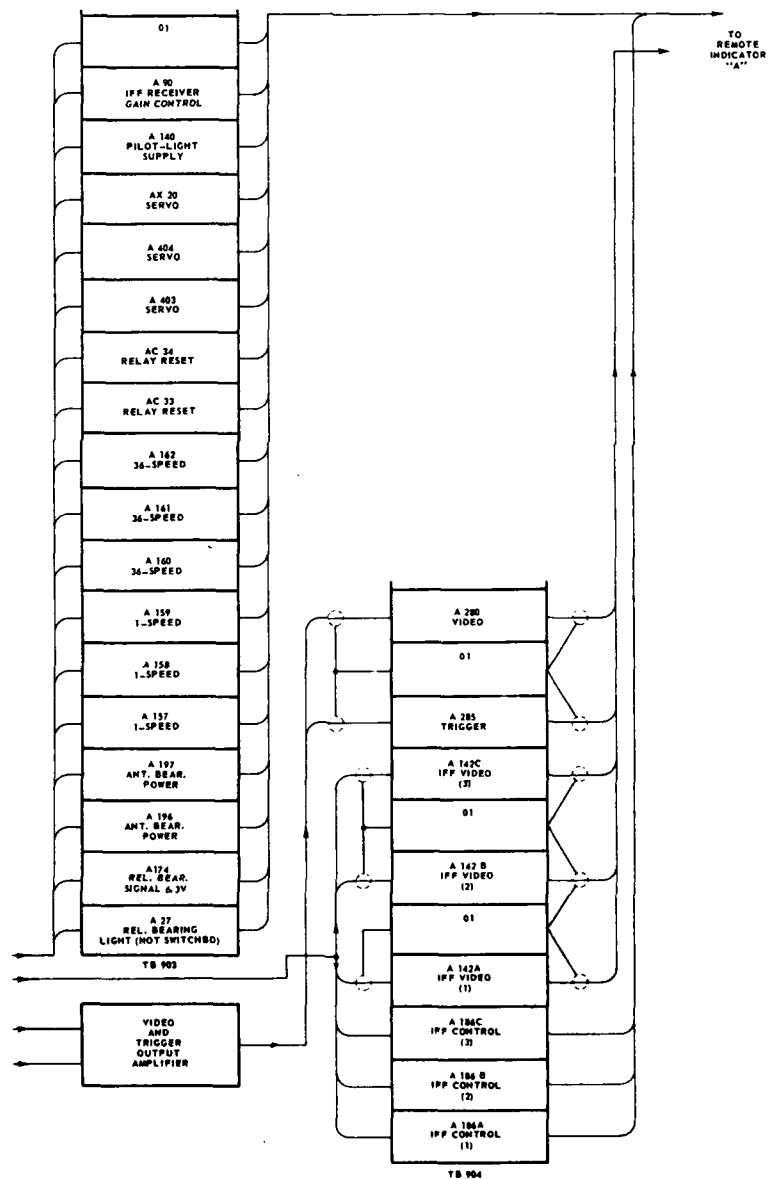


Figure 9-32.—Continued.

The paralleling of switch contacts bearing the same information in the 10 switches is accomplished in the parallel circuits section of the switching group.

QUIZ

1. What is indicated by the toggle switch designation, 4PDT?
2. What is indicated by the push switch designation, 2A1B?
3. What is the meaning of the term, nonshorting, as applied to switches?
4. What is the meaning of the term, shorting, as applied to switches?
5. Why are thermostatic switches used in certain radio transmitters?
6. What design feature of the shorting type of rotary selector switch permits one circuit to be closed before the preceding one is opened?
7. In figure 9-11, why are the band-switch contacts connected so that certain portions of unused circuits will be shorted out?
8. What switch in figure 9-15 must be closed in order to feed the audio output from the medium-frequency (m-f) receiver to remote radiophone station No. 1?
9. What are the five circuits carried by the type SB-83/SRT Transmitter Transfer Switchboard?
10. What is the purpose of the mechanical interlock on the SB-83/SRT Switchboard?
11. Why is it desirable to have at least one spare vertical and one spare horizontal row of switches in both the receiver- and transmitter-switchboard installation?
12. What supplies the -12 v for the microphone in the RPU in figure 9-20?
13. What are two purposes of the audio monitoring circuit in figure 9-20?
14. What is the primary purpose of the type of rotary switch in figure 9-21?
15. Referring to figure 9-22, what function is performed by (a) the front section of each switch and (b) the rear section of each switch?

16. What effect do the 600-ohm decoupling resistors (used in antenna transfer panels) have on the receivers that are connected through them to the antenna?
17. What are two functions performed by the filters used in the assembly shown in figure 9-25?
18. Which jack on the filter assembly (fig. 9-25) is used when maximum signal strength is desired?
19. What two factors determine the number of data switching groups needed for any particular installation?
20. How many radar data inputs and how many remote radar repeaters may be served by a single data switching group?
21. What is the value of the unbalanced potential in the switching control servo system (fig. 9-27) when the remote and the local selector switches are in the same position?
22. When the gyrocompass selected by means of Gyrocompass Selector Switch SA-243/SSA fails, what switches action is then accomplished in the SA-243/SSA?
23. What are the two possible outputs provided to remote repeater equipment by the own ship's course selector switch?
24. How many video amplifiers are contained within a data switching group (OS-946/SSA)?
25. In what portion of figure 9-32 are the switch contacts bearing the same information paralleled?

CHAPTER

10

INTRODUCTION TO SONAR

GENERAL CONSIDERATIONS

History

One of the most critical problems encountered by the Allies in World War II was the submarine menace. Almost five thousand merchant ships were sunk and more than 20 million tons of war supplies were lost by enemy action. The submarine menace was finally eliminated because of the ability of the Navy to detect, locate, and destroy submarines whether they were surfaced, submerged, underway, or lying in wait.

The majority of submarines attacked were detected and located by SONAR. To date, sonar has been the most effective method of detecting completely submerged submarines. Other methods, such as radio, radar, and infrared, have proved ineffective because their range of transmission in sea water is almost negligible.

The word, sonar, is a combination of the first letters of the words, "SOund Navigation And Ranging."

It includes searchlight sonar, scanning sonar, and sonar listening equipment, all of which are briefly described in this chapter.

Similarity to Radar

The basic principle of sonar is similar to that of radar, except that radar uses electromagnetic waves while sonar

uses high-frequency sound waves. Both systems work on the principle of detecting echoes (reflected energy).

The major units in a sonar system are analogous to those in a radar system. A radar system consists essentially of a transmitter, a directional transmitting and receiving antenna, a receiver, and various types of indicators. The sonar system consists essentially of a transmitter (a powerful audio amplifier), a directional transmitting and receiving antenna (loudspeaker and microphone), and various range and direction indicators. The indicators are different from those used in a radar system. One reason is that sonar requires both hearing and seeing, while radar requires only seeing.

The sonar-system transmitter (fig. 10-1) consists of a high-frequency audio oscillator and a power amplifier.

The directional sound antenna is called a TRANSDUCER. It consists of a device that combines the functions of a loudspeaker and microphone. The transducer converts an electrical signal into sound waves, and it also receives sound echoes and converts them back into an electrical signal.

The sonar RECEIVER works on principles very similar to the ordinary superheterodyne a-m broadcast receiver. Low-amplitude, high-frequency signals resulting from the echo are fed to the receiver where they are amplified and converted into lower audio frequencies, which can be heard in a loudspeaker. The sonar receiver also feeds the amplified echo signals into the various indicating devices.

The various sonar indicators perform similar functions to radar indicators and operate basically in the same manner. However, the actual details of the sonar indicators are quite different from those used in radar. Sonar employs the bearing indicator, the range indicator, and the plan position indicator (PPI). Other types of indicators also used in sonar will be mentioned later in this chapter.

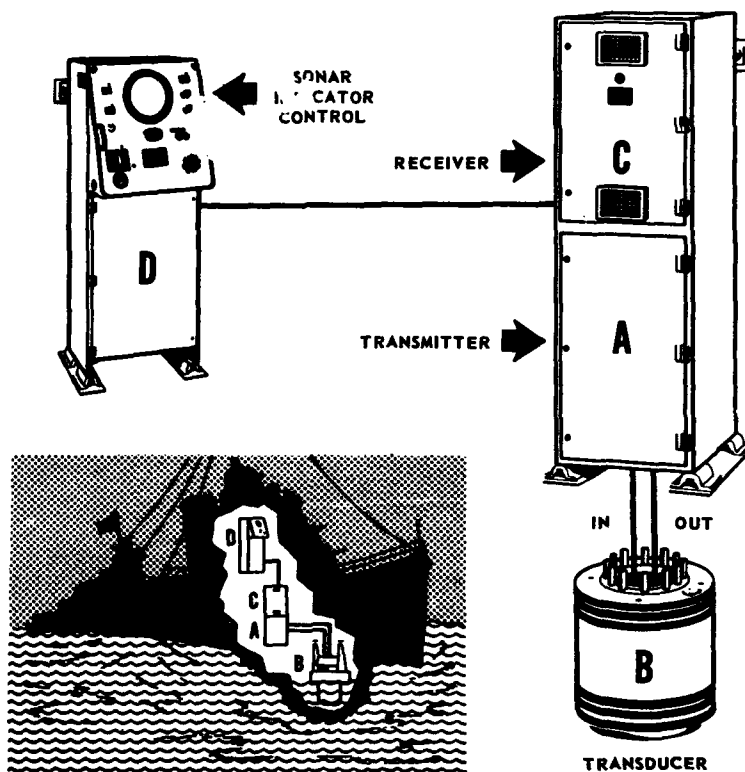


Figure 10-1.—Sonar system.

Before reading the description of how sonar is used to determine range and bearing, the reader should review how a radar does the job (Chapter 14, *Basic Electronics*, NavPers 10087). Sonar works in a somewhat similar manner.

The sonar system sends out a short powerful pulse of sound waves into the water (fig. 10-2). The frequency of the sound waves used is usually too high to be heard by the human ear. The signal is a thin disk of sound waves, which travels through the water at an approximately uniform speed.

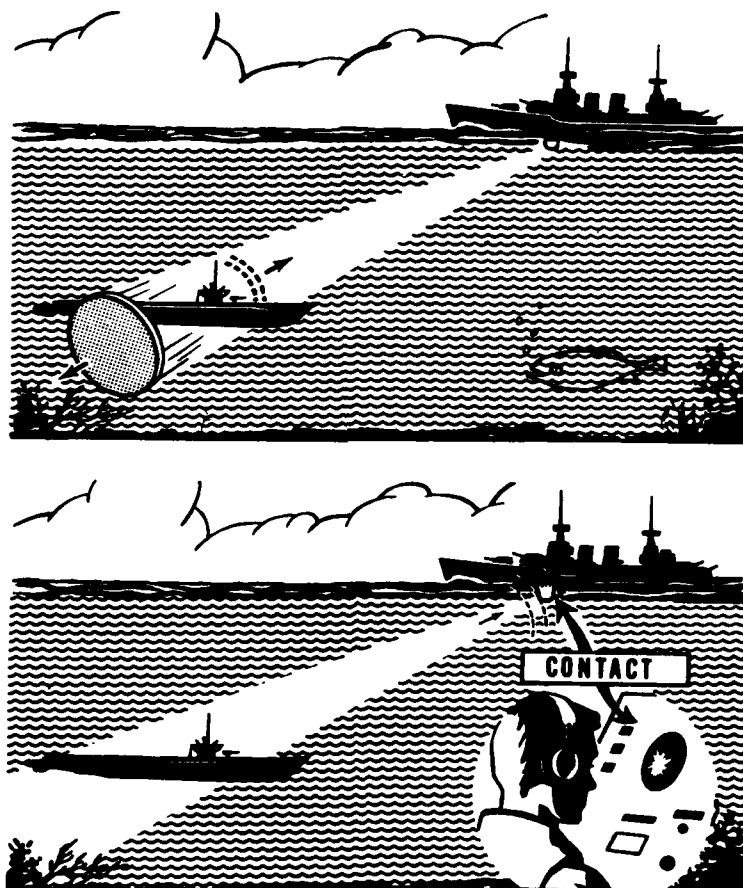


Figure 10-2.—How sonar determines range.

If the signal does not strike any underwater object, it continues on its way and finally disappears. If the signal does strike an underwater object, a small part of the energy is reflected back as an echo. This echo is picked up, amplified, and recorded. The time is measured between the sending of the signal and the reception of the echo. This time interval is a measure of the range of the underwater object.

When a radar pulse is sent out, the echoes come back almost instantly. Even if a plane were 200 mi away, the echo would be returned in only slightly more than 0.002 second ($6.1 \mu\text{s per mi} \times 200 \text{ mi} \times 2 \times 10^{-6} = 0.00244 \text{ second}$).

In sonar it is a completely different story. Sound travels through water at a speed of about 4800 ft, or 1600 yd, per second. If a submarine is 5000 yd away, it will take $\frac{5000}{1600}$, or 3.12 seconds, for the signal to get out to the submarine and 3.12 seconds for the echo to return, or a total of 6.24 seconds, round-trip time.

This tremendous difference in the time required for the echo to be received in a radar system and a sonar system causes important differences in the manner in which the two systems are used and in the indicating devices required.

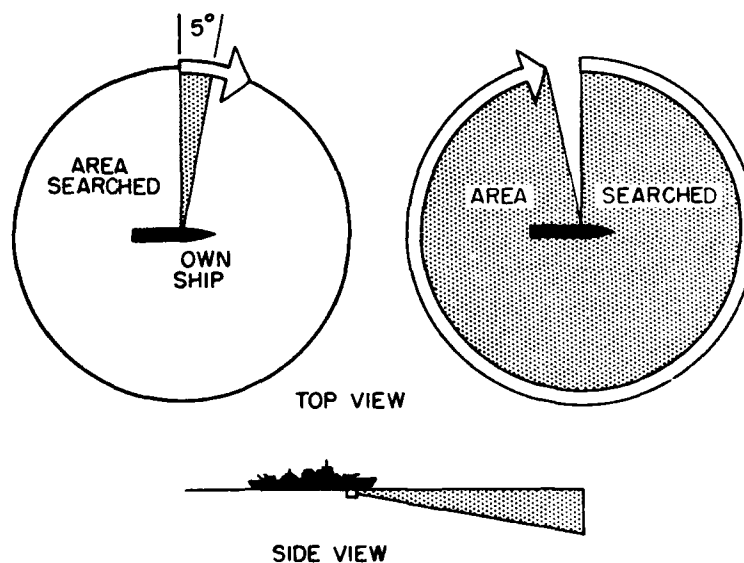


Figure 10-3.—Action of searchlight-type sonar.

Basic Sonar Systems

SEARCHLIGHT-TYPE SONAR.—Searchlight-type sonar (fig. 10-3) corresponds to a radar system with only a range scope. Objects can be detected in one direction only at a time. Many different recordings must be analyzed to get the complete story of what is happening under the water around the ship. This type of sonar sends out a narrow beam of sound, which covers only about 5° of the 360° about the ship. The beam must be trained in all directions to search the entire area about the ship.

In standard search procedure, the operator will ping-train-listen in 5-degree steps, searching from aft to forward. In some searchlight sonars, procedure calls for 10-degree search steps. The advantage of this type of operation is that all of the power output is focused into a concentrated beam, and therefore greater ranges are available. The disadvantages are that a target may be passed over without detection unless the operator is accustomed to the equipment; a target might approach from opposite the bearing being searched without being observed until such time as the searching procedure would allow the transducer to approach the bearing of the target; and the maintenance of contact with a target that has a rapidly changing bearing requires a higher degree of proficiency on the part of the operator than that required of the operator of other equipments.

SCANNING-TYPE SONAR.—Scanning-type sonar (fig. 10-4) corresponds to a radar system with a PPI scope. It provides an indication of all underwater objects around the ship at the same time. Its beam spreads equally and in all directions at the same time rather than in a narrow searchlight beam. Its receiving equipment picks up all the echoes coming from all directions and displays all of this information on the screen of the scope.

Scanning-type sonar has many advantages over the searchlight type. The basic principles of both types are

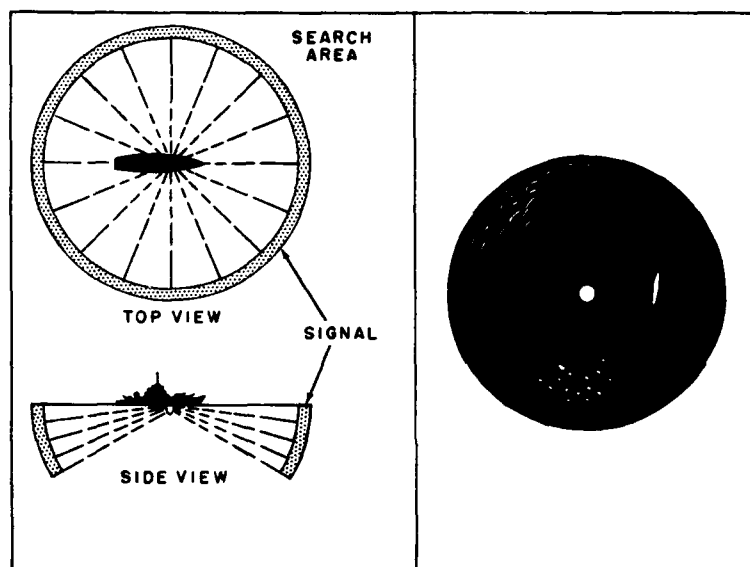


Figure 10-4.—Action of scanning-type sonar.

the same and the equipment for each operates in much the same manner.

CONTINUOUS-WAVE (CW) TYPE SONAR.—The continuous-wave type of echo-ranging sonar differs from the searchlight and scanning types in that (1) transmission is continuous (except for a short blanking period) and not pulsed, as are the other two types; and (2) the frequency is changed gradually. The frequency is decreased at a constant rate for some seconds; then when it approaches the lower limit of the band pass of the receiver, it suddenly is increased to its original value, and the constant rate of decrease begins again. The transmitted sound frequency is a saw-tooth signal. The intensity of the transmitted sound is kept constant during the transmission.

Because of the constant rate of change in the frequency of the transmitter, there is a difference in the frequency of the returning echo and that of the outgoing signal

at the instant the echo is received. The echo is returned and compared for a change in frequency in the receiving circuits of the equipment. From the difference between the transmitted frequency and the frequency of the target echo return, the range of the target is determined. Earphone or loudspeaker signals are also provided to enable the operator to identify targets. A disadvantage of this type sonar is that the operator must be well experienced to interpret by ear the various sounds produced.

USES OF SONAR

Variations of the basic sonar equipment are used to measure the depth of water beneath the ship, to locate submerged navigational hazards, and for underwater communications between ships and submarines.

In brief, sonar can be used in LISTENING, SOUNDING, ECHO RANGING, and COMMUNICATING.

Listening

In listening, the sonar equipment is passive. It does not send out any signals through the water. The transmitting portions of the equipment are not in use. The transducer, acting like a microphone, picks up any sounds in the water, and the receiver amplifies them and feeds them into a loudspeaker. The indicators show only the direction from which the sound is coming. When sonar is used in this manner it is operating merely as a very sensitive and directional hydrophone.

Sounding

In sounding, the sonar equipment is used in much the same manner as that used in detecting submarines, except, in this case, the purpose is to determine the depth of the water beneath the ship. The sonar equipment, known as a Fathometer, sends a sound wave straight down to the bottom and picks up the resulting echo.

Because sound travels through water at a known rate of approximately 4800 fps, the time interval between the start of the sound signal and the return of the echo is an indication of the depth of the water.

Communicating

In one method of communicating, the sonar equipment is used to send long or short bursts of sound to friendly ships and submarines. The sonar operator keys the oscillator with a regular radio sending key. The oscillator signal is amplified by the transmitter, and the transducer sends the dots and dashes of sound out towards the friendly ship or submarine. The friendly ship or submarine picks up these dots and dashes with its sonar listening equipment and replies in code with its sonar transmitting equipment. Another method employing voice modulation is described later.

Echo Ranging

In echo ranging, a short blast of sound waves is sent out through the water. If the sound hits any large underwater object, such as a reef, a school of fish, or a submarine, a small part of the sound signal is reflected as an echo back toward the ship. The echo is picked up by the sonar listening equipment and its range and bearing are determined.

Echo ranging is the most important application of sonar and is the main subject of the remainder of this chapter.

GENERATION AND TRANSMISSION OF SOUND

Meaning of Sound

Sonar equipment depends upon sound and the way it travels. It is therefore important to the sonar student to know about sound waves and how they travel in different mediums, such as air, water, and steel.

Everything that is heard is a sound. The fact that something is heard establishes that there is sound pres-

ent. However, this does not mean that when nothing is heard there is no sound, because there are many sounds that are beyond the range of the human ear.

Sound is caused by the vibration of any type of physical body—for example, a violin string, the head on a drum, a loudspeaker cone, an electric motor, etc. Sounds between the frequencies of approximately 20 cycles and 15,000 cycles are called SONIC because they can be heard by the human ear. Sounds of a frequency below 20 cycles are called SUBSONIC because they are below the hearing range of the average person. Sounds of a frequency above 15,000 cycles are called ULTRASONIC because they are above the hearing range of the average person.

Some people can hear sounds up to 18,000 cycles, and, in rare instances, as high as 20,000 cycles. These people hear sounds that the average person does not notice. It also has been observed that dogs, cats, and other animals can easily hear sounds of 20,000 cycles.

To make use of sound, it is necessary to have a sound SOURCE, a MEDIUM for the sound to travel through, and a DETECTOR to pick up the sound so that information can be obtained from it.

Anything that vibrates back and forth disturbs the material surrounding it, whether that material is a liquid, a solid, or a gas. The object that does the vibrating is called the sound source. It may be a bell, a loudspeaker cone, or a sonar transducer.

Transmission of Sound

An object that vibrates causes a disturbance in the surrounding medium. When the vibrating body pushes in one direction, it compresses the particles of the surrounding material, thereby forcing the particles closer together. When the vibrating body moves in the opposite direction, it decompresses or rarefies the surrounding material, thereby stretching the particles further apart. A material that is compressed or stretched tries to return

to its normal state. The compressed particles expand and push on the material in front of them, causing the compression to move outward. Each time the vibrating body moves outward, it causes another compression, which is transmitted to the surrounding material. These compression waves travel outward from the vibrating body. The number of compressions created each second is the same as the frequency of the vibrating body. The speed at which these compressions travel outward depends upon the nature of the material surrounding the body.

In air, sound waves travel at about 1100 fps; in water, at about 4800 fps; and in steel, at about 16,500 fps.

Nature of the Sonar Signal

As mentioned previously, a sonar system consists basically of a transmitter, a transducer, a receiver, and a group of indicators. A sonar system determines the range and direction of a target in very much the same manner as a radar system. A principal difference is the manner in which the echoes appear on the indicators.

The sonar transmitter creates a high-frequency electrical signal at high-power output. The transducer takes this high-power, high-frequency signal and converts it into a signal of ultrasonic sound and projects it outward through the water.

In searchlight-type sonar (fig. 10-5) the signal is highly directional; it is a small disk of sound that spreads out very little as it travels outward.

In scanning-type sonar (fig. 10-5) the transducer is non-directional; the signal is a thin cylinder of sound that travels equally in all directions, getting larger and larger as it travels outward. The thickness, or pulse length, remains constant.

In the searchlight sonar when the signal hits an underwater object, part of it is reflected back to the transducer as an echo. When the echo strikes the transducer, the transducer transforms the sound back to an electrical signal and feeds the signal to a receiver.

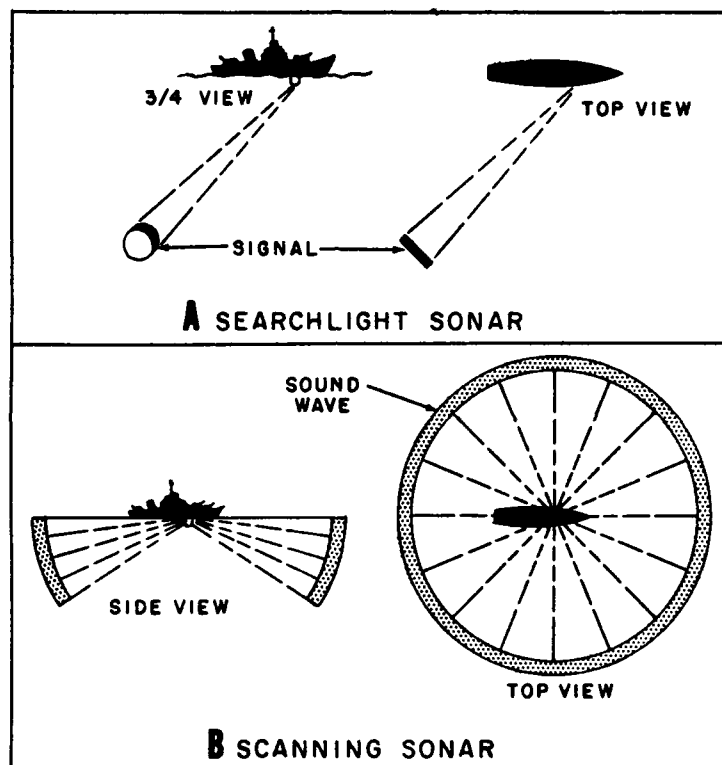


Figure 10-5.—Nature of the sonar signal in searchlight and scanning sonar.

SONAR INDICATORS

Range Indicators

The receiver also drives an indicator, which allows the echo to be seen. Because sound travels through the water at a speed of 1600 yd per second, the time required for the sound to go from the transducer out to the target and back for every 1000 yd between transducer and target is $\frac{1000 \times 2}{1600}$, or 1.25 seconds. This relatively long-time interval requires the use of range indicators, which are specially designed to measure accurately this interval.

CIRCULAR-SCALE TYPE.—In searchlight-type sonar the range indicator may take various forms. A common type that is fairly typical of all other models is one employing a circular scale behind which is a slowly moving light bulb. This type of indicator is essentially a clock, which measures time but is marked off in yards. This indicator usually has a VISUAL-AUDIBLE switch, which allows the operator to measure range in two different ways.

On AUDIBLE (fig. 10-6, A), a white bulb rotating behind the scale causes a white mark to move around the scale. The transmitter is turned on for a fraction of a second when the light passes the zero-yards mark. The sonar operator keeps his eye on the scale, watching the white mark as it indicates higher and higher ranges. At the instant the echo makes a "beep" in the loudspeaker, the operator reads off the range marking next to the white mark, which is the range of the target.

On VISUAL (fig. 10-6, B), a neon bulb, connected to the output of the receiver, rotates behind the scale. This neon bulb is normally dark; it glows only when a sound is picked up by the receiver. When the bulb passes the zero mark, the transmitter is turned on automatically for a fraction of a second, and the neon bulb flashes and goes out. The unlighted bulb moves around the scale until an echo is returned. The instant the echo signal comes out of the receiver, the neon bulb flashes red. The operator reads the scale at the point where the bulb flashes red, and that is the range of the target.

ROTATING MIRROR AND PLEXIGLASS VANE TYPES.—Two additional types of range indicators are the rotating-mirror and the plexiglass-vane, as illustrated in figure 10-6, C. These range indicators have a straight-line range scale and a light bulb. The light from the bulb is projected on the scale by either a revolving mirror or a revolving plexiglass vane, both of which turn at the same rate as the bulb in the circular-scale type. It is possible to have the light stay on steadily as the spot of

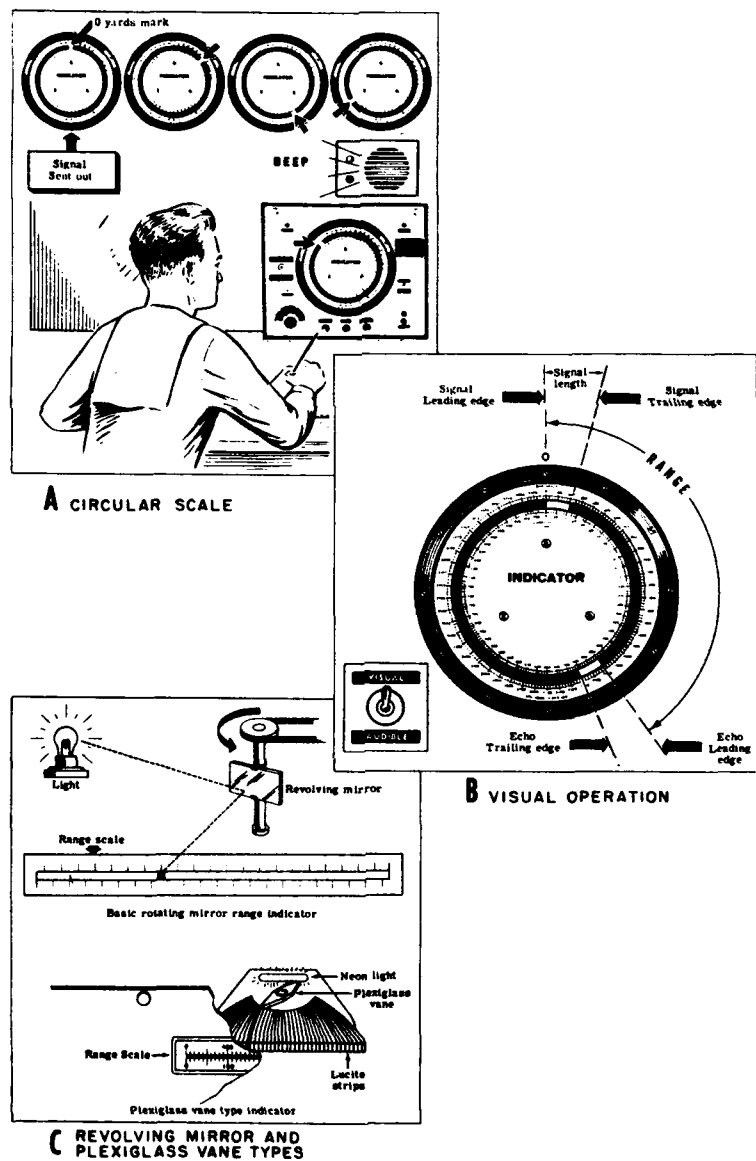
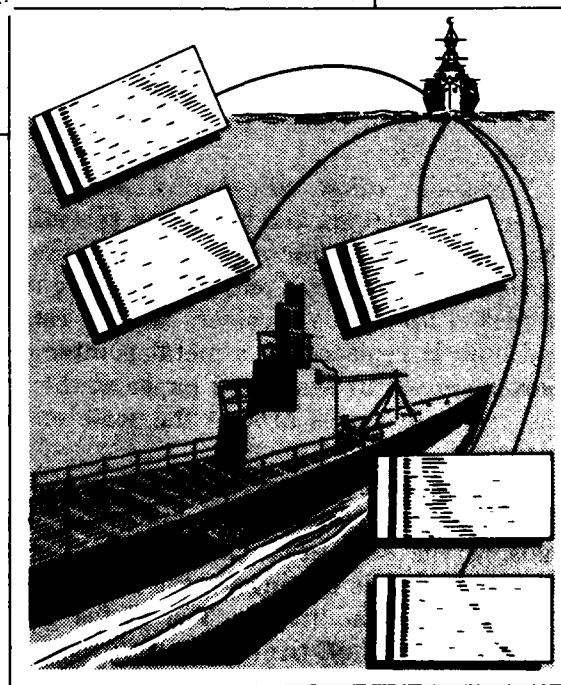
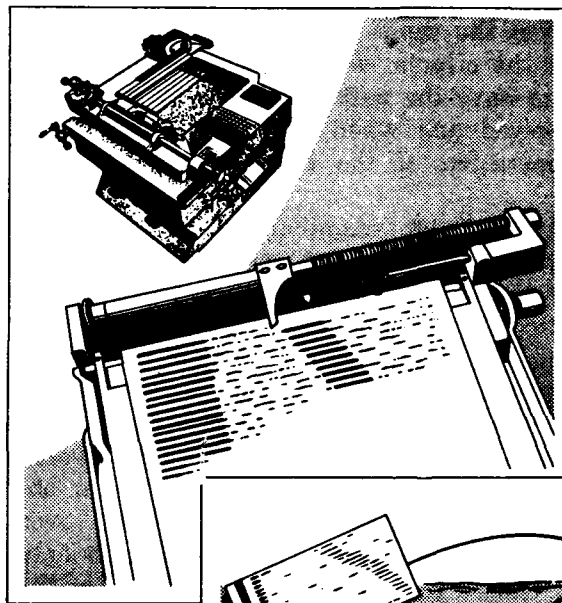


Figure 10-6.—Sonar range indicators.



D SENSITIZED PAPER RANGE RECORDER

Figure 10-6.—Continued.

light sweeps across the range scale, thereby duplicating the operation of the circular-scale type on AUDIBLE. It is also possible to have the bulb light up only when the transmitter is keyed and when an echo returns, thus depicting the operation of the circular-scale type on VISUAL.

SENSITIZED PAPER TYPE.—Another type of indicator widely used with searchlight- and scanning-type sonar systems is the sensitized-paper range recorder. This tactical range recorder (TRR) makes a trace on paper of each outgoing signal and all the echoes from that signal, as illustrated in figure 10-6, D. By comparing matching echoes from a series of successive signal traces, it is possible to distinguish between reverberation, or background noise, and true echoes from underwater objects. An echo mark that is repeated over and over again is a true echo; whereas, an echo that appears only once or twice is caused by temporary disturbance in the water.

The sonar range recorder is, in effect, a range indicator set to VISUAL, and has many special built-in devices. On a range indicator set to VISUAL, the red bulb is attached to the receiver output, and it lights when a sound is picked up by the receiver. In the range recorder the red bulb is replaced by a metal pointer or stylus, which moves across the sensitized paper at the same speed that the red bulb moves around the scale on the range indicator.

When an echo is received, a voltage is built up between the stylus and the metal support underneath the paper, causing the sensitized paper to darken at that point. When no echo is coming in, the stylus has no voltage on it and leaves no trace. The stylus moves across the paper to record all the echoes returning from one transmission. When the stylus has reached the maximum range, it snaps back to the starting point; the paper rolls down constantly so that the pointer is ready to record any echoes coming in from the next signal.

In addition to recording on paper all the echoes returning from each signal, the sonar range recorder gives the range of each echo and the range rate (speed of approach to the target).

It also has provision for directing an attack against a submarine. It allows for the time between the order to FIRE and the entrance of the depth charge into the water; it makes adjustments for the speed of own ship and the time required for the depth charges to sink; and it gives the exact time to fire the depth charges and other items vital to conducting a proper attack.

Bearing Indicator

The direction of the target on a searchlight sonar system is the direction in which the sonar transducer has to be pointed in order to get an echo. A bearing indicator is connected to the transducer to determine the direction in which the transducer is pointing. The bearing indicator (fig. 10-7) consists of two scales and a pointer. The outer scale remains stationary and its zero reading is fixed to point to the bow of the ship in which the sonar system is installed. The center scale is connected to the ship's gyrocompass, and it always follows the apparent motion of the gyro. The pointer lies between the two scales and is connected to the sonar transducer. When an echo is received, the sonar operator looks at the pointer, which is connected to the sonar transducer. The operator can read the true bearing of the target, as shown on the center scale, or he can read the bearing from the outside scale, which shows target direction relative to the ship's bow. This bearing is called **RELATIVE BEARING**.

Bearing-Deviation Indicator

The sonar bearing-deviation indicator (BDI) is used with some searchlight sonar equipments (fig. 10-8). This indicator employs a cathode-ray tube to show when the own ship's transducer is pointed directly at the target.

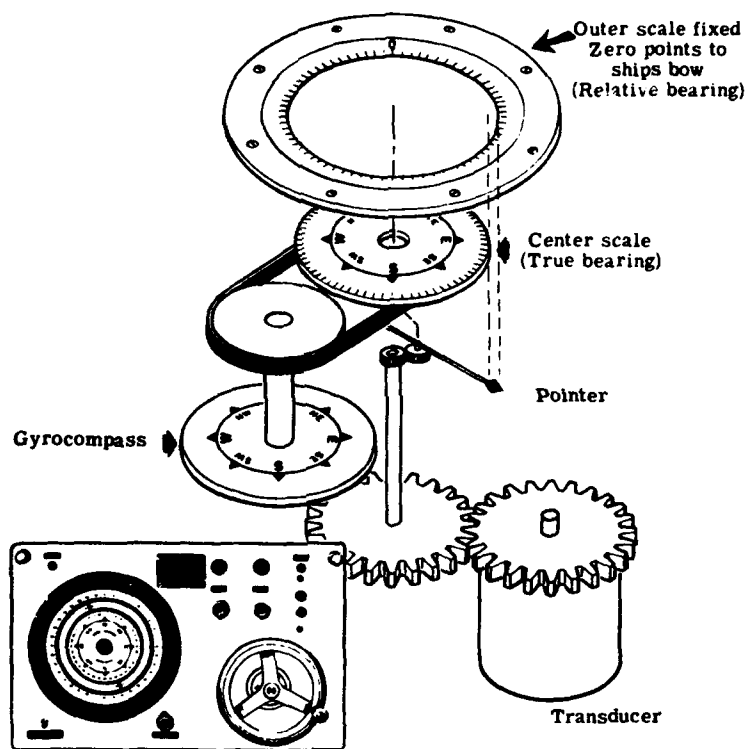


Figure 10-7.—Sonar bearing indicator.

Every time a signal is sent out, a spot of light appears at the bottom of the scope screen and sweeps up to the top, leaving a trace of light behind it. When an echo (not directly in the line of sight of the transducer) comes in, it deflects the sweep trace to the left or right, forming a pip somewhat like the pip on a radar range scope. Any sound picked up by the transducer will cause the trace to be deflected in one direction or the other. A submarine echo is a fairly distinct pip that reappears on each sweep, rather than random pips that reappear in different positions as is the case with multiple echoes caused by disturbances in the water.

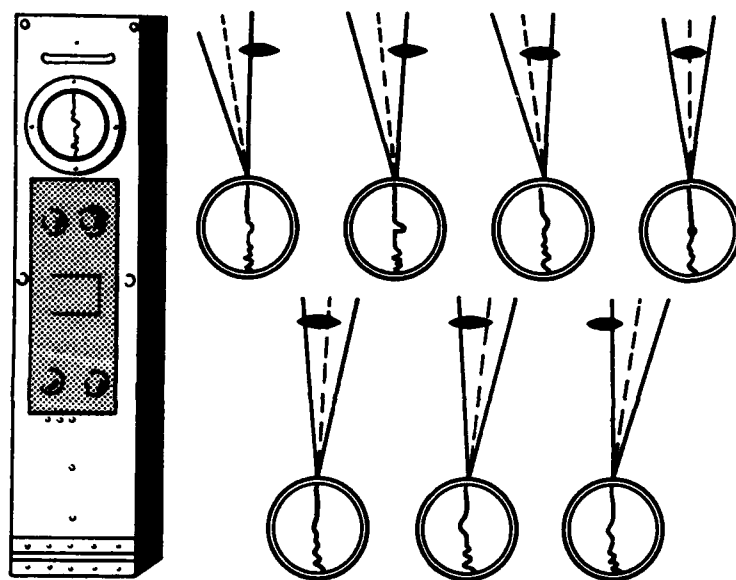


Figure 10-8.—Sonar bearing-deviation indicator.

When the pip is to the right, the submarine is to the right of the direction in which the transducer is pointing. When the pip is to the left, the submarine is to the left of the direction in which the transducer is pointing. When the pip appears as a bright spot centered on trace, the transducer is pointing directly at the target, and an accurate reading may be taken from the regular bearing indicator.

The reason that the pips go to the right or to the left when the target is off the centerline of the transducer is that the transducer is divided into a right and left section. Echoes returning from a target to the right of the transducer centerline affect the right half of the transducer more strongly and shift the pip to the right. The opposite is true for echoes returning from targets to the left of the centerline of the transducer. When the target is right on the centerline of the transducer, the

echo affects both the right and left sections equally, and there is no deflection, but the sweep trace brightens at that point.

Depth-Deviation Indicator

A sonar depth-deviation indicator is similar to a sonar bearing-deviation indicator, except that the plane of operation is rotated 90° , and right and left indications become down and up. When the echo is returned from a target above the axis of the transducer, an up signal is developed, indicating that the operator must train the transducer upward to bring the centerline of the transducer right on the target. This indicator is used with target depth-determining equipment described later in this chapter.

On-Target Indicator

A sonar on-target indicator is generally used with bearing-deviation indicators and depth-deviation equipments. This indicator employs a cathode-ray tube having a linear sweep, either vertical or horizontal. Signals from the two halves of the split transducer are fed to the deflection circuits in such a manner as to modulate the sweep, thereby causing the two signals to appear as pips on the same base line. This method of presentation is called an "A" scan. The two pips are made to coincide to indicate on-target operation.

Attack Plotter

The attack plotter (fig. 10-9) gives a picture on an oscilloscope screen of own ship's track, target's track, the path of own ship's sound beam, and the appropriate firing range for a throwing attack.

Own ship is indicated by a bright spot at the beginning of the sweep trace, and the sweep trace follows the direction of the sound beam. When an echo returns from the target, the sweep trace brightens at the proper range. The trace for each signal lasts approximately two min-

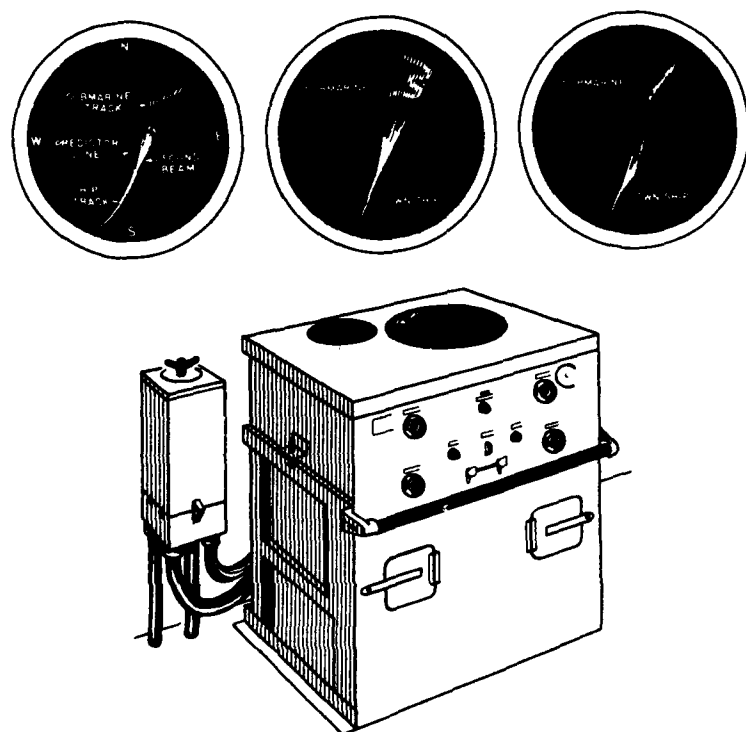


Figure 10-9.—Sonar attack plotter.

utes. When the next signal is sent out, the bright spot caused by the new signal shows the new position of own ship, and the new trace mark shows the new position of the sound beam.

PPI Indicator

In a scanning-type sonar, all targets in all directions are shown on one screen (fig. 10-10). This screen corresponds to the PPI screen used in a radar system. The targets show up as bright spots on a dark background, and the movement of all targets may be observed at the same time. The own ship's position shows up as a bright spot at the center of the screen just as it does on a radar PPI screen. Target range is measured by the distance

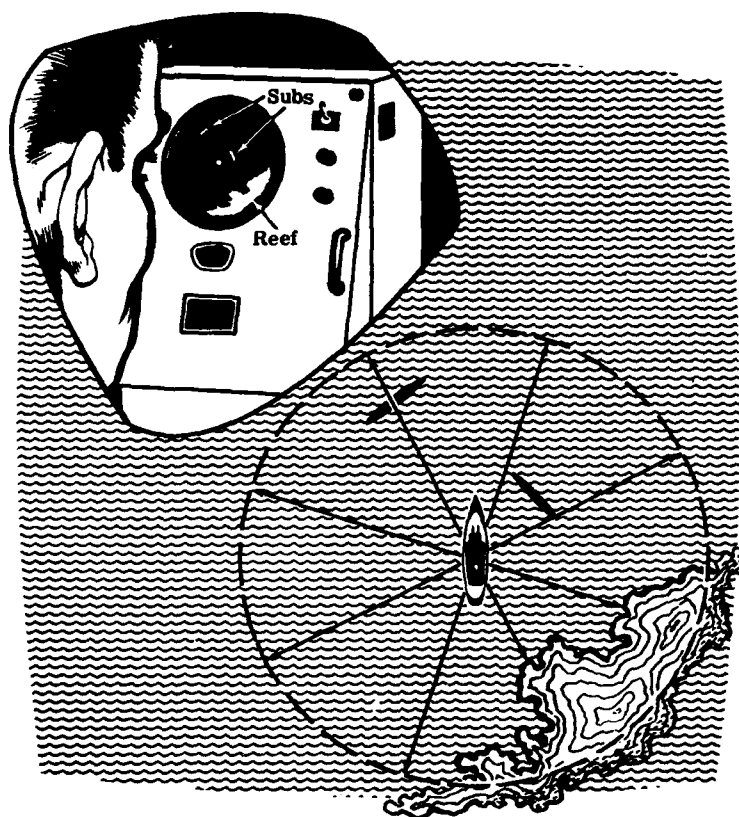


Figure 10-10.—How targets appear on PPI indicator.

of the echo from the center of the screen, and target bearing is determined by the direction of the echo from the center of the screen.

Although the picture on a sonar PPI is not formed in the same way as the picture on a radar PPI, the final results are the same, as will be seen later.

DOPPLER EFFECT

The sound sent out by a sonar transducer has a certain frequency. If the distance between the source and the

receiver of sound (underwater object) is changing, the frequency of the source of the sound energy seems to change. This apparent change in frequency is known as the DOPPLER EFFECT. As soon as the relative motion between the source and the receiver ceases, the Doppler effect is no longer present.

If the distance between the sound source and the receiver of the sound is decreasing, more sound waves will be received at the receiver per unit of time than there will be if the distance is fixed. This condition is accompanied by an increase in the pitch, or frequency, of the sound. For example, a fire engine siren has an apparently increasing pitch as it approaches an observer.

If the distance between the sound source and the receiver of the sound is increasing, there will be fewer sound waves per unit of time at the receiver than there will be if the distance is fixed. This condition is accompanied by a decrease in the pitch, or frequency, of the sound. In contrast with the preceding example, a fire engine siren has a decreasing pitch when it is going away from an observer.

Doppler effect is useful in determining whether the distance to a target is increasing, decreasing, or remaining constant.

Suppose that sound travels out from a transducer, and an echo is received from a submarine. If the distance between the sonar transducer and the submarine is changing, the frequency of the echo will be different from the transmitted frequency. If the submarine is moving toward the transducer, the frequency of the echo will be greater than the frequency of the outgoing pulse. If the submarine is moving away, the frequency of the echo will be less than that of the outgoing pulse.

In present day equipment the sonar receiver is generally muted during transmission so that the operator does not hear the outgoing signal. Instead of comparing the frequency of the echo with the frequency of the outgoing signal, it is compared with the frequency of the rever-

berations received immediately after the end of the outgoing signal. Reverberations are the echoes that are received from small particles of matter in the water, waves on the surface of the water, etc. By comparing the frequency of the echo with the frequency of the reverberations, the effect of own ship's movement is eliminated. Thus, if the target is moving toward the transducer, and the range is either opening or closing, the frequency of the echo will be greater than the frequency of the reverberations (called "up Doppler"). If the target is moving away from the transducer, the frequency of the echo will be less than the frequency of the

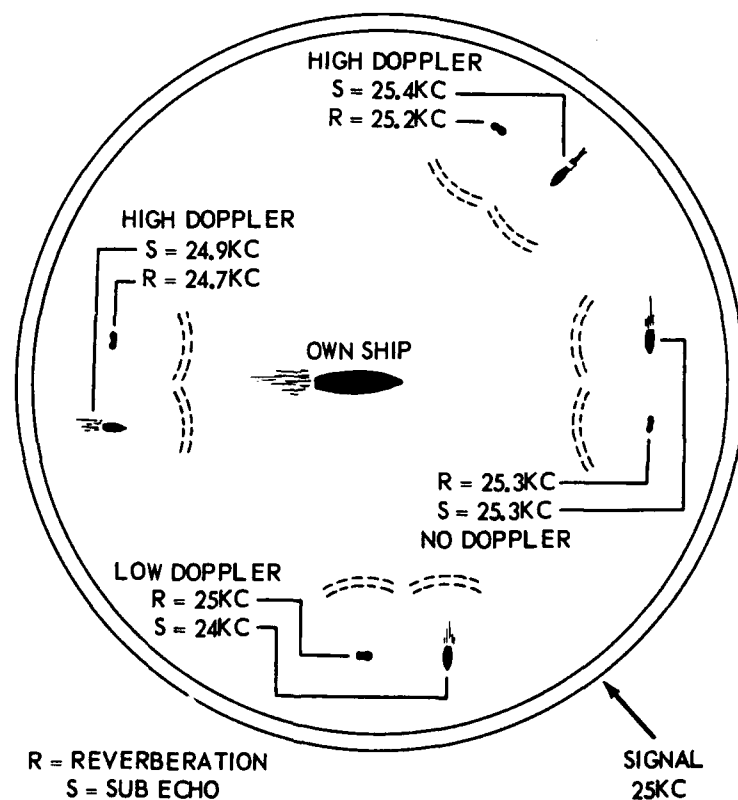


Figure 10-11.—Examples of Doppler.

reverberations ("down Doppler"). Doppler effect is observed only during the time that the target has a component of motion along a line of sight from the transducer to the target. When this condition exists, it is assumed that no currents are present in the water. Thus no Doppler is present from stationary targets or from beam targets (motion is perpendicular to the line of sight). The magnitude of the Doppler is important because it is a measure of the speed and the approximate course of the target.

Figure 10-11 illustrates some of the situations in which Doppler will provide important information.

LIMITATIONS OF SONAR

Sonar cannot detect objects 1000 mi away or even 100 mi distant because certain factors weaken and distort the sound beam as it travels outward; the same factors have a similar effect on the echo returning from an underwater object. Echo ranging is not possible if the sound beam and the echo are excessively weakened in their travel through the water. Neither is it possible if the sound beam is distorted on the way out so that it does not strike the underwater object, or if the echo does not strike the transducer on the way back.

The factors and effects that limit the maximum range at which underwater targets may be detected include:

1. Target composition.
2. Transmission loss.
3. Refraction of the sound beam.
4. Temperature.
5. Pressure.
6. Salinity.
7. Other interference.

Target Composition

The ultrasonic sonar waves travel through the water and are reflected by all obstacles in their path. Some objects reflect more than others, depending on their size,

shape, distance, and material. A large object returns a stronger echo than a small object. A flat surface facing the transducer returns a stronger echo than either a flat surface not directly facing the transducer or a curved or irregularly shaped object. Steel objects return stronger echoes than mud or stone. However, nearly every material seems to reflect a fairly strong echo. This phase of sonar is not yet resolved to simple formulas. These limiting factors may be overcome by increasing the power output of the transmitter and transducer and the sensitivity of the receiver. However, this method would greatly increase the size of the equipment and would not overcome other limiting factors to be described later.

Transmission Loss

Another factor that limits the maximum range at which underwater objects may be detected is the transmission loss, which takes place when sound travels through water. The two main types of transmission losses are absorption and scattering.

Absorption takes place in sea water because it is not a perfect medium for conducting sound. There is a certain amount of drag between the particles that make up water. This effect is called **VISCOSITY**. Because of the viscosity of water, the compressions and rarefactions that make up sound waves work against this drag with a resulting loss of energy, which is converted into heat.

Scattering is an effect caused by foreign matter in the water. When silt, air bubbles, seaweed, and minute animal life are struck by the sound beam, tiny portions of the sound beam are reflected by these bodies, and part of the energy of the sound signal is lost. Some of the reflected portions of the beam strike other foreign bodies and are reflected in other directions. Some of these multiple reflections are picked up by the receiver, but they are so weak and so intermingled that they cause only a slight hiss in the receiver. The bad result of scattering is that both the sound beam and the echo are weakened on their way to and from the target.

Refraction of the Sound Beam

Bending, or refraction of the sound beam is a limiting factor to sonar operation that cannot be corrected by increasing the strength of the sound beam or increasing the sensitivity of the receiver. In fact, this phenomenon imposes the most serious restriction affecting sonar operation.

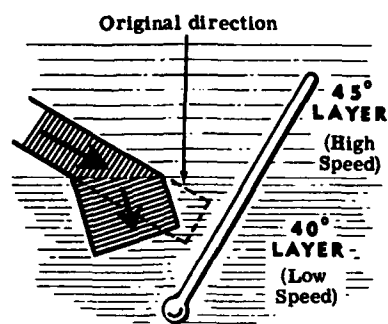
In an ideal medium the sound beam would travel in a straight line. This condition could be fulfilled only if the temperature, the pressure, and the salt content (salinity) were constant throughout the water. Any factor that changes the speed of sound will cause bending of the sound beam. If the temperature, pressure, or salinity of the water vary from point to point in the water, the speed of sound will also vary. Hence the sound beam will be refracted.

Temperature

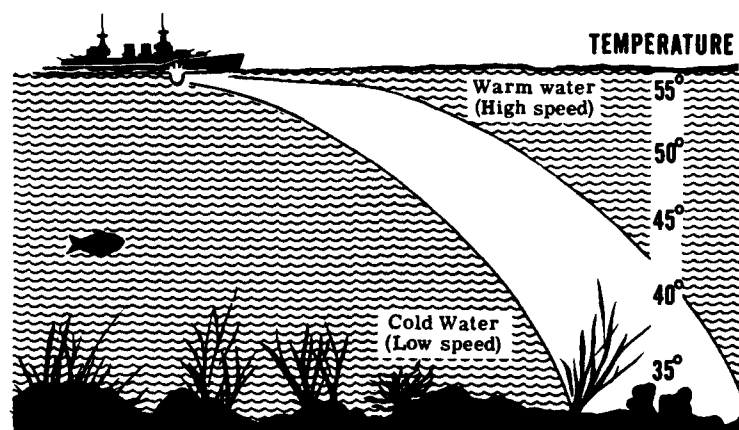
Sound travels through water at a velocity of 4800 ft, or 1600 yd, per second provided the temperature of the water is 39° F. The speed of sound through water varies with the temperature. For example, the speed of sound increases from 4800 fps to 5300 fps when the temperature increases from 39° F to 85° F; the speed decreases to 4700 fps when the temperature of the water decreases to 30° F. This change of speed with temperature has the effect of bending the sound beam away from a high-temperature region and toward a low-temperature region, as illustrated in figure 10-12.

In figure 10-12, A, the sound beam travels through water in which there are two separate layers with a well-defined temperature difference. The lower edge (left side) of the sound beam travels more slowly as it enters the colder layer of water, with the result that the sound beam is bent downward toward the colder water, as indicated by the arrows.

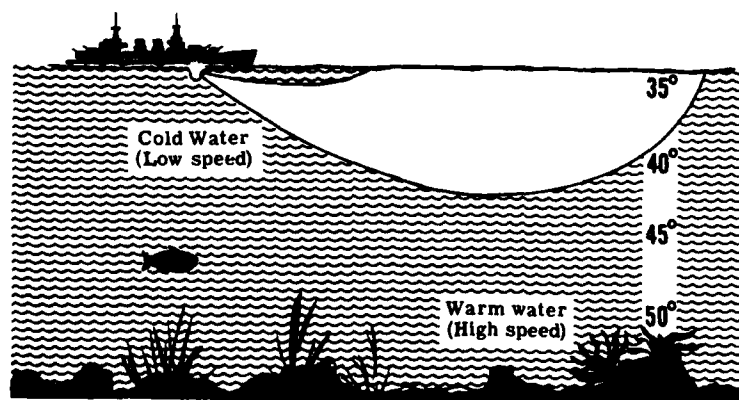
When the surface is warm and the temperature gradu-



A SHARP TEMPERATURE DIFFERENCE



B GRADUAL TEMPERATURE DIFFERENCE



C TEMPERATURE INVERSION

Figure 10-12.—Effect of temperature on sound beam.

ally decreases with depth, the sound beam is bent downward, as illustrated in figure 10-12, B.

When a temperature inversion occurs (not a common occurrence), the warm water layer is below the colder layer and the sonar beam is bent upward (fig. 10-12, C).

Pressure

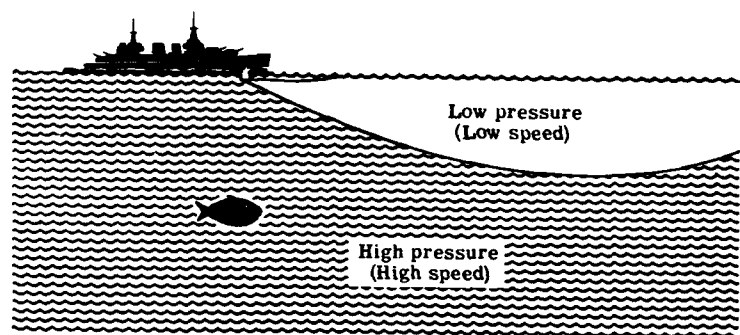
Pressure also bends the sound beam; although this effect is not as great as the temperature effect. The speed of sound increases with an increase in pressure. Because the sound bends away from a region of high speed toward one of lower speed, a sound beam will bend up from the bottom if the water temperature is the same throughout its depth (fig. 10-13, A). This condition is somewhat unusual. However, a not so unusual condition is illustrated in figure 10-13, B.

Frequently a considerable depth of water in the ocean will have a uniform temperature. This is brought about by strong winds and heavy waves that thoroughly mix the upper layers of water and cause them to have the same temperature. Also frequently, the temperature of the lower portion will gradually become less than that of the top portion. When this condition occurs, part of the sound beam is bent upward due to the pressure effect, and the lower part of the sound beam is bent downward due to the temperature effect. This results in a split-sound beam, as shown in the figure.

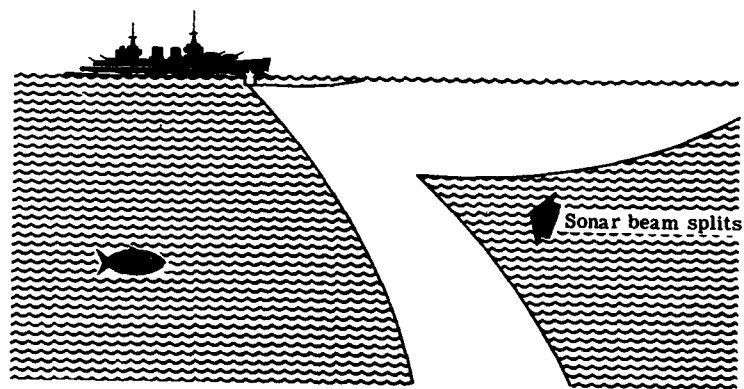
Salinity

The effect of salt in the water is to increase the speed of sound. Just as temperature has the greatest effect on the speed of sound, it also is the principal factor affecting density. The salinity of sea water is fairly constant, except near the mouths of large rivers where it is less. In this case the sound beam is bent away from the salt (more dense) water toward the fresh (less dense) water (fig. 10-14, A).

It is very fortunate for sonar that the bending of the



A BENDING DUE TO PRESSURE ONLY



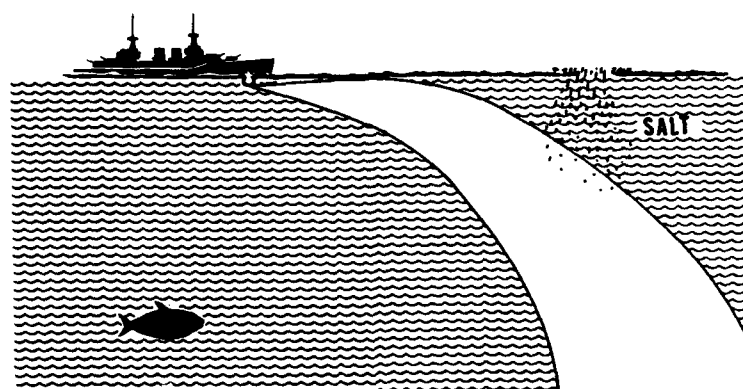
B BENDING DUE TO PRESSURE AND TEMPERATURE

Figure 10-13.—Effect of pressure and temperature on sound beam.

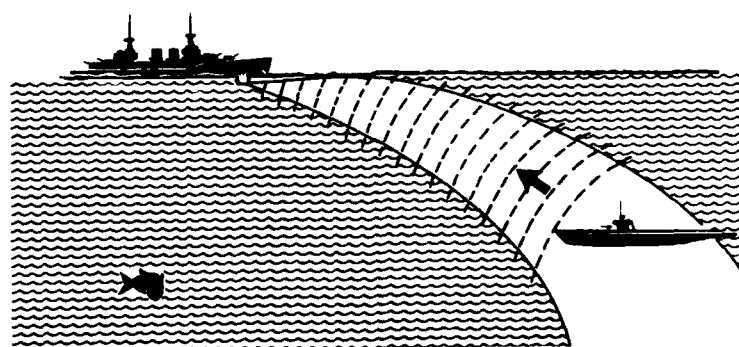
sound beam caused by temperature, pressure, and salinity applies equally to the echo and the original sound signal. The echo returns over the same path as the original sound beam, because it is subject to the same bending forces (fig. 10-14, B).

Other Types of Interference

Reverberation consists of multiple echoes caused by rough surfaces, objects in the water, current changes,



A EFFECT OF SALINITY ON OUTGOING SIGNAL



B EFFECT OF SALINITY ON RETURNING ECHO

Figure 10-14.—Effect of salinity on sound beam.

concentrations of air bubbles, and anything else that disturbs the complete uniformity of the water. All of these small echoes are reflected from various ranges and come back as a continuous sound. Reverberation is loud immediately after the sound signal goes out and becomes less and less loud as the signal travels outward. The reverberation effect can be subdued by suitable electronic circuits in the receiver.

Other natural conditions causing noise in the sonar receiver include breaking wave crests, rain and hail on

the surface, and the agitation of the water molecules. Animal life in the ocean is responsible for considerable noise. The worst offender is the snapping shrimp (not the edible type), which closes its pincers with a loud snap. Where there are hundreds of thousands of these shrimp in one area, a loud sizzle is heard in the sonar receiver. Other animals causing noise are croakers, drumfish, crabs, lobsters, porpoises, and so forth.

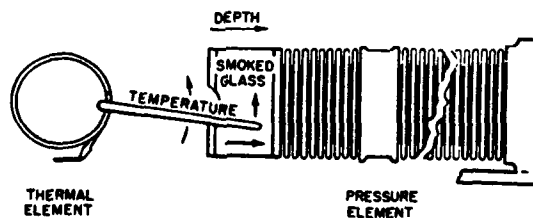
Other sources of noise are from man-made equipment. These sources include the circuit of the sonar system, the rush of water around the transducer, and the engines and propellers of the listening ship and other ships.

BATHYTHERMOGRAPH

Sound conditions in the ocean can be predicted if the temperature of the water at different levels is known. The bathythermograph (BT) is a sensitive recording thermometer, which is lowered into the water to obtain a record of the temperature at various depths. A simplified drawing of a BT is shown in figure 10-15. The in-



EXTERNAL APPEARANCE



CONSTRUCTION

Figure 10-15.—Bathythermograph.

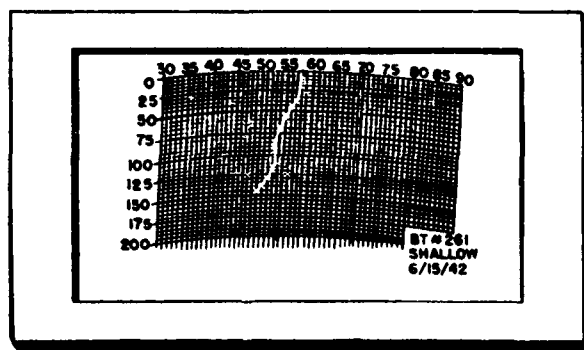
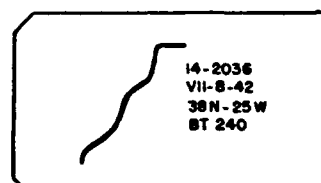
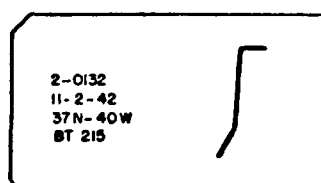
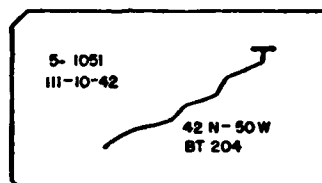
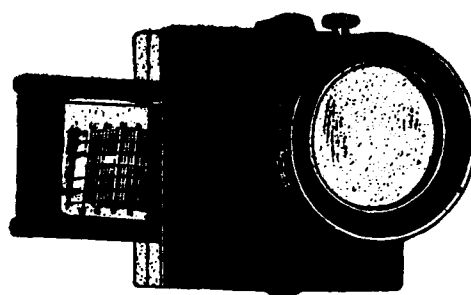


Figure 10-16.—Viewer, grid, and bathythermograph slides.

strument, while being lowered from a ship, automatically draws a graph of the temperature for corresponding depths.

As the BT is lowered, a stylus is moved laterally over a smoked slide by the thermal element, which is activated by the expansion or contraction of the liquid inside the element. Simultaneously, increasing hydrostatic pressure compresses a bellows (the pressure element), which moves the smoked slide at right angles with respect to the stylus movement. The temperature and depth are thus recorded simultaneously on the slide.

To clean the slide after the BT is raised, the slide is removed and dipped into fresh water. The slide is then labeled and dipped into lacquer (for preservation). When the slide is to be read, it is placed in a viewer, as illustrated in figure 10-16.

Several examples of the graphs drawn on slides by a BT are illustrated in figure 10-16. The horizontal line at the top of the slide indicates the temperature at the surface. The letters and numbers on the slide are for identification purposes. The first line contains the slide number and the Greenwich mean time when the BT was lowered. The second line contains the date with the month indicated in roman numerals. The third line indicates the latitude and longitude to the nearest degree. The fourth line contains the serial number of the BT.

TRANSDUCERS

Two main types of transducers are used in searchlight and scanning sonars. One type operates on the principle that certain types of crystals change their length when a voltage difference is applied between two faces of the crystal. This effect is called the **PIEZOELECTRIC** effect, and is described in Chapter 9 of *Basic Electronics*, NavPers 10087. The other type operates on the principle that certain magnetic materials, such as alloys of nickel and iron, will change their length when magnetized. This effect is called the **MAGNETOSTRICTIVE** effect.

Crystal Type

Crystal transducers are made up of several hundred small crystal blocks of Rochelle salt or ammonium dihydrogen phosphate (commonly called ADP). These blocks vibrate at a high frequency when a high-frequency voltage is impressed across them. It is characteristic of crystals to have a natural frequency of vibration. When a voltage of this frequency is applied to the crystal, the amplitude of vibration becomes a maximum. A combination of crystal blocks (of different sizes) is made to operate over a fairly wide range of frequencies. The vibration of the crystal with applied a-c voltage is illustrated in figure 10-17.

Another characteristic of the crystal that is very useful in sonar is that when a crystal is compressed and expanded at a certain frequency, a small signal voltage

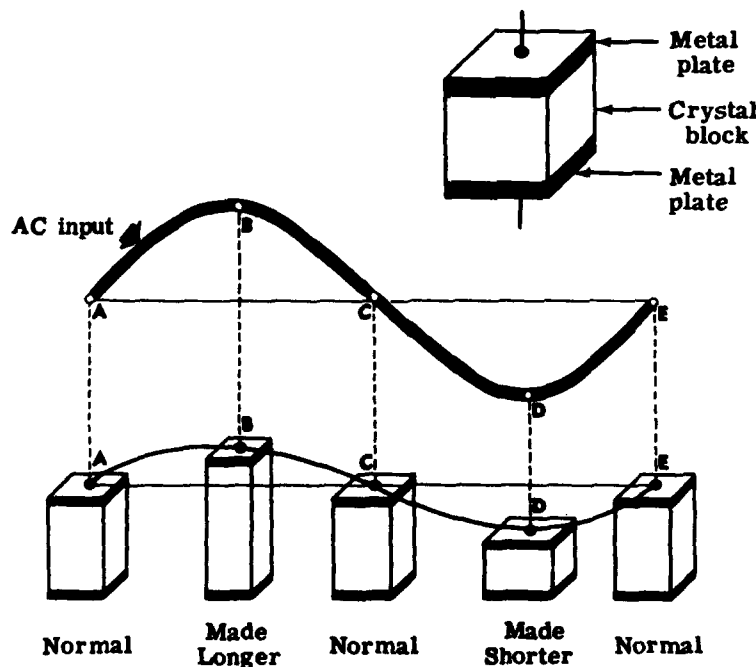


Figure 10-17.—Vibration of crystal with applied a-c voltage.

of the same frequency will appear across the crystal. Thus, the same set of crystals can be used for sending out a signal and reconvertng the associated echoes into an electrical signal, which can be amplified in the receiver.

A searchlight-type crystal transducer is made up of several hundred small crystal blocks, which are stacked together to form a large plate (fig. 10-18). One end of each crystal block is attached to a bakelite-covered steel plate, and the opposite end is allowed to vibrate freely. The free ends of the crystal blocks comprise the sound transmitting and receiving surface. The entire crystal plate assembly is mounted in a case with a face of steel or rubber, which is transparent to sound waves. A sound-insulating baffle is placed behind the fixed ends of the crystal array to prevent back radiation. The transducer case is filled with a special type of purified castor oil, which is air-free and water-free. The oil protects

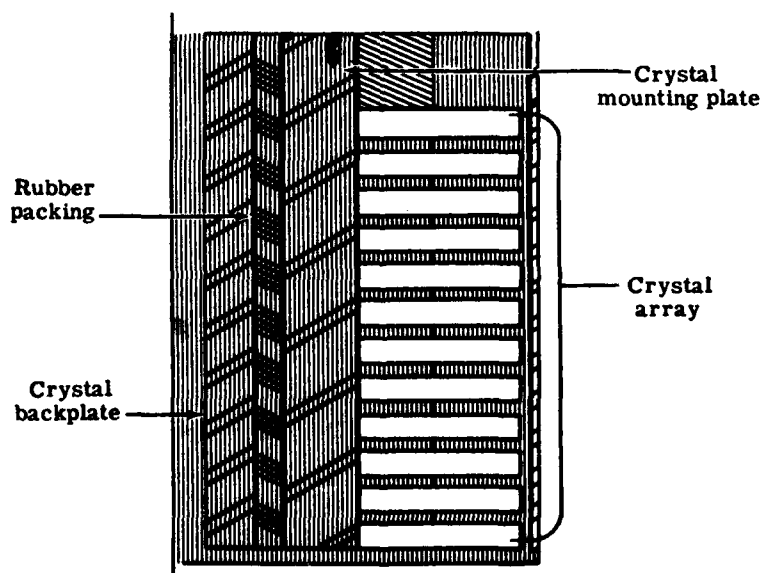


Figure 10-18.—Crystal transducer.

the crystals from water, which would damage them, and serves as a sound-conduction medium, which is similar to sea water.

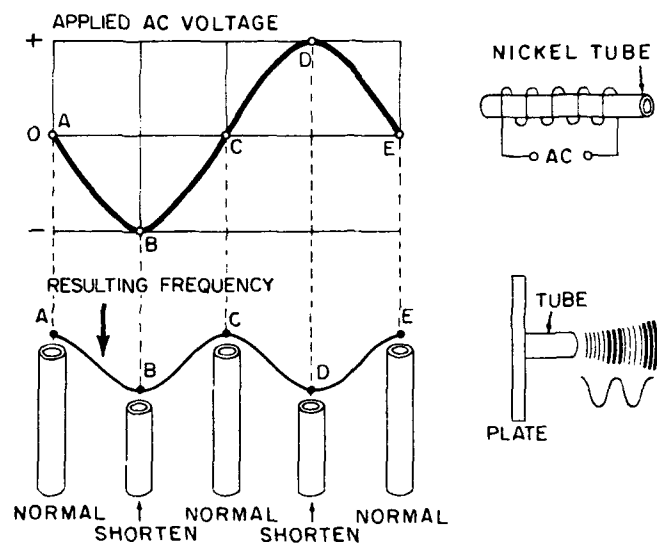
Magnetostrictive Type

Searchlight-type magnetostrictive transducers contain a large number of nickel or nickel alloy tubes. Each tube forms the core of a magnetizing coil, as illustrated in figure 10-19, A. When an a-c voltage is supplied across the coil, a magnetizing field is established, which causes the associated tube to periodically contract with the applied voltage, as illustrated in the figure. The resulting frequency of tube vibration is twice that of the applied voltage because the tube length is normal at zero voltage, and shortens when the voltage is at negative maximum and again at positive maximum.

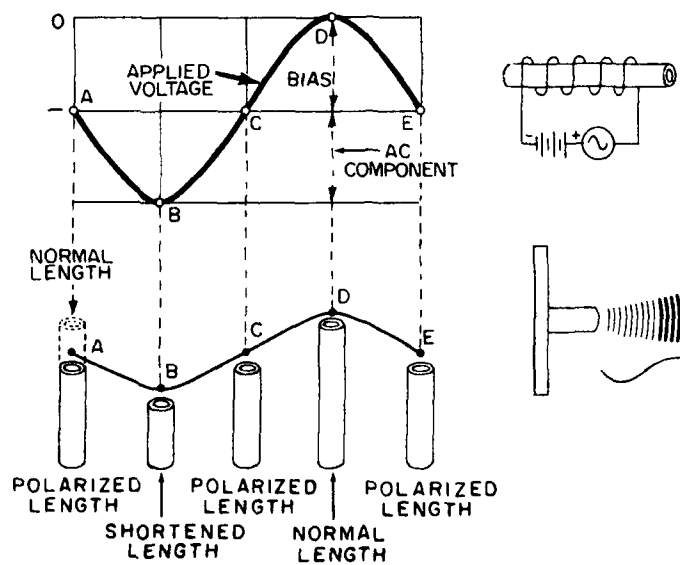
In order for the tube to vibrate at the same frequency as that of the applied voltage, a polarizing d-c voltage is applied with the a-c signal in such a way that the tube only approaches its normal length when the bias voltage and the a-c signal are equal and opposite, as illustrated in figure 10-19, B.

The natural frequency of vibration of the nickel tubes should match very closely the frequency of the applied signal voltage. Unless this condition is realized, the amplitude of vibration of the tube will be too small to be of value. The tubes are made to the proper size so that they will vibrate at the desired frequency. Crystals will operate over a relatively broad band of frequencies. Magnetostrictive transducers are driven at only one frequency—the natural (resonant) frequency of the nickel tubes.

Nickel tubes can also transform a sound echo of the proper frequency into an electrical signal. When the length of the nickel tube is altered, the strength of the magnetic field associated with the nickel tube is caused to vary. This action induces a voltage in the coil surrounding the nickel tube, as the changing field links the



A EFFECT OF MAGNETIZING COIL WITHOUT BIAS



B EFFECT OF DC POLARIZING VOLTAGE

Figure 10-19.—Action of magnetostrictive transducer.

turns of the coil. This signal voltage is connected to the receiver for amplification.

The basic construction of a searchlight-type magnetostrictive transducer (fig. 10-20) is similar to that of a crystal transducer, except that the case and diaphragm are made so that they also have the same natural frequency of vibration as the nickel tubes. Crystal transducers, on the other hand, have a broader range of vibration.

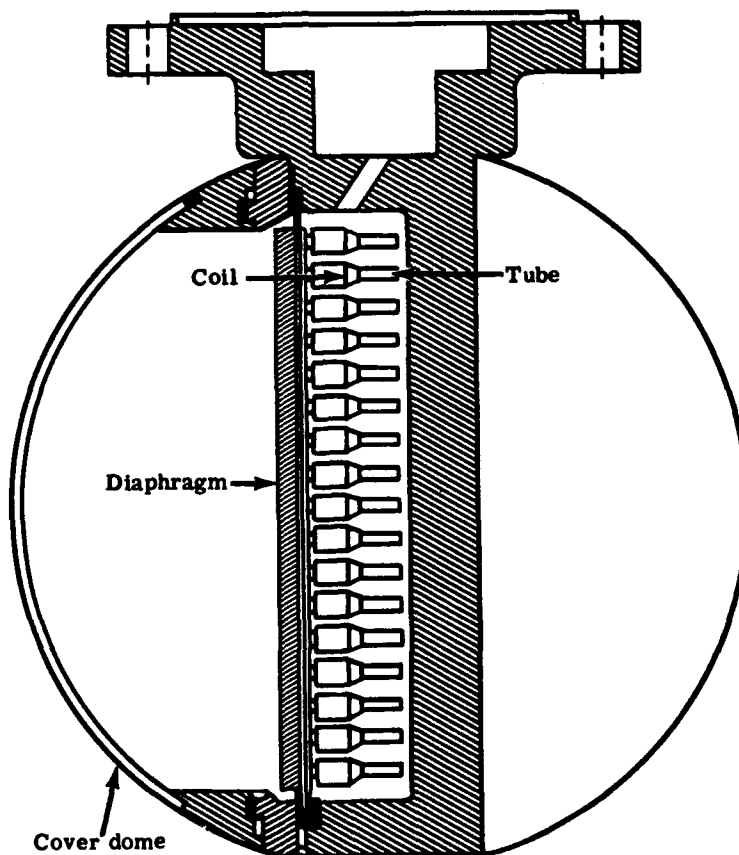


Figure 10-20.—Construction of magnetostrictive transducer.



Figure 10-21.—Lamination type transducer.

The wider frequency range of crystal transducers makes them especially suited for receiving all sorts of underwater signals. By using groups of various size crystals in the same transducer, the frequency coverage can be made very broad. This arrangement permits the sonar operator to hear all sorts of underwater noises, including the sounds from the engines and propellers of other ships and submarines. In addition, the sonar operator may also change the frequency of his signal at will, so as to secure any particular frequency that works best for the conditions existing at the moment. Rochelle salt crystals are more sensitive to picking up echoes than ADP crystals, but ADP crystals can put out a louder signal into the water.

The principal limitation of crystals is that they cannot be driven to put out as strong a sound beam as magnetostrictive transducers. A crystal will break if too large a voltage is placed across it; whereas, a nickel tube can put out many times the power of a crystal without damage.

A magnetostrictive transducer employing staves and nickel laminations in place of nickel tubes, and permanent magnets, in place of a d-c polarizing voltage is illustrated in figure 10-21. Actually, there are two transducers in a common housing. The principal, or search, portion consists of 48 electrically independent, vertical staves (S) arranged symmetrically with their axes parallel to the axis of the cylinder. The upper portion is another ring of 48 staves (M) (approximately one third as long) employed for echo ranging on deep targets at short range.

SONAR RECEIVER

When the sound echo returns from a target, it is very weak. A large amount of the sound energy is lost when it travels out toward the submarine, and only a small portion of the signal ever hits the submarine to be reflected. The reflected echo does not all go back to the

transducer because a submarine is not a flat surface facing the projector. Much of the echo is reflected along different paths, which may never hit the transducer, and the portion of the echo that finally reaches the transducer is weakened by losses caused by absorption and scattering.

The sonar receiver must amplify this very weak echo and convert its frequency to an audible range so that the resulting signal is strong enough to be heard in the loudspeaker and recorded on various indicators.

A sonar receiver has two main requirements—high sensitivity and adjustable bandwidth. It must be sensitive so that it can pick up very weak echo signals from distant targets. It must have an adjustable bandwidth so that it can amplify a broad band of frequencies for listening, and so that it can amplify only a very narrow band of frequencies (only the echo) while echo ranging. A narrow bandwidth is necessary while echo ranging so that only the particular frequency of the echo is amplified, thereby eliminating many other noises that would tend to obscure the echo.

A sonar receiver differs from the conventional communications receiver in that it must pick up signals of audio frequency or ultrasonic frequency rather than radio frequency. The sonar receiver is of the inverted superhet type. In the conventional superhet, the incoming signal frequency is higher than the intermediate frequency. In the inverted superhet the incoming signal frequency is lower than the intermediate frequency. A sonar receiver that is used for both listening and echo ranging picks up a signal somewhere between 13 and 37 kc, and by means of a tunable local oscillator and a mixer increases the signal to a frequency of about 60 kc. The intermediate frequency is amplified, the output detected, and the audio signal amplified, as illustrated in figure 10-22. Either modulated or unmodulated signals may be received. Unmodulated signals, such as those commonly used in echo ranging, are made audible by mixing them with the output of a variable frequency

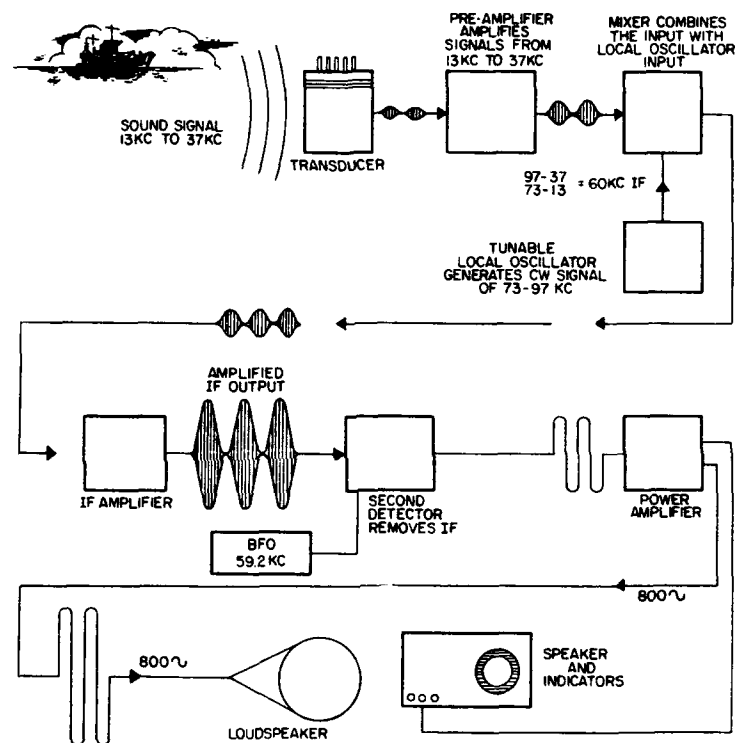


Figure 10-22.—Block diagram of sonar receiver.

oscillator at the second detector. This arrangement is like the BFO used in communications receivers to detect CW signals. The pitch of the output signal may be adjusted to any desired audio frequency. Other sounds such as would be picked up in listening (engine and propeller noises and so forth) are mixed with the local oscillator at the first detector; the output consists of an amplitude modulated i-f signal. The output of the i-f amplifier is demodulated at the second detector without the BFO and the resulting audio signal amplified in a conventional manner.

SEARCHLIGHT-TYPE SONAR SYSTEM OPERATION

A typical searchlight-type sonar system includes a transmitter, transducer, receiver, and various indicators, as illustrated in figure 10-23. The transmitter, D, contains a master keying relay, H, which switches the transducer, G, to the transmitter when signals are being sent out—and to the receiver, C, when echoes are being received. In operation, the transmitter is connected to the

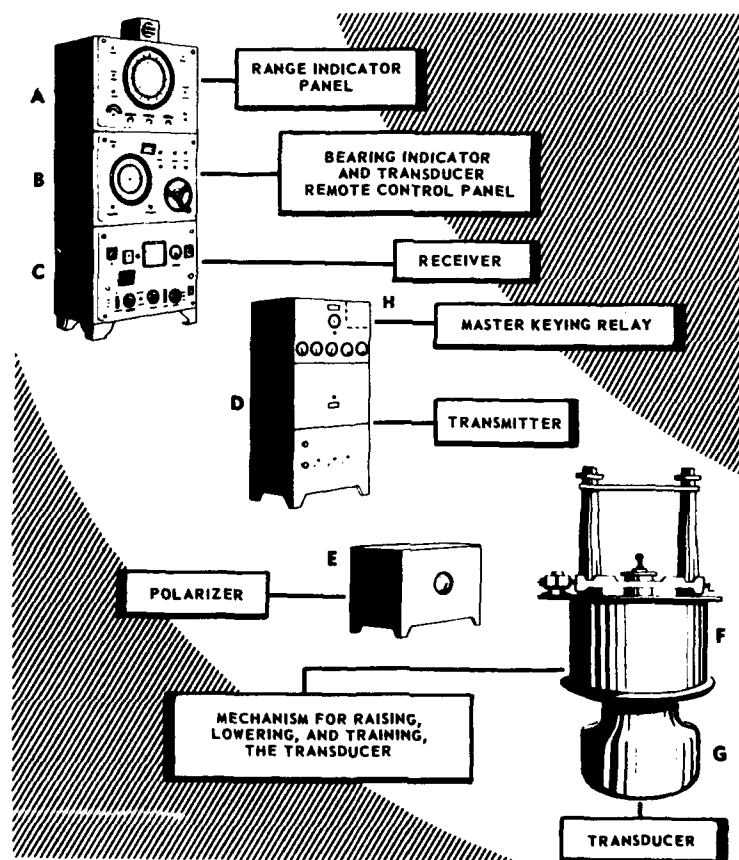


Figure 10-23.—Searchlight-type sonar system components.

transducer only for the length of time that the signal is being sent out. As soon as the signal has stopped, the keying relay immediately disconnects the transmitter from the transducer and connects the receiver to the transducer. Included in the system are controls for raising, lowering, and turning the transducer by remote control. These controls are located in control panel B, next to the bearing indicator dial.

When the sonar system is not in operation, the sound transducer and the waterproof dome in which it is mounted are both up inside the ship. To place the sonar system in operation, the transducer and its dome must be

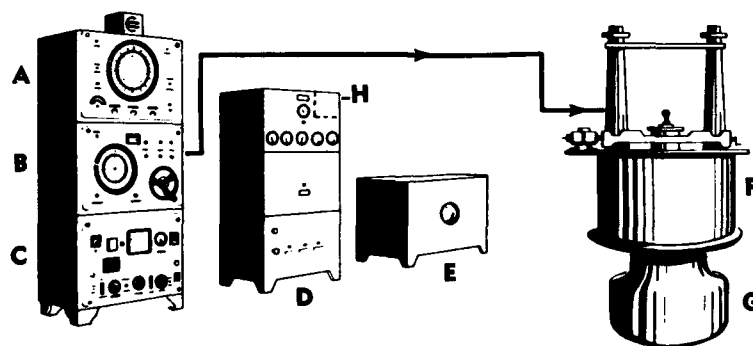


Figure 10-24.—Components used in raising, lowering, and training the transducer.

lowered beneath the ship. Pushbuttons for raising and lowering the transducer are located on the bearing indicator. As soon as the transducer is completely lowered, it can be turned in the desired direction inside its dome by turning the handwheel located on the bearing indicator panel. The pointer on the bearing indicator shows the position of the transducer with respect to true north and relative to the bow of the ship. Figure 10-24 illustrates the portions of the sonar system involved in raising, lowering, and training the transducer.

Transmitting the Signal

When the sonar range indicator (fig. 10-25, A) reads zero yards, it triggers the master keying relay, H. The master keying relay turns on the transmitter, D, and connects the transmitter to the transducer, G. With the aid of the polarizer, E, the transducer projects the sound into the water at the same frequency as generated by the transmitter.

Receiving the Echoes

After the range indicator has triggered the master keying relay for the desired length of time, the triggering impulse goes off (fig. 10-25, B). The master keying relay turns off the transmitter and connects the transducer to the receiver, C. The receiver feeds the amplified signal into the range indicator (on VISUAL) and into the speaker.

Functional Block Diagram

A functional block diagram of a searchlight-type sonar echo ranging system is illustrated in figure 10-25, C. The signal from the keying unit starts a cycle of operation at the instant the range indicator is in the zero range position.

The initiating signal goes to the switching relay, to disconnect the transducer from the receiver circuits and to connect the transducer to the transmitter. Shortly after the end of the transmitted pulse, the switching relay reconnects the transducer to the receiver circuits.

The initiating signal also goes to the transmitter, which then delivers a pulse to the transducer.

The initiating signal also goes to the bearing deviation indicator to start the vertical sweep on the cathode-ray tube.

Objects encountered by the sound beam will reflect a part of the sound energy back to the transducer. The echo signal from the transducer goes through the switching relay to the receiver and to the phase comparison circuits of the BDI.

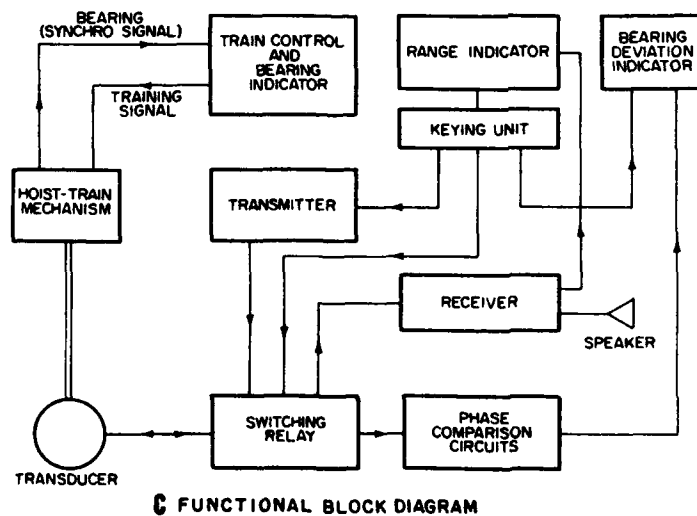
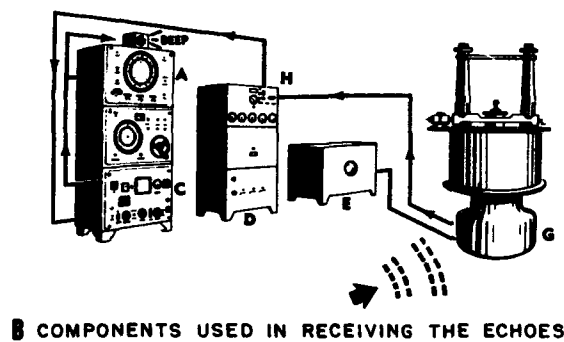
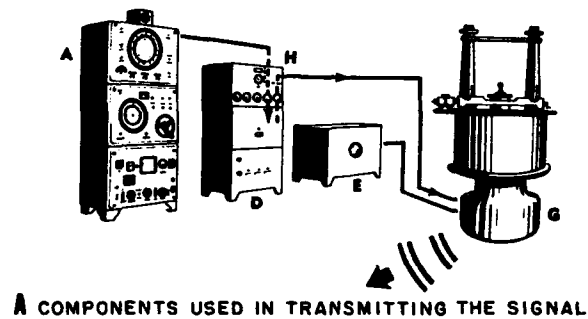


Figure 10-25.—Components used in transmitting the signal and receiving the echoes.

In the receiver the signals are amplified and mixed with a local oscillator to produce the i-f signal. After further amplification, the i-f output is mixed with another local oscillator to give a beat frequency signal in the audible range. After further amplification this signal is fed to a loudspeaker. A part of the audio signal is rectified in the receiver and delivered to the range indicator.

At the end of an interval the keyer produces another signal and the cycle is repeated. The interval depends on the range of the search being conducted. If the range is 5000 yd, the interval must be long enough to allow the transmitted signal to travel 5000 yd and for the echo to return the same distance. At a velocity of 1600 yd per second, this interval is $\frac{5000 \times 2}{1600} = 6.25$ seconds. For shorter ranges the interval is less. The keying unit has an adjustment to vary the interval between transmissions for different ranges.

Sounds from the water or from the target that are not a reflected portion of a transmitted pulse may also be received, provided they are in the transducer beam and within the frequency range of the transducer and receiver. These sounds will be heard in the loudspeaker and will produce indications on the BDI and range indicator. Because they have no fixed relation to time, the range indications are of no value.

The hoist-train mechanism is operated by remote control from the training control and bearing indicator unit, through a power drive.

Limitations

To accomplish a well ordered underwater search with a typical searchlight-type sonar, the sonar operator must wait 12.5 seconds for echoes to return from targets 10,000 yd away, as illustrated in figure 10-26, A $\left(\frac{10,000 \times 2}{1600} = 12.5\right)$. Even if he is searching at a 1000-

yard range (which is too short for ordinary searching) he must wait 1.25 seconds for echoes to return from targets that are 1000 yd away, as illustrated in figure 10-26, B ($\frac{1000 \times 2}{1600} = 1.25$).

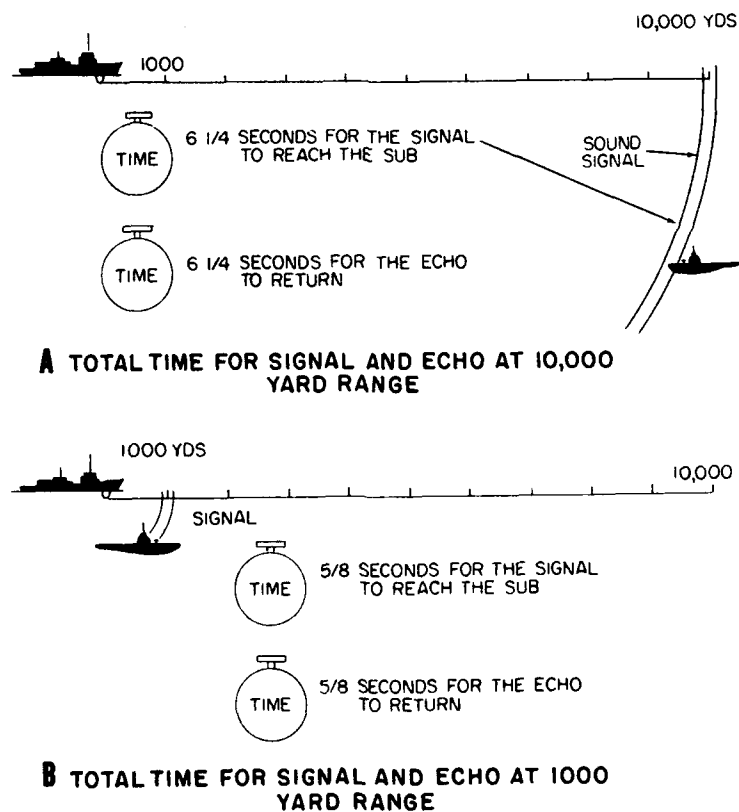


Figure 10-26.—Factor of time in searchlight-type sonar.

When this time-consuming operation is added to the fact that in a well organized search the transducer should not be trained more than 5° between signals, the result is a large amount of time required to search only a half

circle (180° of the area around the ship). Thirty-six signals would be required to search $180^\circ \left(\frac{180}{5} = 36 \right)$. Searching at a 10,000-yard range would require $\frac{10,000 \times 2}{1600} = 12.5$ seconds for each signal and for 36 signals would require $\frac{36 \times 12.5}{60} = 7.5$ minutes. A lot can happen in this interval of time. A submarine can pick up the sonar signal and if in the right position it may take evasive action before the sonar operator can detect it; or, which is more important, a submarine can get into position in this time interval and torpedo its target.

Another major disadvantage of searchlight-type sonar is the fact that once the operator picks up a target and identifies it as a submarine, he must spend all of his time keeping track of it. Even with the help of the BDI and the attack plotter, normal search operations must stop. If there are two submarines at different bearings from the sonar ship, the chances are that the operator will only be able to keep track of one of them, while the other gets away. Also the hazards of trying to get through a mine field by depending on a typical searchlight-type sonar are great. The time consumed in locating one mine might cause the sonar operator to miss others in the path of the ship.

SCANNING-TYPE SONAR SYSTEM OPERATION

Scanning sonar has solved the problem of the large amount of time required to search a wide area. It permits the operator to search the entire area around his ship in the time required for one signal. Thus a circle 1000 yd in radius can be searched in 1.25 seconds, or a circle 2000 yd in radius can be searched in 2.5 seconds, and so forth. The same operation would take at least 80

times as long with a conventional searchlight-type sonar. Scanning sonar also allows the operator to keep track constantly of all underwater objects within his range. It presents a complete and continuous picture of all underwater objects and all noise sources within its range, thereby enabling the operator to keep track of many targets at the same time, as illustrated in figure 10-27.

PPI Presentation

The picture presented by a scanning type of sonar is projected on a PPI screen, and the final picture looks very much like a radar PI presentation; it gives very

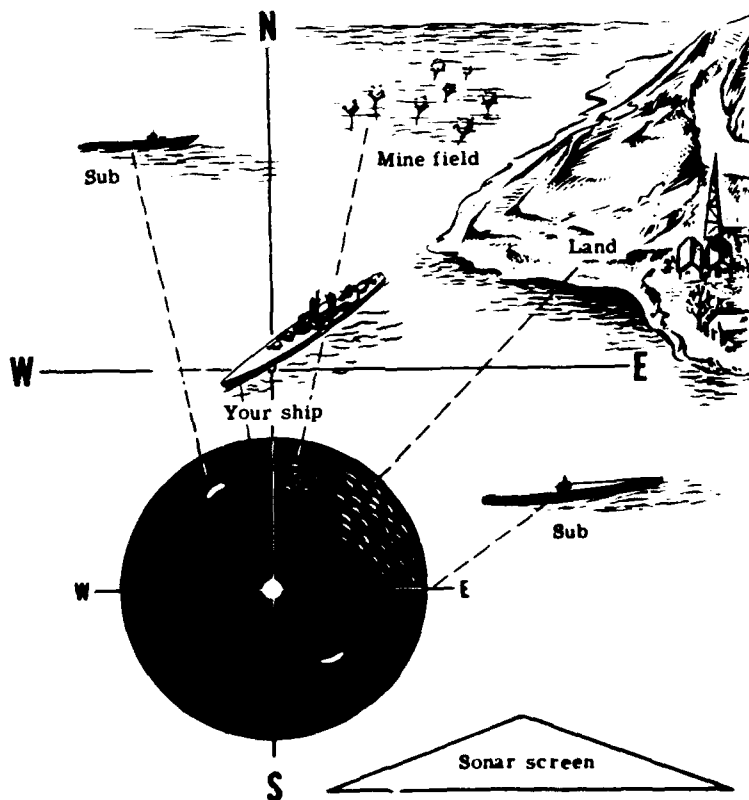


Figure 10-27.—Scanning sonar presentation.

much the same information. At the center of the screen is a bright spot that indicates the position of own ship. Various underwater objects are represented by bright spots on the screen. The picture on the screen is actually an underwater map of the area about own ship. The following things may be observed from the map:

1. The size of the various bright spots enables a fair estimate of the size of the underwater object.

2. The distance of the various bright spots from the center of the screen gives an estimate of the distance of the underwater object from own ship.

3. The bearing of the various underwater objects can easily be determined from the screen. The top of the screen is north, the bottom is south, the right is east, and the left is west. The outside edge of the screen is marked off in degrees so that bearings can be measured with accuracy.

4. If the target is moving, its motion will be visible on the screen. Fixed underwater objects, such as a reef or bed of seaweed, will appear to move on the screen, but they will move only in a line parallel and opposite to the motion of own ship. A target such as a submarine will have a motion all of its own on the screen. This independent motion may be at any angle with respect to the direction of own ship, as indicated in figure 10-28, A.

5. Under certain conditions, it is possible to see the wake of a submarine under observation. By examining the wake, the operator will be able to tell in which direction the submarine is headed even before he has had time to detect its own motion on the screen (fig. 10-28, B).

6. Submarines that are too far away for echo ranging may still emit enough noise to be detected. Under these conditions, a small segment of the screen will appear to be filled with a rippling pattern, which is caused by various noises given off by the submarines. The direction of the noise source can be told immediately by reading off the bearing from which it comes (fig. 10-28, C).

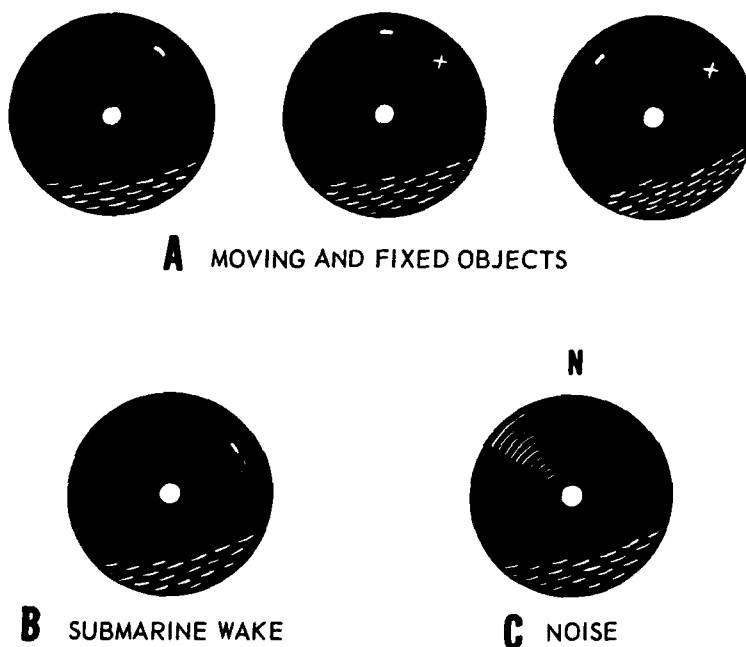


Figure 10-28.—Appearance of various objects on PPI screen.

Transducer

The scanning sonar transducer is nondirectional. It is of cylindrical shape, and the magnetostrictive elements are distributed uniformly around it. Now when the nickel elements are made to vibrate by the transmitter, the sound will be projected equally in all directions. Instead of the signal being a disk of sound as with searchlight-type sonar, the signal will be a thin-walled cylinder, which expands in diameter as the sound travels outward.

Video Scanning Switch

When the sonar is receiving (listening), the video scanning switch makes the transducer sensitive to signals returning from a narrow sector or beam, as illus-

trated in figure 10-29. The switch blade rotates rapidly around the stationary segments that lead to the individual transducer elements. This switch is the core of the scanning sonar system. The signals derived from it are equivalent to those that would be obtained from a highly directional, rapidly rotating transducer. A rotating transducer would not be practicable because of mechanical and electrical difficulties resulting from the high speed required.

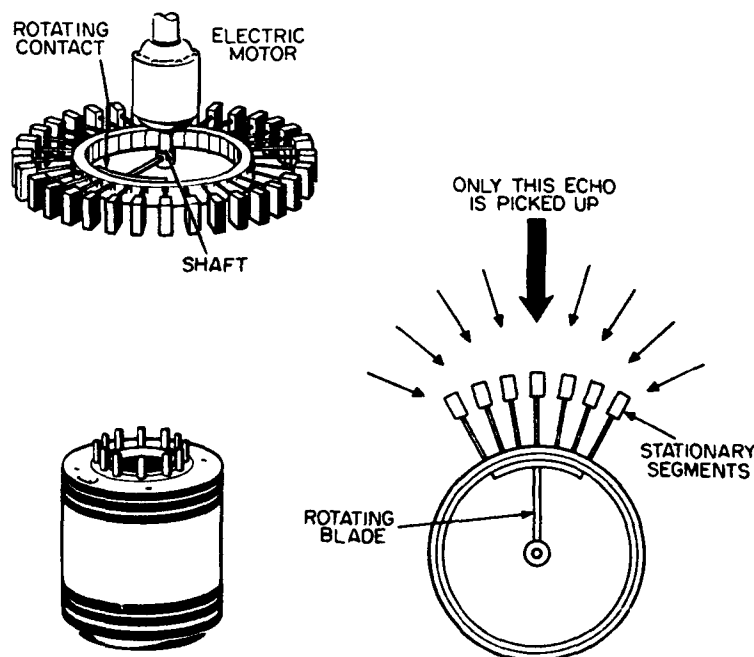


Figure 10-29.—Scanning switch.

The video scanning switch rotates at a speed of approximately 1750 rpm. The width of the rotating blade is sufficient to span several of the stationary segments (about seven) at any instant. The video scanning switch thereby receives the signals from as many transducer elements and gives, in effect, a rotating and highly directional listening pattern. Approximately 29 scans (complete revolutions) are obtained each second.

The coupling between the rotating blade and the stationary segments is capacitive. The blade forms one plate of a capacitor, and the segments spanned by it form the other plate. The coupling occurs across a narrow air gap only a few thousandths of an inch thick. This arrangement eliminates all sliding contact noise.

The ring of sound that makes up the signal travels outward at 1600 yd per second; and sound reflected by underwater objects travels back in the same amount of time that it took to go out. Because of this relationship, the area from which echoes are returning at any given moment is a narrow ring half way between the outgoing original signal and the transducer, as illustrated in figure 10-30. This area is called the ACTIVE REGION.

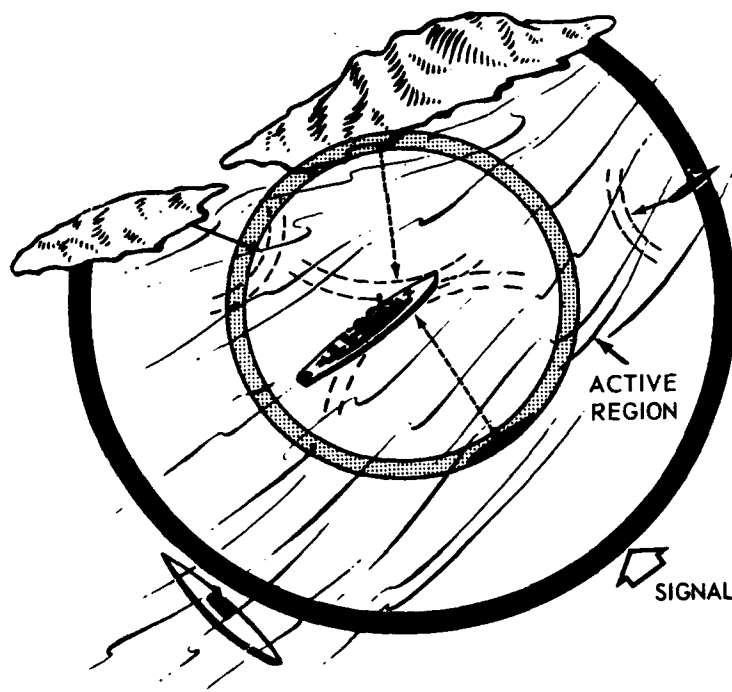


Figure 10-30.—Active region.

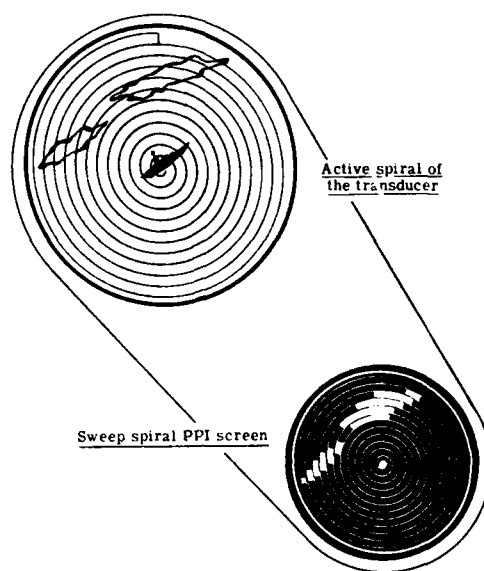
Spiral Scan

Spiral scan is used on the cathode-ray tube to obtain the PI presentation (fig. 10-31, A).

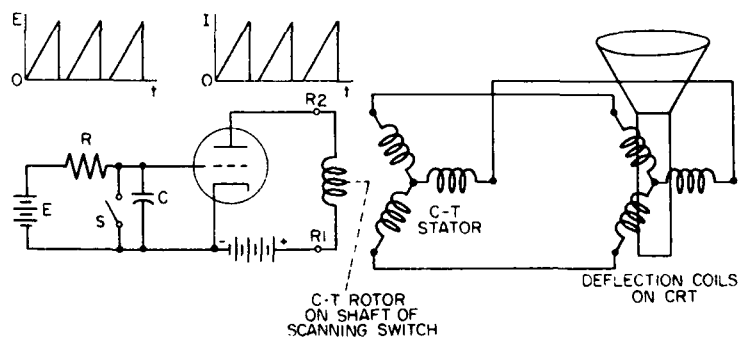
One way to obtain the spiral scan with magnetic deflection is to rotate the field of the deflection coils in step with the shaft of the video scanning switch, and, at the same time, to vary the strength of the field uniformly between zero and a maximum value. This action causes the electron beam to begin the trace at the center of the scope screen and to rotate at a constant speed and with a uniformly increasing radius to the outer edge of the screen. The outer edge corresponds to full deflection. At this location the trace is then cut off, and the action begins again at the center.

The control transformer, CT (fig. 10-31, B) is mounted on the shaft of the video scanning switch and makes one complete revolution for each revolution of the switch. The three stator windings of the control transformer are connected to the magnetic deflection coils on the neck of the cathode-ray tube. Thus, the deflecting force applied to the electron beam at any instant depends upon (1) the orientation of the axis of the CT rotor with respect to the axes of the associated stator windings at that instant and (2) the relative magnitude of the current in the CT rotor at that instant.

If the voltage applied to the CT rotor is of constant amplitude and the rotor revolves synchronously with the scanning switch, rotationally induced voltages will be generated in the CT rotor field coils. These voltages will cause currents to flow in the corresponding deflection coils of the cathode-ray tube. The accompanying magnetomotive forces will produce a rotating magnetic field about the neck of the cathode-ray tube. The deflection coils are arranged so that the speed of rotation of the field will be the same as that of the scanning switch. Thus, the electron beam will be acted upon by a rotating magnetic field that will generate a circular trace. The diameter of the circular trace will be proportional to



A SPIRAL SCAN



B SIMPLIFIED CIRCUIT

Figure 10-31.—Spiral scan and circuits.

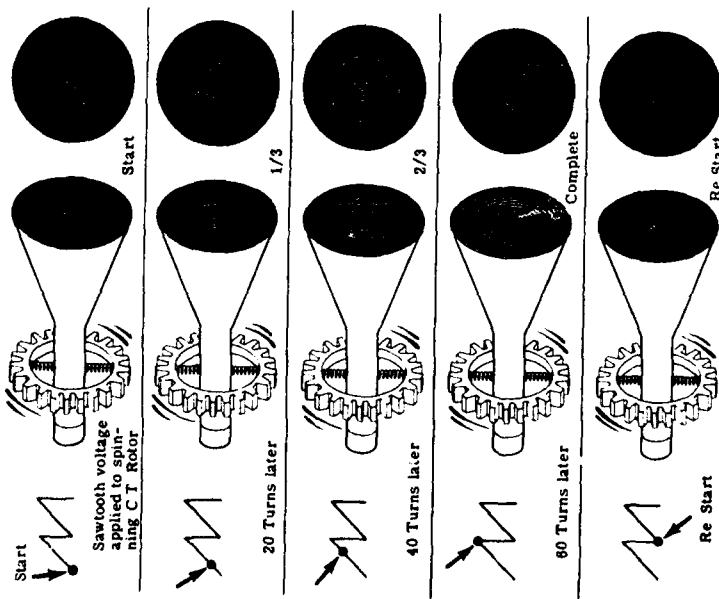
the magnitude of the voltage applied to the CT rotor. This voltage, in turn, will be proportional to the distance between own ship and the active area (area from which echoes are being returned to the transducer).

If the voltage applied to the CT rotor is varied in accordance with a saw-tooth waveform as the CT rotor revolves, a spiral trace will be produced. The RC circuit at the left in figure 10-31, B, represents the source of the saw-tooth voltage. Before the equipment is keyed, switch S is opened and capacitor C charges at a uniform rate through R. This action applies a positive-going signal to the triode grid, thus causing the plate current through the CT rotor to increase linearly. When a signal is being transmitted, switch S is closed for a short time, and C discharges quickly to zero. The switch is then opened again. When C charges to a value corresponding to full deflection on the scope screen, the keying circuits are triggered, thereby starting another cycle.

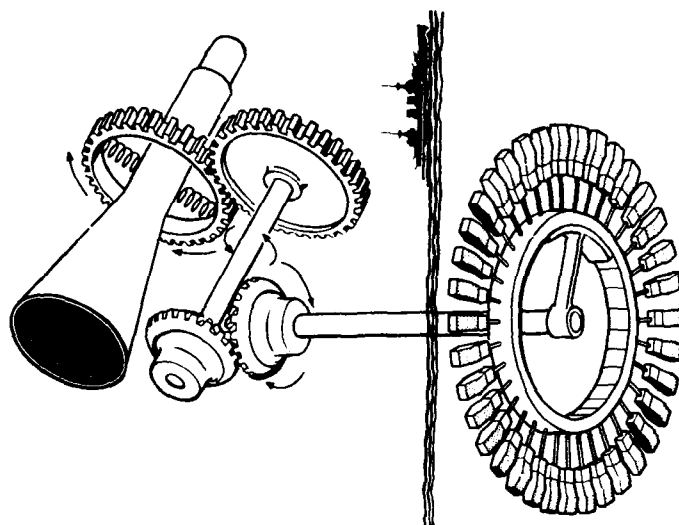
The increase in current in the CT rotor as C charges up is relatively slow compared with the time for one complete rotation of the video scanning switch. Thus, many complete rotations of the switch occur during the time that the plate current through the CT rotor is increasing from zero to the maximum value. The action is illustrated diagrammatically in figure 10-32, A. The spiral on the scope screen is made to duplicate the spiral of the active region about the transducer by synchronizing the deflection field of the cathode-ray tube with the spinning of the scanning-switch connection from the transducer to the receiver (fig. 10-32, B).

This relation is in marked contrast to a radar PPI indicator. In the radar indicator the saw-tooth voltage rises very rapidly, and many cycles of saw-tooth voltage are applied for one complete rotation of the radar antenna. However, in the sonar equipment, only one cycle of saw-tooth voltage is applied for many complete rotations of the video scanning switch.

Because the rotation of the magnetic field of the deflection coils of the cathode-ray tube is synchronized with that of the video scanning switch, the spiral on the scope screen will exactly duplicate the spiral of the active region.



A STEP BY STEP GENERATOR OF SPIRAL SCAN



B SYNCHRONIZING THE SWEEP WITH THE SCANNING SWITCH

Figure 10-32.—Generation of spiral scan.

If the receiver output is connected between the cathode and grid of the cathode-ray tube, every echo coming in will create a bright spot on the spiral trace. The result will be a reproduction of the underwater region around own ship.

Audio Scanning Switch

In addition to the video scanning switch, a similar switch called an audio scanning switch is used. This switch enables the operator to listen to the audio signals coming in from a particular direction at the same time he is observing the pattern of echoes coming in from all directions. A radial trace, or CURSOR, line (fig. 10-33) is produced on the scope screen to indicate the direction of train of the audio scanning switch. The cursor is also used to determine range more accurately than it can be estimated directly on the scope screen without the cursor. The length of the cursor line can be read off a dial, which tells the target range in yards. The angle of the cursor line can be read off another scale, which tells the bearing of the target in degrees from true north or in degrees relative to the course of own ship.

The audio scanning switch does not rotate continuously as does the video scanning switch, but may be trained by the operator from one position to another at a maximum rate of about 8 rpm.

During the transmission of a sound signal the deflection coils of the cathode-ray tube are disconnected from the CT on the video scanning switch and connected to a CT on the audio scanning switch. The CT rotor on the audio switch is excited from a single phase, 60-cycle source in order to establish a magnetic deflecting force on the electron beam of the cathode-ray tube. In this case no rotating field is produced. Instead, the axis of the beam deflection is a straight line, the bearing of which is the same as that of the audio scanning switch. A signal from the same 60-cycle source is applied between grid and cathode of the cathode-ray tube to brighten the

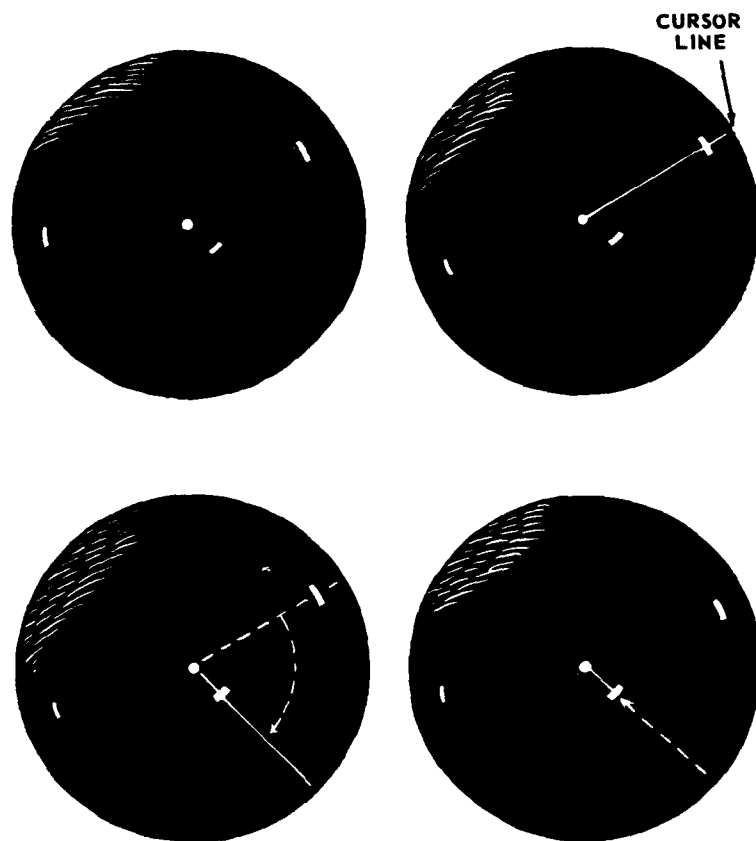


Figure 10-33.—Audio cursor line.

trace during the positive half cycle and to cut the tube off during the negative half cycle.

The action provides a continuous trace from the center of the scope screen to a point corresponding to the maximum field strength of the 60-cycle exciting voltage. At this time the cathode-ray tube is blanked so that the cursor becomes the radius of a circle rather than its diameter, and bidirectional ambiguity of the target is eliminated.

The magnitude of the 60-cycle, exciting voltage may be manually adjusted to place the end of the audio

cursor directly on the target and the operator reads the target range on the associated range scale.

Summarizing, the operator can see all the echoes coming in on the PPI screen and hear them in the loud speaker. He can investigate a particular echo by rotating the audio cursor to it and adjusting its length until its end falls on the target. Then he can hear the incoming echo and listen for other sounds coming from the target; at the same time he can read the range and bearing accurately.

Analysis of Block Diagram

The keying circuits initiate the action by pulse signals that go to four units (fig. 10-34) as follows:

1. Transmit-receive switch.
2. Transmitter.
3. Sweep generator.
4. Control circuits.

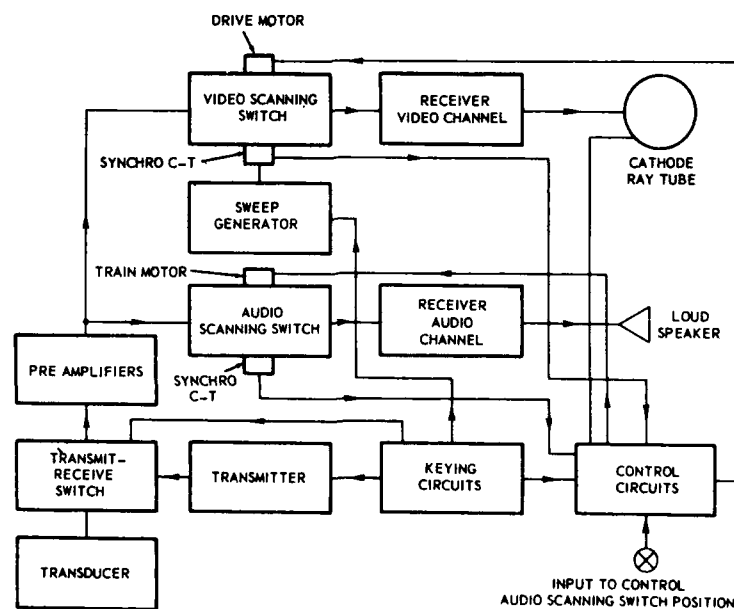


Figure 10-34.—Block diagram of a scanning-type sonar system.

The transmit-receive switch switches the transducer from the receiver circuits to the transmitter circuits. The transducer is reconnected to the receiver circuits about 0.1 second after the end of the pulse.

The transmitter is triggered by the keying pulse; this action forms a pulse of the proper length, amplitude, and frequency.

The keying pulse returns the sweep generator to zero range and initiates a new cycle.

The keying pulse causes the control circuits to disconnect the cathode-ray tube deflection coils from the control transformer on the video scanning switch and connect them to the CT on the audio scanning switch.

The keying pulse also causes the control circuits to generate a positive blanking voltage and to apply this voltage to the cathode of the cathode-ray tube to blank out any spurious traces. However, the blanking voltage is removed long enough to permit the audio cursor line to be formed, as previously described.

At the end of the keying interval the control circuits are returned to the listening condition.

The pulse formed by the transmitter goes through the transmit-receive switch to the transducer where it is applied simultaneously to all of the transducer elements. The transducer then emits a sound pulse of the same frequency and length as the keying pulse; the emission is equally strong in all directions.

Target echoes or other sounds returning to the transducer generate electrical pulses that go through the transmit-receive switch to the preamplifiers. There is one preamplifier for each transducer element. In the preamplifiers the signals are amplified before going to the scanning switches.

The video scanning switch couples these signals to the receiver amplifier (video channel), as previously described. The effect is similar to that which would be produced by a rapidly rotating and highly directional transducer. The amplified output of the receiver video channel is rectified and applied to the grid of the cathode-

ray tube to brighten the trace on the scope screen; thus, the echoes become visible on the screen as they are received.

The signal from the preamplifier is also applied to the audio scanning switch. In this switch the signal is picked up, in effect, as though it were coming from a highly directional transducer trained on a particular bearing, as determined by the switch position. The audio scanning switch is positioned by a train order from the control circuits to the associated drive motor. The output of the audio scanning switch is amplified in the receiver audio channel where it is converted to the desired audio frequency before being fed to a loudspeaker.

The sweep generator controls the rotor current in the control transformer associated with the video scanning switch. When this voltage rises to the value corresponding to full deflection (center to edge of the scope screen), it triggers the keying circuits, and another cycle of operation is begun.

TARGET DEPTH-DETERMINING SONAR

Active Searchlight Type (QDA)

Although scanning sonar and searchlight sonar can pick up target echoes and determine their range and bearing, they cannot determine the depth of the target. In order to determine the depth of a target so that depth charges can be set properly, a special depth-determining sonar system is required. The QDA sonar system is a special active searchlight-type, depth-determining sonar, which can be used with either searchlight or scanning sonar. Thus, the QDA sonar and the QHB—a scanning sonar are used together as a team to give all the information as to the location of a submarine.

Using the target bearing information obtained from an echo ranging equipment, the QDA equipment is trained to the bearing of the target and used to search in the vertical plane until the target is located. This

equipment uses a crystal-type transducer. The transducer is referred to as a "sword" and is mounted with its largest dimension vertical. It is long and thin, and provides a rather wide horizontal but narrow vertical beam pattern, permitting accurate depression angle determination, as illustrated in figure 10-35.

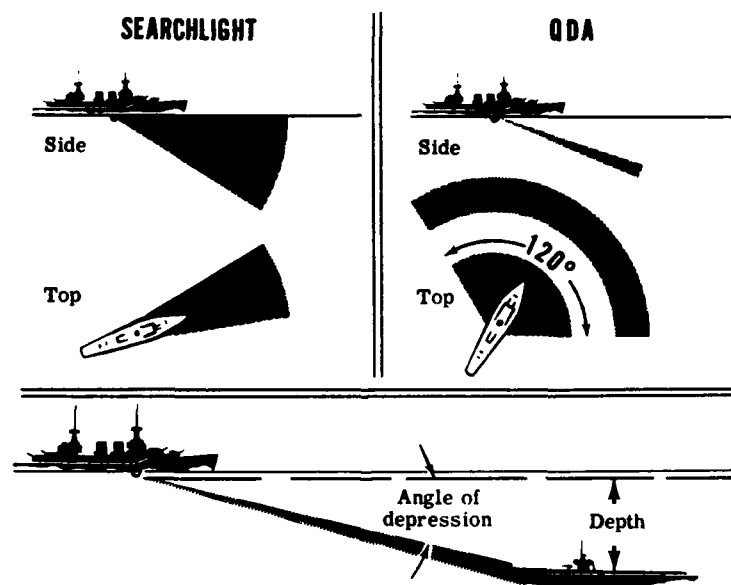


Figure 10-35.—Comparison of searchlight and depth-determining sonar.

Depth-determining sonar works on the same principle as searchlight-type echo ranging sonar. The only difference is that the depth-determining transducer can be tilted so that it can send its searchlight beam down into the water at any desired angle. The QDA uses a device like the BDI so that the operator will know when the beam is aiming directly at a submarine. This device is called the DDI (Depth Deviation Indicator).

The QDA tells the operator the angle of depression of the submarine below the surface, and the range of the submarine to the transducer. Several calculations are

necessary to reveal the depth of the target below the surface, and the surface range from own ship to a spot directly over the target.

Passive Scanning Type (AN/SQR-4)

The sonar set AN/SQR-4 is a depth-determining equipment designed primarily for use aboard vessels as a part of an integrated sonar system. The integrated system is explained later. The AN/SQR-4 does not transmit a signal. It is always associated with an azimuth echo ranging system that does transmit, and the echoes from the transmitted pulse of the azimuth system are utilized by the AN/SQR-4. The display circuits of this sonar are synchronized with the display circuits of the associated azimuth system. An audio system is provided to obtain more detailed information on a particular target at any desired depression angle. This equipment is passive because it depends on the transmitted signal of another equipment; it is a scanning-type equipment because it receives on all bearings at the same time rather than at a particular bearing, as with searchlight operation.

SONAR RESOLVING EQUIPMENT

Recording the depth of a submarine is not just a simple matter of measuring the angle of depression of the QDA beam and calculating the depth. Other factors are involved. The angle of depression increases as own ship approaches a position over the submarine, and account must be taken of the effect of a change in water temperature that will bend the QDA beam.

The OKA sonar resolving equipment is designed to keep a continuous record of the position of a submarine while both own ship and the submarine are moving (fig. 10-36).

The OKA resolving equipment performs the following functions:

1. It makes a record of the distance the signal must travel from the transducer to the submarine.

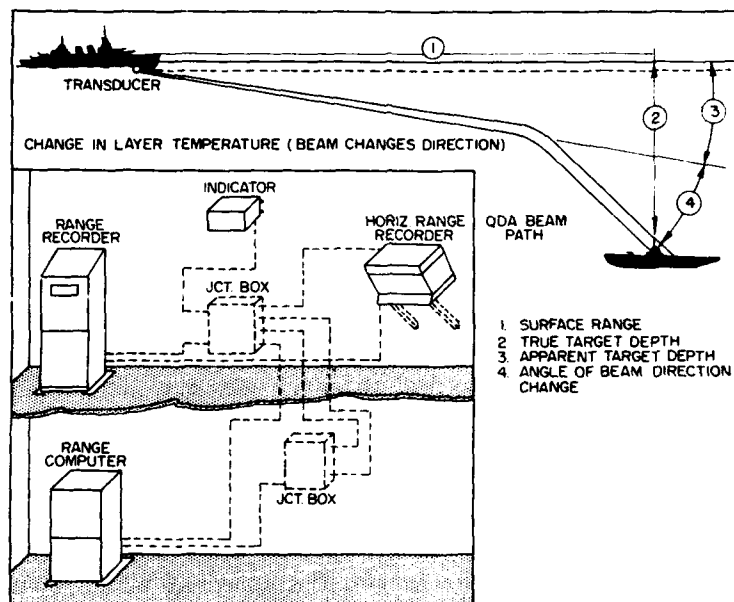


Figure 10-36.—The OKA sonar resolving equipment.

2. It makes computations based on information from the bathythermograph record, and transforms the computation into an electrical signal, which is fed into the QDA depth recorder. The QDA depth recorder then gives a continuous record of the true depth of the submarine.

3. After the QDA searchlight beam is trained on the target and the true depth is determined, the OKA resolver sends out control signals that automatically tilt the QDA transducer so as to keep the depth-determining beam always trained on the submarine. The QDA operator watches the DDI to see that the submarine is always in the center of the QDA beam. If the beam drifts off the target, the QDA operator enters a correction factor, and the OKA resolver continues to direct the beam on the submarine for the new conditions. This feature is called **AIDED TRACKING**.

4. The OKA resolver synchronizes the sound signals of the QHB—a scanning sonar and the QDA depth-determining sonar and synchronizes the various recorders of these systems.

5. The OKA resolver calculates and records the horizontal range between own ship and a point directly over the submarine, as illustrated in figure 10-36.

SCANNING SONAR SYSTEM

The QHB/OKA/QDA system furnishes all the information and much of the automatic assistance required to locate a submarine and to carry out a well-directed attack against it.

An ATTACK DIRECTOR is also used with the system. This unit gives the A/S officer a summary of all he needs to know about the submarine. The attack director is a panel on which are mounted various dials that tell the horizontal range of the target, the speed at which own ship is approaching the submarine, the course of own ship, the course and speed of the target, the change in the course and speed of the target, and the proper time to fire.

SOUNDING EQUIPMENT

Sonar sounding equipment is designed to determine the water depth beneath the hull of a vessel. The equipment, known as a Fathometer, operates by emitting a pulse of ultrasonic energy into the water and measuring the time required for the pulse to travel to the bottom and return. A representative sounding equipment is the AN/UQN-1B. This sonar sounding equipment consists of a sonar transducer and a transmitter-receiver unit. The transducer consists of an array of ammonium dihydrogen phosphate (ADP) crystals in a pressure tight, flanged housing. The housing is designed for flush mounting in a standard hull ring in the bottom plating of a surface vessel, or outside the pressure hull of a

submarine. This transducer, when transmitting, converts the electrical energy of the transmitter into sound energy in the water. This energy is directed downward and when the reflected energy strikes the transducer, it is converted into electrical energy and amplified by the receiver. The echoes are indicated in two ways—(1) by a recorder and (2) a depth indicator.

Recorder

The recorder allows the receiver output to be visible on an electrically sensitive paper as a plot of depth below the vessel versus time. The plot on the chart paper

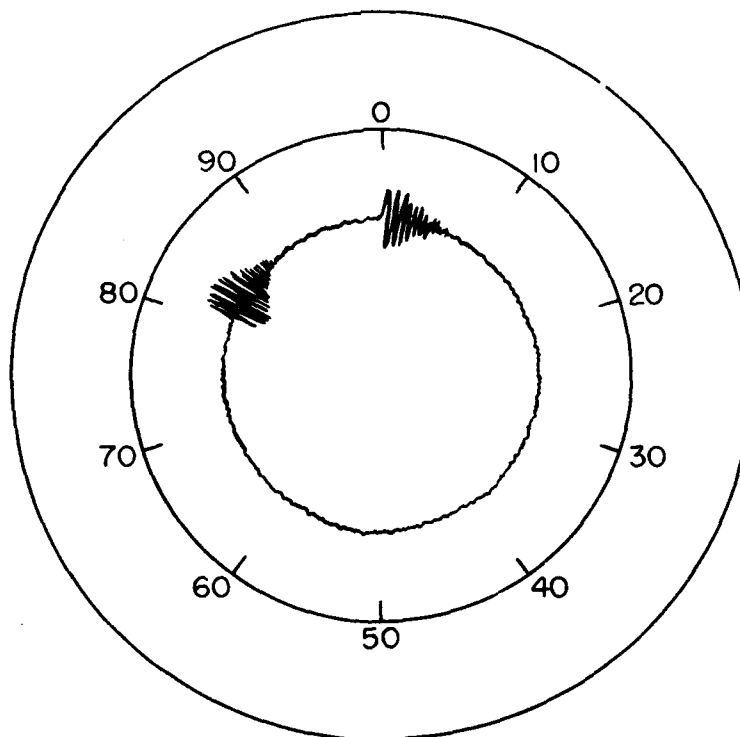


Figure 10-37.—J SCAN presentation.

becomes a representation of the contour of the bottom when the surface vessel proceeds at a constant speed and in a straight line. The action is similar to that of the range recorder, previously described.

Depth Indicator

Depth indication on the 100-foot or 100-fathom range (full scale) is obtained on the face of a 3-inch cathode-ray tube by radial modulation of a circular sweep (fig. 10-37). This method of presentation is called J SCAN. The illuminated trace follows a circular course at constant angular velocity. The time to complete one revolution is the time required for an echo to return from 100 feet or 100 fathoms at an assumed speed of sound in water of 4800 feet per second. Both the transmitted pulse and the returning echo cause a radial modulation (perpendicular to the circular sweep), as illustrated in the figure. An engraved translucent shield in front of the scope screen furnishes the scale. The transmitted pulse appears at zero depth and the echo at a position on the scale corresponding to the depth of the object from which the echo is returned.

UNDERWATER COMMUNICATIONS

CW Transmission

All echo-ranging sonar equipments are provided with a means of underwater CW communication. An example of such an equipment is Azimuth Scanning Sonar Set AN/SQS-10. The equipment is placed in normal operating condition, except that the transmitter keying relay is disabled. During normal operation the keying circuits generate a pulse having a selected length. This pulse is applied to the transmitter keying relay coil. For CW operation the transmitter keying relay remains energized as long as the hand key remains depressed. Thus the operator has direct control of the transmitter keying and pulse length.

Voice

A typical underwater voice communication equipment is the Sonar Set AN/UQC-1. This sonar set is a single-sideband, suppressed-carrier transmitter-receiver designed to provide communication between submarines and surface vessels at ranges up to 12,000 yards or beyond under favorable sonar conditions. Because the medium of transmission is water, sound waves transmit the intelligence. The carrier is 8.0875 kc. In the transmitter, voice frequencies from 250 to 3000 cycles are converted to the upper sideband frequencies of 8338 cycles to 11,088 cycles. The carrier suppression and lower sideband elimination are accomplished by a balanced modulator and a band-pass filter. The carrier is reintroduced after reception of the signal and then converted to voice frequencies by demodulation.

On transmission, the microphone converts the audio signal into a voltage, which is amplified by the speech amplifier. The output from the speech amplifier is limited to maintain a constant output level. The modulator beats the audio signal with the 8.0875-kc carrier signal and removes the carrier; a band-pass filter removes the lower sideband. The driver amplifier amplifies the upper sideband and provides the necessary power to drive the power amplifier. The power amplifier drives the transducer, which delivers the sound energy to the water.

On reception, the transducer converts the sound signal in the water into electrical signals, which are amplified by the receiver amplifier and then heterodyned in the detector with the 8.075-kc carrier to separate the intelligence. The driver amplifier increases the magnitude of the audio signal before it goes to the loudspeaker.

LISTENING

Detection of underwater objects by listening for the sounds they emit is known as LISTENING. The success of detection by listening is primarily dependent on the

ability of the operator to hear and properly evaluate the sounds picked up by the listening equipment.

The listening system consists of a hydrophone, an electronic receiver, a bearing indicator, and a loud-speaker or headphones. The hydrophone is a directional type of transducer designed only for listening.

The sound-listening problem for the operator consists primarily of learning to distinguish between (1) sounds emitted by another ship's machinery through the hull and from the propeller and (2) the multitude of other sounds that exist in the ocean.

Listening is used chiefly by submarines. A surface vessel produces considerable noise, and this noise interferes with the detection of the sounds of other ships, especially the low-volume sounds by submarines. On the other hand, the difference in the noise output enables a submarine, which has a very low noise level, to detect the presence of a surface vessel rather easily.

In order that listening will be a tactical aid, the sonar operator by means of his ear must be able to:

1. Distinguish the sounds emitted by the target from the usual background noises.
2. Distinguish between the various kinds of ship sounds with a view to possible identification of the type of vessel emitting them, and obtain information on the ship's operating conditions.
3. After detecting and partially identifying a target, obtain information concerning its approximate location and motion while it is still at comparatively long range.

Much research has been done on ship and submarine sounds, with a view towards controlling or possibly eliminating revealing noises. The basic principle in this problem is the same as that underlying visual camouflage—that is, to render the target inconspicuous by making it resemble its background. Thus, the sounds that are unavoidably emitted should, in the ideal case, have frequencies that are the same as those of the background noise.

Another application of listening is in the design and operation of acoustic mines and in the prediction of their actuating ranges. This application, as well as the defense against mines of this type, requires a knowledge of the sounds emitted by the vessels against which they are to be used.

Sonic Listening Equipment

Sonic listening equipment consists of a hydrophone; a training unit; a receiver amplifier; and indicator, headphones, or loudspeaker. This system is illustrated in figure 10-38.

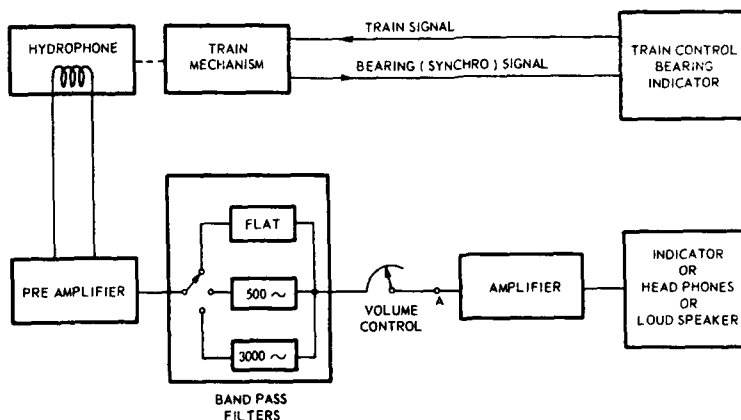


Figure 10-38.—Sonic listening system.

The hydrophone used in listening equipment is generally of the magnetostrictive type. Some equipments use the crystal type. The function of the hydrophone is to convert sound energy in the water into electric energy that can be amplified and heard in the loudspeaker. The hydrophone must have a directional characteristic, which is used in two ways. First, it permits the operator to discriminate against unwanted sound, and second, it

enables the operator to determine the direction from which the desired sound is coming.

The method of training the hydrophone may be either manual or power. The more modern equipments use an electrically operated drive called a SERVOMECHANISM. This drive is usually an amplidyne servomechanism similar to that described in Chapter 17 of *Basic Electricity*, NavPers 10086. The operator can train the hydrophone on any bearing relative to the ship. A synchro repeater system is used to give bearing indications to the operator in both relative and true bearings, as described earlier in this chapter. The two functions of the training device are to allow the operator to train the hydrophone and to provide him with a visual indication of the bearing to which the hydrophone is trained.

The receiver amplifier is an audio amplifier with wide frequency response. The electrical signals from the hydrophone enter the receiver where they are amplified until their intensity is sufficient to operate a loudspeaker or headphones, as the need may be. There is no need for any frequency conversion because the signals entering the receiver in sonic listening are already in the audible range. It may be desirable, under some conditions, to limit the frequency response of the receiver in sonic listening. If the principal signal desired by the operator were 500 cycles it would be possible to increase the signal-to-noise ratio by reducing the band pass of the receiver just enough to include this frequency. Any noise falling outside the band pass of the receiver would not be heard.

The choice of headphones or loudspeaker depends upon the airborne noise of the surroundings. The purpose of these devices is to convert the electrical signals from the receiver into sound impulses that can be heard by the operator. The cycle is completed by this conversion. In the water the signal is sound energy (first), and when it falls on the hydrophone, electric impulses are generated. These electric impulses are amplified and reconverted into sound by loudspeakers or headphones.

Ultrasonic Listening Equipment

Ultrasonic listening equipment employs an ultrasonic hydrophone when a sharper bearing indication is desired. The principal difference in sonic and ultrasonic listening is in the receiver amplifier. When the sound to be heard is in the ultrasonic frequency range, some method must be used to bring it into the audible or sonic range. Heterodyning in the receiver accomplishes this change in frequency, as illustrated in the block diagram of figure 10-39.

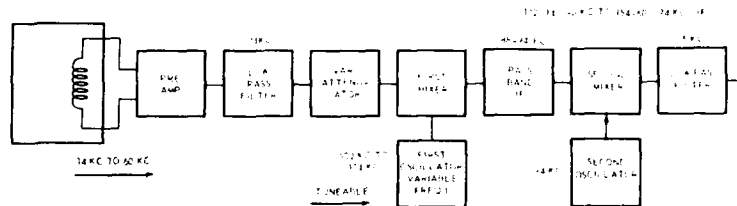


Figure 10-39.—Block diagram of ultrasonic converter.

The preamplifier is a broad-band stage at the receiver input. This stage is followed by a filter system and an attenuator. The signal is then fed into the first mixer where it is mixed with the output of a variable frequency oscillator. The tuning of this oscillator provides for the adjustment of the receiver to various frequency inputs. The signal from the mixed stage is amplified through an i-f amplifier similar to that of a superhet radio receiver, as previously described (fig. 10-22). The intermediate frequency is usually above the frequency of the ultrasonic signal and is the sum of the ultrasonic signal and the output of the oscillator. The intermediate frequency is then fed into a second mixer where it beats with a second oscillator to give an output in the audible-frequency range. This converting system supplies the regular audio amplifier of the receiver, which drives the speaker.

QUIZ

1. What is the derivation of the word sonar?
2. What underlying operational principle is common to both radar and sonar?
3. What is the relative speed of a sonar echo compared to that of a radar echo?
4. A searchlight sonar can detect underwater objects in how many directions at a time?
5. A scanning sonar can detect underwater objects in how many directions at a time?
6. What are four principal uses of sonar?
7. What are sound waves called that have frequencies above 15,000 cycles?
8. What is the speed of sound in (a) air, (b) water, and (c) steel?
9. What four basic components comprise a sonar system?
10. A circular scale range indicator is essentially similar to what very familiar instrument?
11. How is it possible, with a sensitized paper range recorder, to distinguish between a true echo and temporary disturbance in the water?
12. What type of sonar may employ a bearing deviation indicator?
13. What general transducer arrangement is employed with bearing-deviation indicators?
14. In what way is the plane of operation of a sonar bearing-deviation indicator modified to make it a sonar depth-deviation indicator?
15. The sonar attack plotter (fig. 10-9) gives what three items of information concerning the problem of carrying out an attack against an enemy submarine?
16. How do targets show up on the screen of a PPI indicator?
17. If the distance between the source and the receiver of the sound energy is changing, the frequency of the source of the sound energy seems to change. What is this apparent change in frequency known as?
18. A change in what three factors influences the speed of sound and hence the bending of the sound beam in sea water?
19. What is the name of the instrument used to determine a record of the temperature of sea water at various depths?

20. What two general types of transducers are used in searchlight and scanning sonars?
21. What is the relative output power capability of a magnetostrictive transducer compared to that of a crystal transducer?
22. What are the two principal requirements of a sonar receiver?
23. How long does it take for echoes to return from targets having a range of 10,000 yards?
24. How long does it take to search through 180° of bearing with a searchlight-type sonar for targets having a range of 10,000 yards?
25. What is the relative length of time required to scan through 360° of arc with a searchlight-type sonar compared to the time required to scan the same arc with a scanning-type sonar?
26. On a scanning sonar PPI presentation, where is own ship's position on the screen?
27. To what distance on the PPI screen is target range proportional?
28. What are the directional characteristics of the scanning sonar transducers?
29. What, in effect, is the function of the video scanning switch?
30. What type of scan is used on the cathode-ray tube to give the PPI presentation?
31. What is the relative speed of rotation of the field about the neck of the cathode-ray tube (fig. 10-31, B) and the video scanning switch?
32. What is the function of the audio scanning switch?
33. What is the function of the audio cursor?
34. What is the principal difference between a searchlight-type echo ranging sonar and a depth-determining sonar?
35. Which component in a sonar system gives the A/S officer a summary of all he needs to know to carry out a well directed attack against an enemy submarine?
36. What is the principle of operation of a sonar Fathometer?
37. What method of voice transmission is provided by Sonar Set AN/UQC-1?

CHAPTER

11

INTRODUCTION TO RADIAC

BACKGROUND INFORMATION

The Necessity For A Knowledge of Radiac

Because of the great unseen radiation dangers that will be present in the event of nuclear warfare, it is necessary to use instruments that will make the personnel involved aware of these dangers so that all possible safety precautions can be taken to reduce the exposure. Even in peacetime, the danger is still present for those who work in many of our laboratories and at the various reactors. Another important factor that must be kept in mind is that the nuclear Navy is already here and growing fast; and the Electronics Technician will very likely be involved with control mechanisms and protective devices such as air and water monitors.

Our physical senses alone cannot give us warning, and therefore it is necessary to depend solely on instruments. These instruments must be accurately calibrated and functioning properly and used in the most effective manner if they are to serve their basic function of saving human life.

It is therefore extremely important that the technician know the instruments(their capabilities and limitations), know how to use them, and know how to calibrate and repair them. Calibration and repair are jobs for well-trained technician specialists.

The harmful consequences of radiation result from their ionizing effect on the human body. Plants as well as animals are affected by radiations. Much remains to be learned about the specific effects on the human body, but the destruction of blood and tissue cells and the formation of bone cancer are certainly well-known possibilities.

There are at least two ways that a person can acquire (externally) an overdose of nuclear radiation: (1) he can be caught in the open when an atomic bomb explodes nearby or (2) he can remain too long in a radioactive area. Another danger is thermal radiation; however, this is not discussed in this chapter.

The second of these situations may be avoided in many instances by the proper use of RADIAC instruments. The term is derived from the words, "Radio, Activity, Detection, Identification, And Computation."

Two distinct classifications of instruments are used for detecting and measuring ionizing radiations—RARE METERS (SURVEY METERS, when portable) and DOSIMETERS. Rate meters indicate the intensity of ionizing radiations (for example, in roentgens per hour) at the location of the sensitive element of the detector at the time the reading is being made. Dosimeters (self-reading and non-self-reading) indicate the total dosage (for example, in roentgens) of ionizing radiations accumulated by the instrument during the time of exposure to the ionizing radiations. The units of intensity and dosage are explained later. CHARGERS and READERS are used in connection with dosimeters; their functions are described later.

It is the purpose of this chapter to give, first of all, enough background information so that the technician can understand the basic principles of operation of the various types of radiac instruments falling under the two general classifications. Next, brief descriptions of typical Navy equipments and their principles of operation are given. Following this, some general information about the calibration of certain typical instruments

is included. As the title suggests, this chapter merely introduces the prospective ET 3 to the subject of radiac.

The repair and calibration of radiac equipment is a highly specialized type of work and special training in the Navy Radiac Instrument Maintenance School may be required. The four-week course is taught largely by ET 1's or ETC's.

Table 19 includes some of the radiac instruments that have been considered acceptable for Navy use. Additional specialized equipments are used in Navy laboratories and in special applications. It should be emphasized, however, that radiac equipment is continually being improved, and currently used equipment will eventually become obsolete. The Special Equipment Section of the Bureau of Ships has a long-range, planned program for acquiring the best type of radiac equipment suitable for use by Navy personnel.

Many of the instruments listed in the table are described in this chapter.

In this course it is assumed that the technician has had basic courses in electricity and electronics (*Basic Electricity*, NavPers 10086 and *Basic Electricity*, NavPers 10087), and therefore the basic information included in these courses will not be repeated in this chapter.

It should be emphasized that in one chapter of reasonable length the subject cannot be covered in great detail. Additional information may be found in *Atomic Warfare Defense*, NavPers 10097; *Nucleonics for the Navy*, NavPers 10850; special texts put out by the Department of Defense—for example, *Nuclear Physics*, NavPers 10854; and *Theory and Operation of Radiac Instruments*, draft STRDS-5; *Bureau of Ships Journal* for February and March of 1956 and January of 1957 (later issues will also contain valuable information); the *Electron* magazine for May 1950; and there are also numerous commercial books on the subject.

TABLE 19

RADIAC INSTRUMENTS USED BY THE NAVY

Type of Instrument	Radiation Detection or Dose Indication	Radiac Set or Radiacmeter
Survey Meters-----	Alpha	AN/PDR-10 series
	Gamma (high range)	AN/PDR-18 series
	Gamma (high range)	IM-118/PD (with probe)
	Beta/Gamma (low range)	AN/PDR-27G series
Dosimeters-----	Low Dose (indicating)	IM-9D/PD (or higher)
	Medium Dose (indicating)	IM-19/PD (or higher)
	High Dose (indicating)	IM-94/PD
	High Dose (neutron)	IM-112/PD
	Casualty Dose (nonindicating)	DT-60/PD
Casualty Dosimeter Reader-----		CP-95/PD
Dosimeter-----		PP-311A/PD (or higher); battery operated.
Chargers-----		PP-354C/PP (or higher)

Source and Nature of Radiations

The four families of radioactive elements are uranium, thorium, actinium, and neptunium. The first three decompose (by emitting particles from the nucleus) through intermediate steps to form different types of lead. The fourth radioactive family begins with the newly created element, neptunium, and ends by decomposition in a

form of bismuth. Neptunium is an intermediate product of the atomic pile.

From the beginning, man has lived in the presence of a form of radiation from space known as COSMIC RAYS. At the intensity found on the surface of the earth, these rays are not dangerous to man. The natural decay of the radioactive families of elements gives rise to three other types of radiations: alpha and beta particles and gamma rays.

ALPHA PARTICLES, or alpha rays, are fast-moving helium ions. In the un-ionized state, the helium atom has a nucleus made up of two protons and two neutrons; around this nucleus revolve two electrons. When both electrons are stripped from the helium atom in the ionization process, the nucleus then carries two positive charges (two protons). The helium nucleus, with both electrons missing, is the alpha particle. Alpha particles are emitted from the nucleus in atomic disintegrations with considerable velocity—generally between 2000 and 20,000 mi/sec.

BETA PARTICLES, or beta rays, are streams of fast-moving electrons that have been ejected from the nucleus following the conversion of a neutron into a proton and an electron. The electron becomes the beta particle. Because beta particles have small mass (about 1/7500 of the mass of the alpha particle) they may have very high velocities, even approaching the velocity of light.

A beta particle that has the same energy as an alpha particle will move much faster and farther than the alpha particle before its velocity is brought to zero by collisions with the atoms that it ionizes.

GAMMA RAYS behave very much like X rays of very high frequency; they carry no electrical charge. They move with a wave motion and at the speed of light. Essentially, gamma rays differ from visible light only in having a much higher frequency, or a much shorter wavelength. As a matter of fact, the variation in wavelength is the principal distinction between the different types of electromagnetic radiations including (in order

of decreasing wavelengths) radio waves, radar, radiant heat, infrared, visible light, ultraviolet, X rays, gamma rays, and cosmic rays.

The shorter wavelengths are more penetrating. To stop most of the gamma rays that are emitted from radium, several inches of lead are required. Alpha and beta particles can be stopped much more easily.

The NEUTRON is a fourth type of radiation. As the name implies, it carries no electric charge. Because it is neutral it can enter into the nuclei of atoms of the human body and produce nuclear changes that might lead to artificial radiation. (Of course, this action is not limited to the atoms in the human body.) Destruction of the cell is the usual result, and the person who has been subjected to intense neutron radiation is liable to suffer serious injury if not death as a result of the exposure.

The effects of a magnetic field on alpha, beta, and gamma radiations are illustrated in figure 11-1, A.

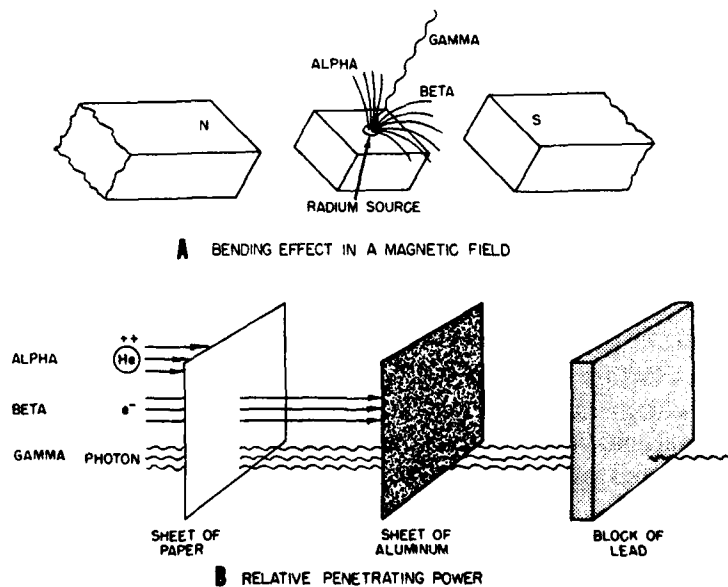


Figure 11-1.—Alpha, beta, and gamma radiations.

The alpha and beta particles are bent in opposite directions because they have opposite charges. However, the gamma rays, which have no charge, are not affected by the magnetic field.

The relative penetrating power of alpha, beta, and gamma radiations is illustrated in part B of the figure. Alpha particles may be stopped by a sheet of paper, and beta particles may be stopped by a sheet of aluminum. Gamma rays, however, can penetrate several inches of lead. Several feet of concrete may be used for absorbing fast neutrons.

Detection of Radiations

Various methods are used for detecting radiations. Each of them depends on a certain effect produced by the radiations—for example, the ionizing effect, the photographic effect, scintillation, and various secondary effects. These effects will be treated more in detail later when instruments are discussed, but for the purpose of an introduction they are treated briefly in this section.

IONIZING EFFECT.—An alpha or a beta particle removes electrons by impact from some of the atoms of a gas through which it passes. These electrons may be collected and used to produce a visual or aural indication in a radiac instrument. A discussion of these instruments makes up the bulk of this chapter.

PHOTOGRAPHIC EFFECT.—Radiations falling on the emulsion of a photographic film cause a darkening of the emulsion, and this effect becomes visible when the film is properly developed. Because the darkening is a cumulative effect, film may be used to indicate the total amount of radiation penetrating the film rather than the rate at which radiation penetrates the film. Film badges (explained later) are worn by thousands of laboratory employees and others who may be exposed to radiation hazards.

SCINTILLATION.—Scintillation is the conversion of radiation energy into visible light. One of the earliest types of radiation detectors employing scintillation was the

spinhariscope, a simplified diagram of which is shown in figure 11-2. When an alpha particle strikes the fluorescent screen, a change occurs in the zinc sulfide and visible light is given off. The tiny flashes of light are magnified by the lens.

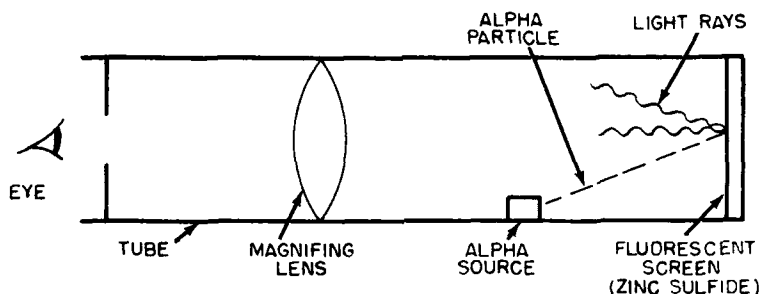


Figure 11-2.—Diagram of spinthariscopes.

Essentially the same effect occurs in the "radium" dials of clocks and watches. A minute amount of a compound of radium is mixed with zinc sulfide, and the continuous bombardment of the zinc sulfide by alpha particles from the radium compound produces visible light because of scintillation.

Because of the development of photomultiplier tubes capable of magnifying the effects of the small flashes of light due to scintillation, scintillation counters are becoming increasingly important in radiac instrumentation.

RADIOPHOTOLUMINESCENCE.—Luminescence is the emission of light from a substance as a result of the absorption of radiations. If the luminescence is caused by visible or ultraviolet radiations, it is called **PHOTOLUMINESCENCE**. Radiophotoluminescence is the luminescence exhibited by certain substances (for example, phosphor glass) when it is exposed first to X or gamma radiations and then exposed to near ultraviolet radiations.

Radiac Detector DT-60/PD is a nonself-reading personnel dosimeter that operates on this principle. The sensitive element (radiophotoluminescent glass) is en-

closed in a case $1\frac{1}{2}$ inches in diameter and is worn about the neck like a pendant.

The sensitive element emits luminescent light under near ultraviolet irradiation after prior exposure to X or gamma radiation. The intensity of this luminescent light is detected and indicated as a roentgen dosage by Radiac Computer-Indicator CP-95/PD.

This radiac detector is an integrating device, and therefore the readings shown by the computer-indicator the total amount of radiation to which the detector has been exposed up to the time of the reading. These readings do not indicate the radiation level at any one time.

WILSON CLOUD CHAMBER.—The Wilson cloud chamber is one of the most useful indicating instruments available to the nuclear scientist. The operation of this instrument depends on the ionizing effects of the radiation that penetrates the chamber. A simplified schematic diagram of a Wilson cloud chamber is shown in figure 11-3, A; tracks left by the various radiations are illustrated (by a rough approximation) in part B.

A little water in the bottom of the cylinder (just above the piston) saturates the air in the cylinder with water vapor. When this piston is moved quickly downward, the air in the cylinder is expanded and thereby cooled slightly. Because cool air normally holds less moisture than warm air, some of the moisture is condensed out (if there are ions present around which the water droplets (fog) can form). If ions (or dust particles) are not present, the air will remain supersaturated for a time.

If radiations from a radioactive source are present in the chamber, strings of ions will be produced in the air inside the chamber, and water droplets will form around them. Thus, if sufficient light shines into the chamber, the white fog tracks become visible against the black surface of the piston top. This affords an excellent opportunity for observation of the movement of CHARGED particles. Neutrons do not produce ions in the

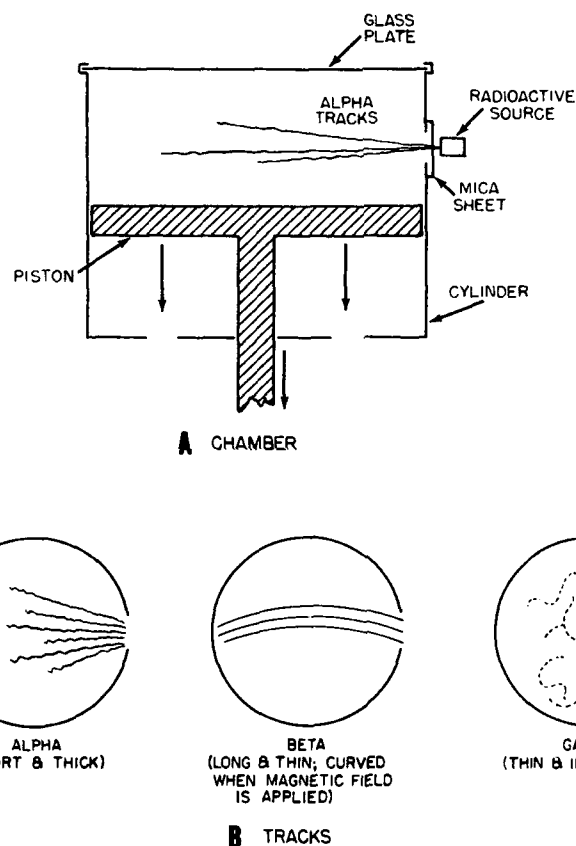


Figure 11-3.—Simplified diagram of a Wilson cloud chamber.

chamber; they cause no fog, and therefore they cannot be detected directly in the chamber.

An inspection of the tracks that the charged particles make in the cloud chamber affords considerable information about the nature of the particles—their size, energy, charge, etc (especially when auxiliary equipment is used).

Tracks of alpha, beta, and gamma radiations are illustrated in figure 11,3, B. Alpha particles make short, thick tracks because they have low velocity and relatively

large mass and charge. Beta particles travel further and leave a thin track because they move at high velocities and have less mass and charge than alpha particles. Gamma rays likewise produce ions and leave tracks, but the mechanism by which the ions are formed is somewhat involved. They produce thin, irregular tracks that can be readily distinguished from alpha and beta tracks.

Units of Radiation

Two different quantities are measured by radiac instruments: INTENSITY (or DOSAGE RATE) and DOSAGE (total amount of radiation absorbed). Intensity (I) is measured in MILLIROENTGENS PER HOUR (mr/hr) or similar convenient units; dosage (D) is measured in ROENTGENS, or similar convenient units.

A roentgen of radiation is defined as follows:

1. The quantity of X or gamma radiation that produces by ionization 1 esu (electrostatic unit; this unit is equivalent to 2.083×10^9 electrons) of positive or negative electricity per cm^3 of air at standard temperature and pressure (0°C and 1 atmosphere).

2. The quantity of X or gamma radiation that produces 2.083×10^9 ion pairs/ cm^3 of dry air under standard conditions.

3. A more recent definition is—the quantity of X or gamma radiation such that the associated corpuscular (alpha and beta) emission per 0.001293 grams of air produces, in air, ions carrying 1 esu of quantity of electricity of either sign.

If the intensity is multiplied by time, the result will be the quantity, or dosage, received. If the intensity of radiation varies at the measuring instrument (during the time the measurement is being made) because the instrument is moved, or for some other reason, the dosage will be the summation of a number of $I \times t$ increments.

As an example, assume that at a certain spot the intensity of radiation is 5mr/hr . If a person stayed at that spot for 1 hour, he would receive a dosage of 5 mr

by the end of the hour. If he then moved to a spot where the intensity was 10 *mr/hr*, at the end of 1 hour he would receive a dosage of 10 *mr* for this hour. His total dosage for both hours would be 15 *mr*.

For calibration purposes, a radioactive source of known strength is required. This may be either RADIUM or COBALT 60; Cesium 137 is also used. The strength (activity) of the calibration source is usually expressed in millicuries.

The CURIE is that weight of any member of the radium radioactive family that disintegrates (emits a ray or particle) at a rate of 3.7×10^{10} atoms per second. One gram of pure radium undergoes 3.7×10^{10} disintegrations in one second, and a milligram therefore undergoes 3.7×10^7 disintegrations in one second. A MILLICURIE is the weight of the radium radioactive family that disintegrates at the rate of 3.7×10^7 atoms per second.

It has been determined that 1 mg of radium (with its disintegration products) enclosed in 0.5 mm of platinum or its equivalent will produce an intensity of 1 *mr/hr* at a distance of 1 yd. The inverse square law may be used to calculate the intensity at other distances.

Because the roentgen is by definition a measurement of the quantity of X or gamma radiation only, another unit is needed for alpha, beta, and neutron radiations.

The unit is called the ROENTGEN EQUIVALENT PHYSICAL, abbreviated "rep." One rep is that quantity of ionizing radiation (alpha, beta, and neutron) that, upon passing into tissue, gives up 83 ergs per gram of tissue (93 ergs per gram of tissue have been suggested).

An ERG is a unit of work (unit of energy which can exert a force of one dyne through a distance of 1 centimeter). When a force of one DYNE (unit of force) acts on a body for a distance of 1 centimeter, one erg of work is done on the body. A dyne is the force necessary to give 1 gram of mass an acceleration of 1 centimeter per second².

The unit of absorbed dosage adopted in 1953 by the International Commission on Radiological Units is the

rad. It is a measure of the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. One rad of absorbed dosage is 100 ergs absorbed in 1 gram of mass.

As may be seen, there is not a great deal of difference, numerically, between the rad and the rep.

Even though the same amount of energy may be given up to the tissue by the different types of ionizing radiation, yet the effect on the tissue may be different. Therefore, another unit, the ROENTGEN EQUIVALENT MAN, abbreviated "rem" has been introduced.

One rem is that quantity of radiation of any type that produces the same effect in man or other mammals as that resulting from the absorption of one roentgen of X or gamma radiation.

The term, RELATIVE BIOLOGICAL EFFECTIVENESS, abbreviated "rbe," is also sometimes used. It is the ratio of gamma or X ray dosage to the dosage that is required to produce the same biological effect by the radiation in question.

Because the experimental values for the rem are based largely on small mammals, the rem values for man (based on the experimental values) may not be entirely accurate. Although the best study of man is man, in this particular case the study must necessarily be a mouse or other small mammal.

Table 20, which is extremely tentative, gives the approximate equivalences between r, rep, and rem.

Health Hazards

It is impossible to predict how much exposure will cause a specific injury to a particular person. The best policy is to acquire the least amount of exposure possible under the circumstances. A general idea of the effects of continuous exposure over various periods of time may be obtained from table 21. The estimated effects listed in the table are based on data extrapolated (estimated beyond the limits of actual experience) from animal ex-

TABLE 20

RADIATION UNITS SHOWING RELATIONSHIPS

Types of Radiation	Roentgen	rep	rem	Remarks
X or gamma-----	1	1	1	
Betal (internal)-----		1	1	
Neutrons (fast)-----		1	10	Based on mice; probably smaller for man.
Neutrons (thermal*)-----		1	2.5	Based on mice; probably smaller for man.
Alpha (internal)-----		1	20	Emitter at fixed point in vital and sen- sitive region.

* Thermal neutrons are relatively very slow neutrons; their velocities are about that of the molecules in the medium at normal temperature.

perimentation and Japanese experience during and since World War II. However, the information is the best now available. The table appeared in the March 1956 issue of *Bureau of Ships Journal*.

The peacetime tolerance dosage has been established at 0.3 r/week for persons who are often exposed to radiation or who work in small-intensity radiation for long periods. However, it is possible that the tolerance dosage may be changed (perhaps lowered).

In times of war, the tolerance dosage for military personnel will very likely be different from the peacetime limits set up for everyone.

Half-Life

The products formed when a nuclear device is detonated continue to emit ionizing radiation for varying amounts of time, depending on the product and the cir-

TABLE 21
EFFECTS¹ OF CONTINUOUS EXPOSURE

Total dose (roentgens)	Duration of continuous exposure ²					Late effects
	1 day	3 days	1 week	1 month	3 months	
0 to 75	0% sick				0% sick	None
100	2% sick	0% sick			0% sick	None
125	15% sick	2% sick			0% sick	None
150	25% sick	10% sick	0% sick		0% sick	None
200	50% sick	25% sick	2% sick	0% sick	0% sick	Some late effects ³
300	100% sick	60% sick	15% sick	2% sick	0% sick	Some late effects ³
	20% die	5% die	40% sick	15% sick	0% sick	
450	100% sick	100% sick	90% sick	50% sick	0-5% sick	Some late effects ³
	50% die	25% die	15% die			
650	100% sick	100% sick	100% sick	80% sick	5-10% sick	Some late effects ³
	95% die	90% die	40% die	10% die		

¹ Estimated medical effects of gamma radiation dosages expressed as percentages of personnel exposed.

² This table applies to healthy young adults under usual duty conditions. The percentage figures are based on an interpretation of the best evidence on hand, and may be changed as more information is accumulated.

³ The specific late effects that may be found are not well understood and at present cannot be adequately described. Late effects such as various types of cancer (principally leukemia) and anemia are thought to be a possibility.

cumstances under which the detonation occurs. The decay of radioactive elements (for example, radium) into other elements is a statistical process. This means that the number of particles going through some type of reaction is proportional to the total number of such particles in the source of radioactivity. This can be clarified somewhat by thinking in terms of population.

For example, assume that in a certain community an average of 10 more people per thousand died or moved away than were born or moved into the community during the course of a year. Under these circumstances, it can be shown that in approximately 69 years the population will be cut in half; that is, the "half-life" of the community is 69 years. The mathematics involved in this computation employs an exponential equation and is included in nuclear physics texts.

The decay of radioactive elements may be compared to this population decrease. For example, the rate of decay of radium is such that in about 1600 years (actually 1620), a given amount of radium will be halved. Starting with 1 gram of radium, in 1600 years $\frac{1}{2}$ gram remains; in 1600 more years, $\frac{1}{2}$ of the $\frac{1}{2}$ gram (or $\frac{1}{4}$ gram) remains. This process of decay is repeated during successive 1600-year intervals until an insignificant amount remains.

The rate of decay of radioactive elements is given in terms of the half-life of the element, and this is a very important characteristic of the element.

Half-lives vary from several billion years in the case of U^{238} (the most abundant isotope of uranium) to a small fraction of a second in the case of polonium (PO^{214}).

The graph in figure 11-4 shows the percentage of any given amount of radium that remains after successive half-lives. Theoretically, the curve would never move down to zero percent. However, for all practical purposes, the radioactive material has disappeared when it becomes less than a measurable quantity.

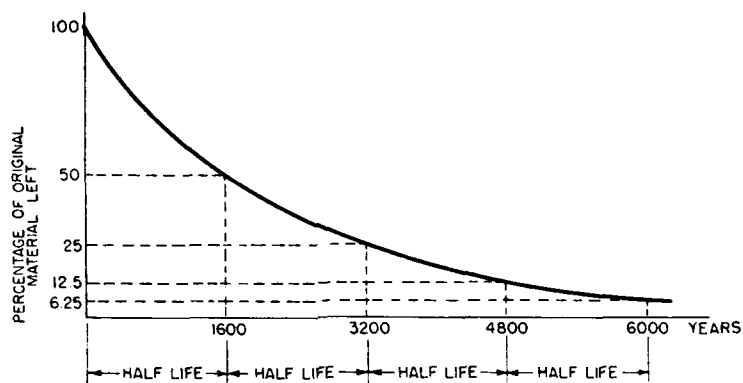


Figure 11-4.—Decay curve for radium.

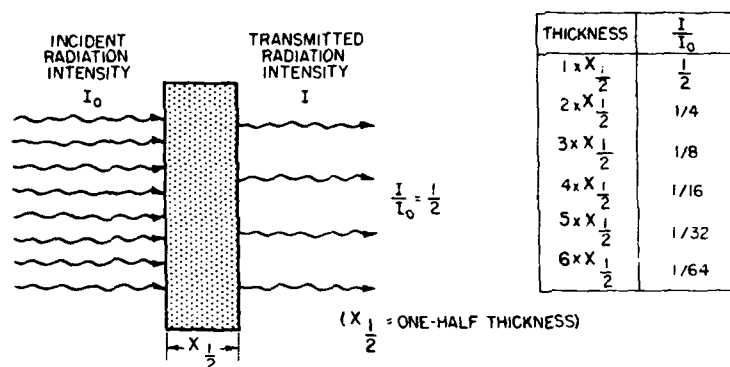
The decay of a radioactive substance cannot be speeded up or slowed down.

Half-Thickness

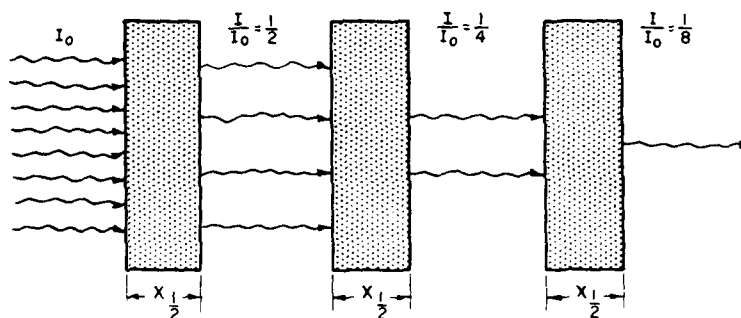
Great care is necessary in the handling, shipping, and storing of radioactive materials in order to avoid overexposing the personnel to the hazards of gamma radiation. In all types of shielding work it is necessary to know how effective the shield is in stopping this type of radiation. A very convenient and valuable concept in describing the absorption characteristics of a material is that of HALF-THICKNESS.

A half-thickness is a thickness of the shielding material that will absorb or shield out one-half of the incident radiation. The denser the material, the better will be its gamma shielding properties. For example, less lead than steel is required to stop half of the gamma radiation. This means that the half-thickness of lead is less than the half-thickness of steel.

Half-thickness ($X_{1/2}$) is illustrated in figure 11-5. In part A, the intensity, I_o , of the incident gamma radiation is reduced to one-half of its initial value by the half-thickness of the shielding material. In other words, the ratio of I (transmitted intensity) to I_o is $\frac{1}{2}$.



A HALF THICKNESS



B EFFECT OF MULTIPLE HALF-THICKNESSES

Figure 11-5.—Illustration of half-thickness.

In part B the effect of multiple half-thicknesses is illustrated. Theoretically, some of the gamma radiation will get through no matter how many half-thicknesses are used. However, enough half-thicknesses may be used to reduce the radiation to a relatively safe value.

The half-thickness of a given material may be determined by the use of a graph like the one shown in figure 11-6. The curves are essentially straight to the half power point. The thickness values given are only approximately of the right magnitude. Many factors are involved that could change these values.

The general procedure in plotting the graph is to place the radiation detector at a distance from the point source of radiation that will cause it to read a convenient value—for example, 50 *mr/hr* (milliroentgen per hour). A certain thickness of the absorber is then placed between the source and the detector, and the detector indication recorded. The thickness of the absorber is increased (more slabs added) and the new readings taken. The thickness that reduces the original intensity (50 *mr/hr*) to one-half of this value (25 *mr/hr*) is the half-thickness.

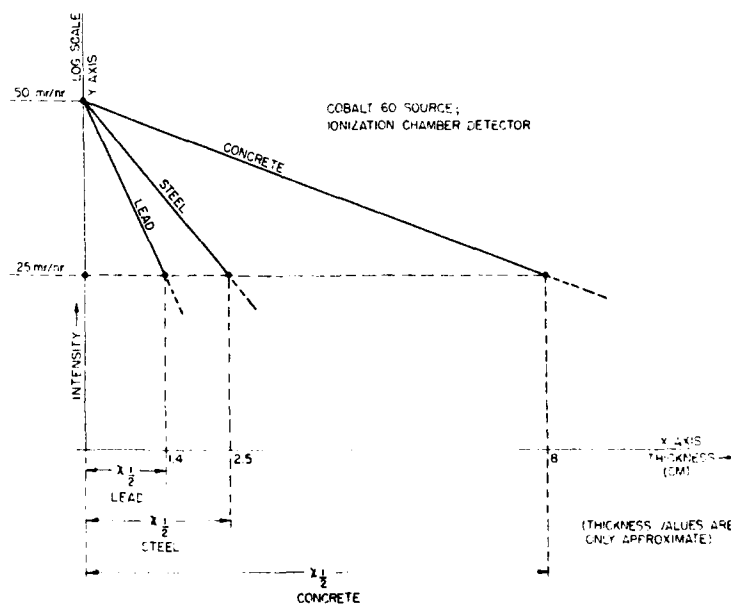


Figure 11-6.—Determination of half-thickness.

The thickness is plotted on the *X* axis, and the intensity is plotted on the *Y* axis. Curves are then drawn through the plotted points. It is then relatively easy to find the point on the thickness vs intensity curve that corresponds to the thickness when the intensity is reduced to one-half of its initial value.

IONIZATION OF GASES

The measurement of the intensity and amount of alpha and beta particles and gamma rays is very important (in a sense as important as the well being of the people involved), and the measurement of neutrons is becoming more important as more ships use nuclear reactors.

Except for photographic film and a few special methods of detecting radiation, radiation-detecting devices depend for their operation on the ionization produced in gases by the incident radiation. The flow of ions formed in the gas constitutes an electric current that may be amplified and used to activate a meter or other indicating device. It is therefore important that the technician acquire at least some understanding of the mechanics of ionization.

Neutral Atom of a Gas

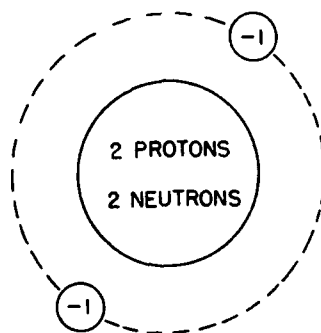
Normally, a gas consists of an enormous number of atoms or molecules, each electrically neutral—that is, each carrying balanced charges. Because there is no unbalanced charge on a neutral atom (or molecule), it will not be moved by an electric or magnetic field.

A diagram of a neutral helium atom is shown in figure 11-7, A.

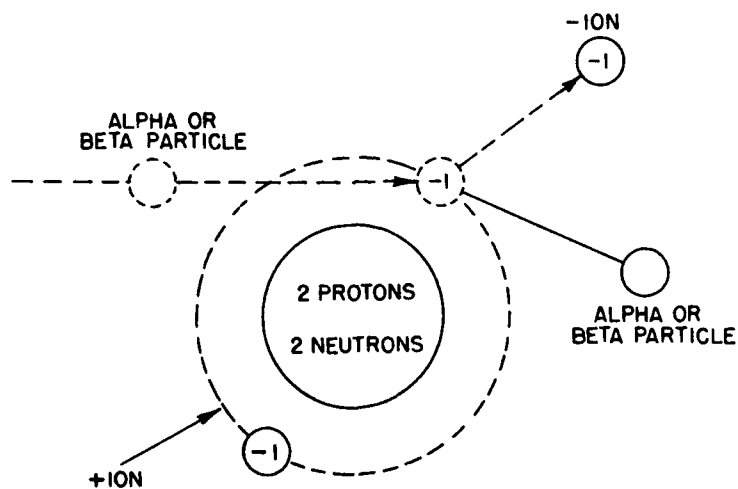
The nucleus contains two neutrons (no charge) and two protons. Each proton is assumed to have a charge of one (unity), and therefore the charge on the nucleus is $+2$. Each electron has a charge of -1 ; the total charge on both of the electrons is therefore -2 , and the atoms is electrically neutral.

Ionization of a Gas by Alpha and Beta Particles

When an alpha or beta particle enters a gas, it may act on a neutral atom or molecule with enough force to dislodge one or more electrons. The exact manner in which the electron is dislodged will not be treated here; but it can be assumed, for simplicity, that the alpha or beta particle collides with the electron and dislodges it.



A NEUTRAL HELIUM ATOM



B IONIZATION PROCESS

Figure 11-7.—Neutral helium atom and the ionization process.

The particle then moves on with reduced energy and dislodges another electron from an atom, and so on until it loses all of its energy.

Each time that an electron is dislodged from a neutral atom, two ions are formed (fig. 11-7, B). The dislodged

electron is one of the ions (the negative ion) and the nucleus with its remaining electron (or electrons) is the positive ion. It is possible to knock out more than one electron; if this occurs, more than one negative ion will be formed. However, it is more probable that only two ions will be formed during one ionizing event, and therefore it is customary to speak of the formation of ion pairs in a gas. PAIR PRODUCTION is something else altogether. This is an event in which an electron and its counterpart, the positron, are created, or materialized, from a high-energy gamma photon (treated later).

The energy that a particle must have in order to dislodge the most loosely bound (outer) electron from the atom or molecule of a certain gas is known as the IONIZATION ENERGY, or IONIZATION POTENTIAL, for that particular gas. When the total energy of the ionizing particle is known, and the total number of ion pairs formed by it is determined, it is discovered that the average energy given up by the particle for each ion pair formed is considerably greater than the ionization potential of the gas. The reason for this is that the ionizing particle sometimes collides and loses energy but does not cause ionization. Also, in some cases the particle removes a more tightly bound inner electron and therefore gives up more energy than it would in removing a less tightly bound outer electron.

The energy not otherwise lost by the bombarding particle in the ionization process (or in other internal losses) is expended in accelerating the resulting ions.

In table 22 the ionization energies of several gases are listed together with the average energy given up by the ionizing particle per ion pair formed. The average energy given up per ion pair formed in air (or oxygen) is about 33 electron volts (ev). (The electron volt is quite different from the volt commonly used in electric work. It is a unit of energy rather than electrical pressure. It is the energy acquired by an electron when it is accelerated through a potential difference of one volt.) Thus, if a beta particle (a high-speed electron) having

TABLE 22
IONIZING ENERGIES OF SEVERAL GASES

Gas	Ionization energy (ev)	Average energy given up by the ionizing particle for each ion pair produced (ev)
Oxygen.....	12.5	33
Hydrogen.....	15.4	32
Nitrogen.....	15.7	36
Argon.....	15.7	25
Helium.....	24.5	28

an energy of 1 mev (million electron volts) enters an air chamber it will produce of the order of $10^6 \div 33$, or about 3×10^4 , ion pairs. The total number of ions produced will, of course, be twice this value.

Because of its relatively large size and its two positive charges, an alpha particle causes a larger amount of ionization for a given distance than does a beta particle. Each event in which two ions are formed requires an AVERAGE of 33 ev because much of the energy of the particle is lost on electrons that are influenced but are not completely removed from the parent atom. The energy of the alpha particle is dissipated rapidly, even in air, because it produces many ions. The range of a high-energy alpha particle is only about 5 to 7 centimeters in air.

As an example, assume that the energy of the alpha particles from a certain form of radium is about 7.7 mev. The number of pairs of ions formed is

$$\frac{7.7 \times 10^6}{33} = 2.33 \times 10^5.$$

The length of the path of these ionizing particles can be measured by means of the Wilson cloud chamber. If the length of 7.7 mev alpha particles is 6 cm, the number of ion pairs produced per centimeter of path is

$$\frac{2.33 \times 10^5}{6} = 3.88 \times 10^4 \text{ ion pairs/cm of path.}$$

The number of ion pairs formed per centimeter of path is known as the SPECIFIC IONIZATION of the particle.

A 1-mev beta particle produces about

$$\frac{1 \times 10^6}{33} = 3 \times 10^4 \text{ ion pairs.}$$

If the particle travels 200 cm in air, the specific ionization is about

$$\frac{3 \times 10^4}{200} = 150 \text{ ion pairs/cm of path.}$$

Ionization of a Gas by Gamma Rays

Although gamma rays (as well as X rays) are electromagnetic radiations, they behave (certainly, as far as ionization is concerned) as though they were minute particles of energy, called PHOTONS.

Gamma photons are not charged electrically, and are therefore not detected DIRECTLY by common types of instruments. They do, however, produce secondary ionization effects that are readily detectable.

The energy of gamma radiation is absorbed in three ways as it passes through matter. The three ways are the PHOTOELECTRIC EFFECT, the COMPTON EFFECT, and PAIR PRODUCTION. These subjects are treated briefly in the following paragraphs. They are treated in greater detail in the Department of Defense special text, *Nuclear Physics*, NavPers 10854.

PHOTOELECTRIC EFFECT.—As illustrated in figure 11-8, A, a gamma photon can remove an electron from an atom in much the same way that it may be removed by an energetic (fast moving) electron (beta particle). All of the energy of the incident photon is absorbed and it ceases to exist. Some of its energy is used in dislodging the electron from its orbit, and the remainder is imparted to the ejected electron. The photoelectric effect is important for photons having less than 0.1 mev energy.

COMPTON EFFECT.—Energetic photons (between 0.1 and 10 mev) may collide with electrons (after impact, called RECOIL electrons), give some of their energy to

the recoil electron (fig. 11-8, B), and scatter as photons of lesser energy (longer wavelength). The change in wavelength depends on the angle, θ , being greater as the angle becomes greater. The maximum increase in wavelength occurs when θ is 180° , or when the photon is returned along the incident path.

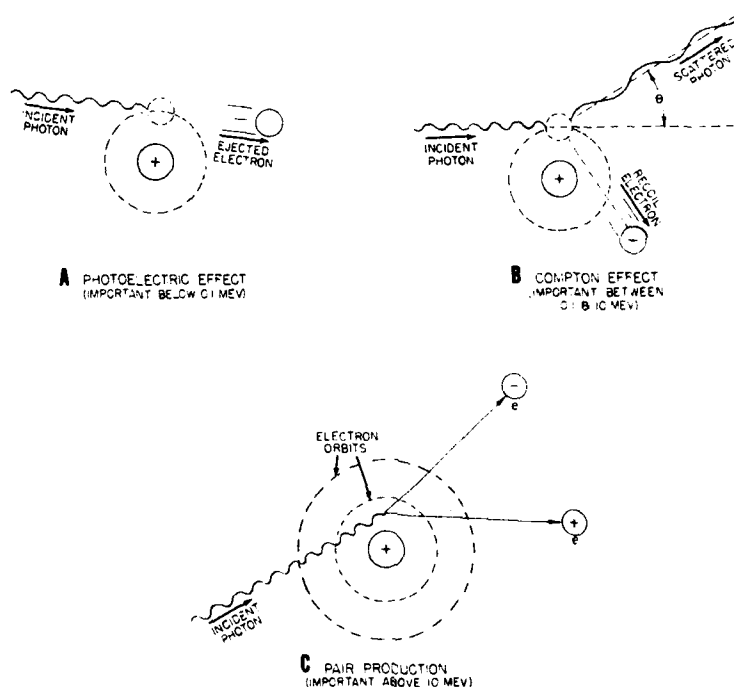


Figure 11-8.—Ways in which gamma radiation is absorbed.

PAIR PRODUCTION.—Pair production can occur only when the incident gamma photon has energy equal to, or greater than, 1.025 mev. In pair production an electron (negative charge) and a positron (positive charge), each having the mass of an electron (9.107×10^{-28} gm), are created from the energy of the incident photon. At least 1.025 mev of energy is needed to make $2 \times 9.107 \times 10^{-28}$ gm of mass, according to Einstein's

mass-energy equivalence equation, $E = mc^2$. E is energy, M is mass, and C is the velocity of light.

Figure 11-8, C, illustrates what is thought to happen in pair production. In the strong electrostatic field of the nucleus the incident photon, which must have at least 1.025 mev of energy, is converted to an electron ($-e$) and a positron ($+e$). Photon energy in excess of 1.025 mev is imparted as kinetic energy to the newly created particles.

The positron has a very short life. It soon interacts with an orbital electron; the two particles unite and annihilate themselves, giving off two 0.5125-mev photons. The sum of the energies in these two photons is 2×0.5125 , or 1.025 mev. This is the amount of energy that was used to create the two particles in the first place.

In part A of figure 11-8 the photon ceases to exist because all of its energy is imparted to the ejected electron. In part B, some of the energy of the photon is imparted to the recoil electron, and the remainder of the energy is contained in the scattered photon. In part C, however, something entirely different happens. Two new particles are created from the energy of the photon, and the photon ceases to exist.

It should be emphasized that uncharged radiation, such as gamma photons, must produce charged particles as a secondary process if they are to be detected or measured by the various instruments that are commonly used in the Navy.

Recombination of Ions

If no electric field exists in the vicinity of a gas that is exposed to ionizing radiations, the positive and negative ions will move with random motion among the neutral gas molecules until the positive ion can accumulate enough electrons to become a neutral atom. This process is called RECOMBINATION.

Movement of Ions in an Electric Field

The effects produced by the movement of ions, particularly negative ions (electrons), in an electric field

are utilized in many radiac survey instruments. Survey instruments are used, for example, to determine if an area is radioactive. It is therefore important to learn something about these effects and how they are utilized in radiac instruments.

If an electric field is applied across a chamber containing ions of a gas (assume that the ions are formed by the effects of radiation), a force will be exerted on each ion, causing the negative ions to move toward the positively charged anode and the positive ions to move toward the negatively charged cathode, as illustrated in figure 11-9. The speed attained by these ions as they move toward the electrodes depends on (1) the voltage applied to the electrodes, (2) the mass of the ions, and (3) the pressure of the gas.

As the ions reach the electrodes they give up their charge and become neutral. This results in electron flow in the battery circuit. In general, the magnitude

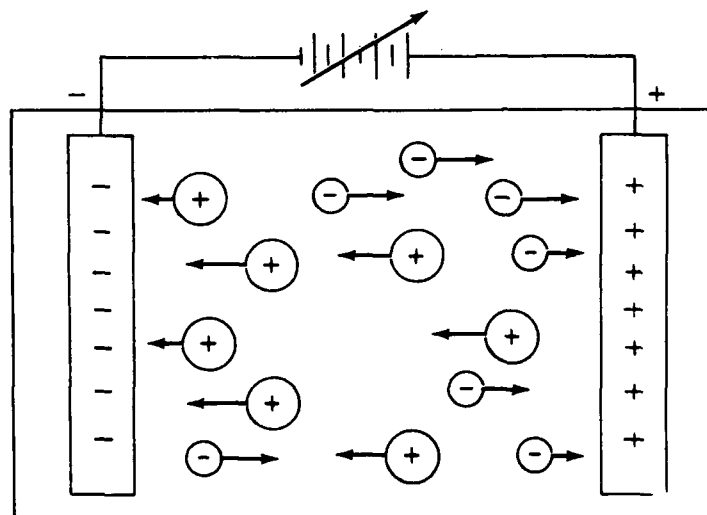


Figure 11-9.—Movement of ions in an electric field.

of the electron flow is extremely small, and special amplifying circuits are needed in portable field-type instruments to produce an indication on an indicating meter.

When the voltage applied across the electrodes is increased, the ions are acted on by a greater force and they speed up as they move toward the electrodes. The negative ions are lighter and accelerate more than the heavier positive ions. The movement of the electrons is of primary interest because they flow through the external load and develop a voltage that can be amplified to activate an indicator.

When the voltage applied across the electrodes is low, only a few ions reach the electrodes. As the voltage is increased, more and more ions will reach the electrodes until a point is reached where an increase in voltage does not cause any further increase in current. This is the condition of SATURATION, and the maximum current is the SATURATION CURRENT.

Saturation can be explained as follows. When the voltage is low, considerable time is needed for the ions to reach the electrodes. During this time many of the ions have a chance to recombine and are thus lost before they can make a contribution to the load current. Thus the load current is small. As the voltage is increased, the velocity of the ions toward the electrodes is increased, the load current increases until at saturation no recombination takes place within the gas chamber, and all of the ions (that are produced for a given amount of radiation) contribute to the external current through the load. A further small increase in voltage will have on appreciable effect on the current flow. The relationship of ion current to electrode potential is illustrated in figure 11-10.

For the maximum possible current from a given amount of ionization, it is desirable to work with saturation currents. Because variations in voltage in the saturation region have no effect on the ion current, precise voltage regulation is not needed.

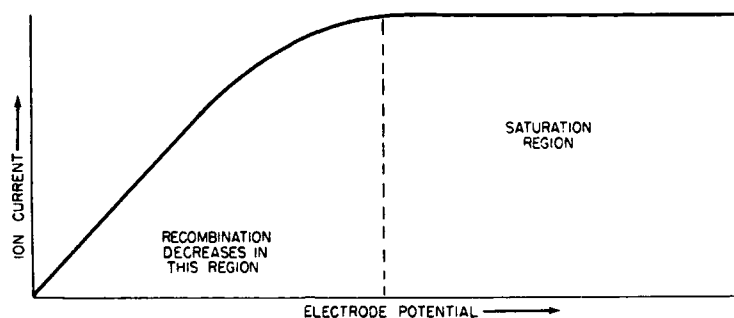


Figure 11-10.—Relationship of ion current to electrode potential.

Elastic and Inelastic Collisions

From the time an ion is formed until it is neutralized, force is exerted on it by the electric field. Consequently it moves toward the electrode having a charge opposite to its own. When there are many gas molecules present, the ion will collide often on its way to the electrode. When the molecules are present it will not collide so often.

If it is assumed that many gas molecules are present and that the applied voltage is low, the ion will collide often with molecules and will acquire only a small amount of energy (from the electric field) between collisions. The energy of the ion may not be sufficient to dislodge an electron from its orbit when a collision occurs. This type of collision is called an **ELASTIC** collision because there is no change in momentum or kinetic energy. The direction of motion of the ion, however, is changed. This is somewhat like a collision between two billiard balls.

If it is assumed that few gas molecules are present and that the applied voltage is high, the ion will travel a relatively long distance before it collides with a gas molecule. During the time interval between collisions the ion is accelerated by the applied field and acquires considerable energy. If the energy is sufficiently great, an electron will be dislodged when a collision occurs; thus, secondary ions are produced. In this type of col-

lision some of the kinetic energy of the ion is used in dislodging the electron. This type of collision is therefore INELASTIC.

Avalanche Ionization

The secondary ions that are formed by inelastic collisions are accelerated by the electric field and they, in turn, produce further ionization. The effect is cumulative and is known as AVALANCHE IONIZATION. This type of ionization is illustrated in figure 11-11. The ionizing

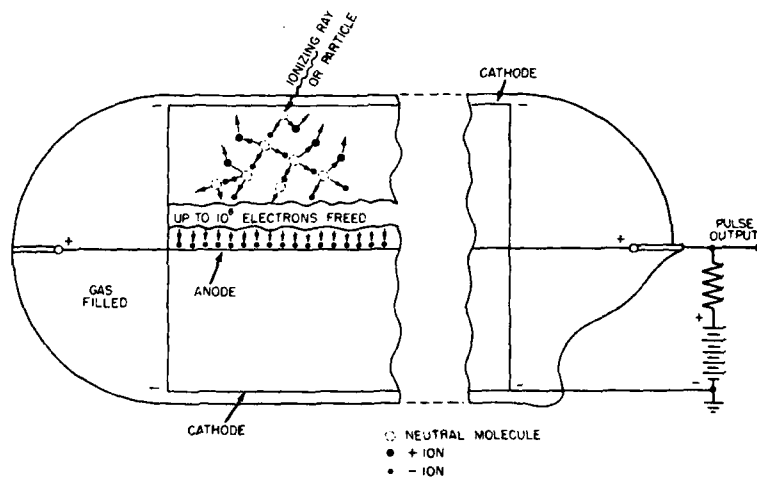


Figure 11-11.—Avalanche ionization in G-M tube.

ray or particle dislodges an electron from a neutral gas molecule as it enters the Geiger-Muller (G-M) tube. This is the detector tube used in many radiac survey instruments. The resulting +ion moves toward the cathode, but the electron moves on to ionize other molecules. The process develops into a chain reaction, and by the time the free electrons reach the positive terminal (center wire), their number has grown to about 10^8 . The total number of ion pairs resulting from the initial pair is called the GAS AMPLIFICATION FACTOR. For gas-filled

photoelectric cells it may be about 10; for the G-M tube just described it may be 10^8 .

Relationship of the Ionization Effect to the Applied Voltage

The part that ionization plays in the operation of the various types of instruments used for detecting and measuring radiation may be understood more clearly from a consideration of figure 11-12. Part A shows a simplified schematic diagram of the circuit, and part B shows the ionization effects produced as the applied voltage is increased.

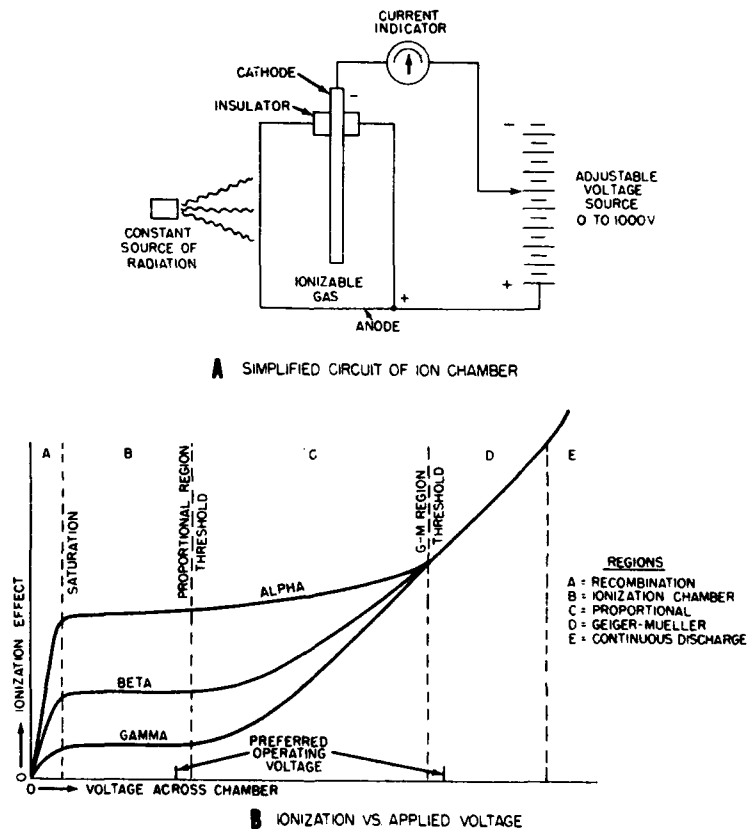


Figure 11-12.—Relationship of the ionization effect to the applied voltage.

Assume that the gas is being subjected to the radiations from a constant source and that the voltage source is adjusted to zero. Ions are produced in the gas, but because there is no applied potential to attract them, they wander around inside the gas and recombine, and the meter reads zero. This action is represented between the zero-voltage point and the saturation point in region A, the region of recombination.

If a small potential is now applied to the ion chamber, electrons will move toward the anode and the $+$ ions will move toward the cathode. If the potential is increased to the point at which all of the available ions are collected by the electrodes, a further increase in voltage will not cause the meter reading to increase. This is the point of saturation.

To the right of the point of saturation in region B, only those ions formed directly by the radiation contribute to the current flow through the current indicator. IONIZATION-CHAMBER type of radiac instruments are operated at saturation voltage (in region B). This type of instrument is described later.

Beyond the flat part of the curves (region B), an increase in voltage causes an increase in current (region C). Beginning at the proportional region threshold, it is evident that some new effect is taking place to provide ions over and above those created by the radiation from the constant source. At the higher voltages applied in the proportional region (region C), the negative ions attain a relatively high velocity and have sufficient energy to dislodge other electrons. These electrons then contribute to the current flowing through the current indicator.

Because the total amount of ionization produced by an ionizing particle depends on the type and energy of the particle, it is possible (for example, in region C) to differentiate to some extent between alpha, beta, and gamma radiation pulses. Alpha particles have the greatest ionizing power, and gamma rays have the least.

PROPORTIONAL counters operate in region C. This type of instrument is described later.

If the voltage is increased sufficiently, the Geiger-Muller region (region D) will be reached. The curve here is very steep. The current increases rapidly with increase in voltage because of avalanche ionization, which takes place in this region. This type of ionization is illustrated in figure 11-11.

Under the influence of the high voltage applied across the chamber, the electrons dislodged by the radiation, which comes from the constant source, are speeded up sufficiently (and acquire sufficient energy) to dislodge other electrons; the process is repeated. The result is an avalanche of electrons that move to the positive terminal.

Any ionizing event can trigger off the avalanche and cause a pulse of current through the meter. Pulse-type instruments employing Geiger-Muller tubes are used extensively. They are also described later in the chapter.

The E region (fig. 11-12, B, region of continuous discharge) is of no importance as far as radiac instruments are concerned because in this region it is impossible to distinguish between individual ionizing events.

IONIZATION CHAMBER INSTRUMENTS

Introduction

The basic operating principle of ionization chamber instruments is illustrated by means of the gold-leaf electroscope in figure 11-13. If the battery is connected temporarily between the top of the stem and the case, the stem and the gold foil attached to it will acquire a positive charge, as shown. Because of the mutual repulsion of like charges, the gold foil will be pushed aside. When the battery is removed, the gold foil will remain diverged.

If negative ions are now produced within the chamber (it is assumed that the chamber is fully enclosed and

that the ions will make contact with the positive charges), the positive charge on the foil and the stem will be neutralized in proportion to the number of ions formed. The gold foil will drop (because of gravity) in proportion to the number of ions formed, and hence in proportion to the amount of radiation passing into the chamber.

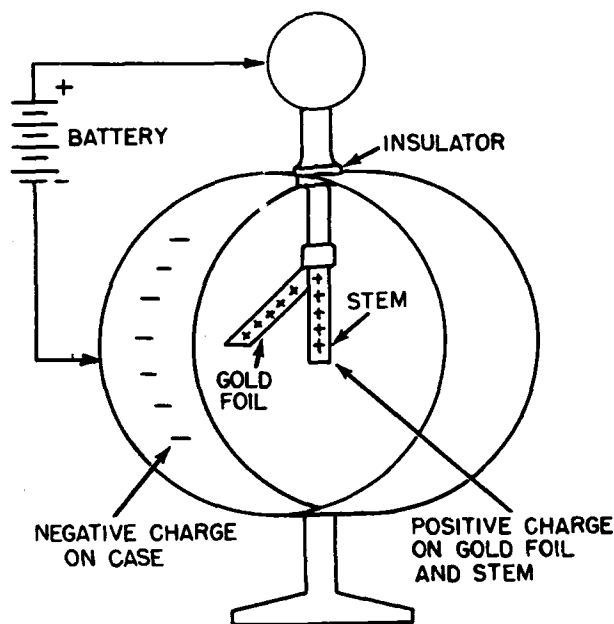


Figure 11-13.—Gold-leaf electroscope.

It is possible to calibrate such an instrument in terms of the amount the leaf drops for a given amount of ionization so that an indication of the amount of radiation entering the chamber following the charging may be obtained. The instrument then becomes an ELECTROMETER.

This type of instrument is not convenient for field use. Modern instruments utilize metalized quartz fibers for their moving parts. Extremely small fibers are

used, and this enables the moving member to be decreased in weight and improved in sensitivity. As a matter of fact the whole instrument is about the size of a fountain pen. These instruments are commonly called DOSIMETERS, or POCKET METERS.

Dosimeters

SELF-READING TYPE.—One type of dosimeter is shown in figure 11-14, A; the charging device is shown in part B.

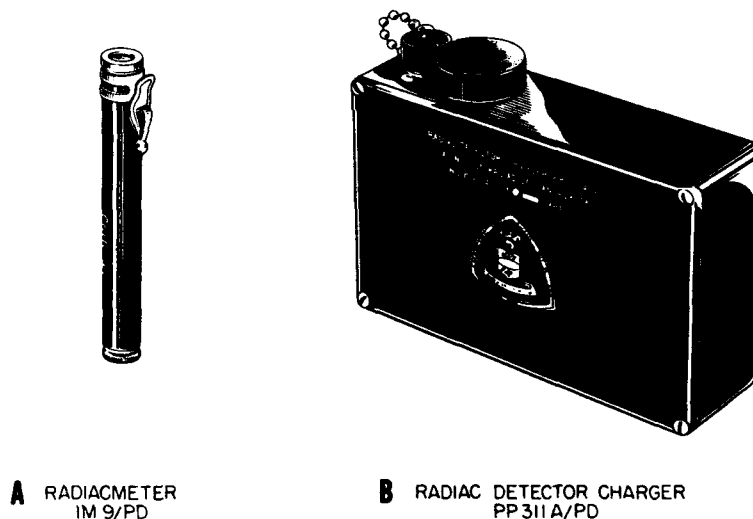


Figure 11-14.—Dosimeter and charger.

A cross-sectional view of radiacmeter IM-9/PD is shown in figure 11-15. The lower portion represents the electrometer section of the radiacmeter; the upper portion represents the microscope section.

The electrometer section of the instrument operates in essentially the same manner as the gold-leaf electroscope discussed previously. The application of a charging voltage (from the charger) to the charging contact causes the quartz fiber, which is coated with a conduct-

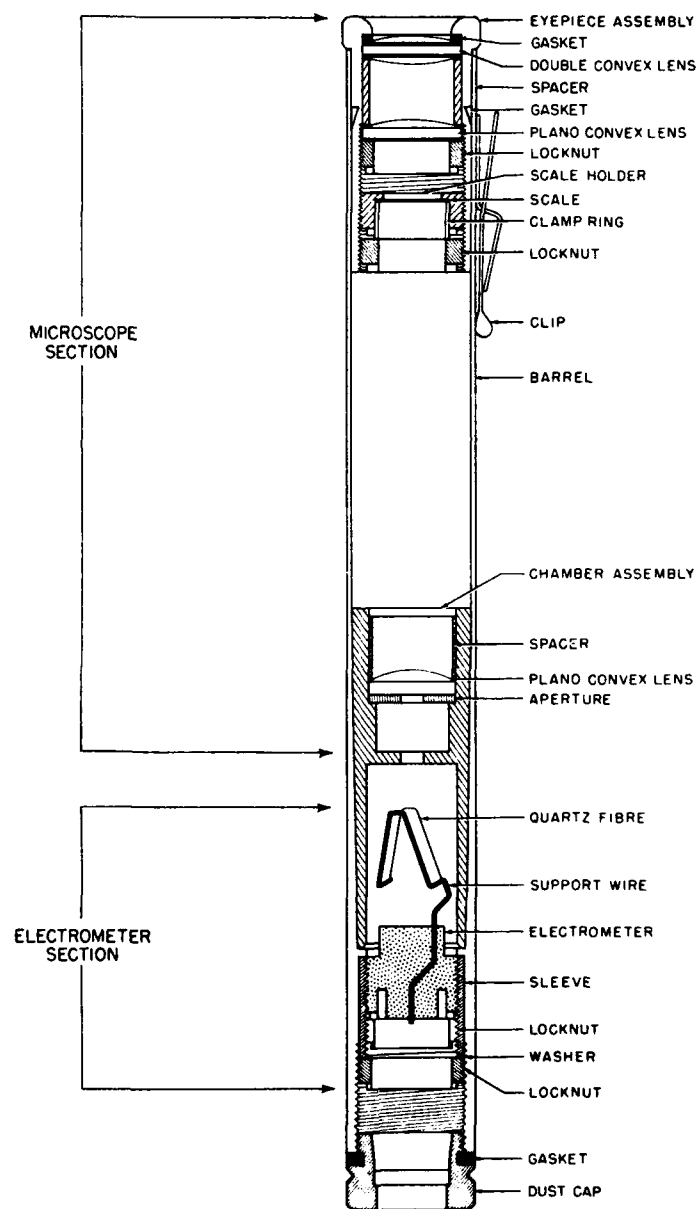


Figure 11-15.—Sections of radiacmeter IM-9/PD.

ing material, to be deflected away from the bronze support wire and toward the wall of the ionization chamber. The fiber will maintain its deflected position for some time in the absence of gamma radiations (alpha and beta radiations cannot penetrate the walls) because the polystyrene insulator has a resistance of about 10^{19} ohms, and the charge cannot readily leak off. This instrument operates in the B region of the ionization curves shown in figure 11-12, B.

The purpose of the microscope section is to give a magnified view of the scale with the shadow of the quartz fiber superimposed on it, as shown in figure 11-16.

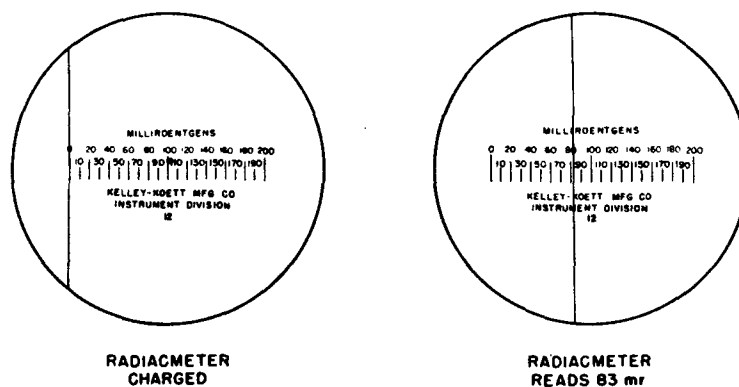


Figure 11-16.—Scale indications for two conditions of charge.

In part A, the meter is charged sufficiently to cause the quartz fiber to be deflected to a position corresponding to the zero point on the scale. The scale is viewed through the eye piece as the correct charge is applied from the charger. Illumination is supplied by a bulb in the charger.

Part B shows the scale reading after the instrument has been exposed to 83 mr of gamma radiation. The charge on the quartz fiber has been partially neutralized

by the ions formed in the ionization chamber, and it has fallen part of the way toward the support wire.

At any time he wishes, the wearer of this instrument may look through the instrument toward a light source and determine the dosage he has acquired since the instrument was charged.

In the charger there are two batteries, a 1.5-v battery (dry cell) for illumination purposes and a 180-v battery for charging the radiacmeter. A potentiometer is used in connection with the 180-v source so that the correct charge may be applied to the radiacmeter. The correct charge is the one that brings the scale reading to zero.

NONSELF-READING TYPE.—This type of dosimeter is entirely different in construction from the self-reading type. A diagram of one type of nonself-reading pocket chamber dosimeter is shown in figure 11-17.

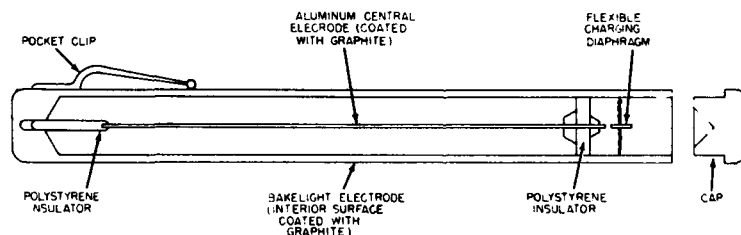


Figure 11-17.—Diagram of nonself-reading dosimeter.

This dosimeter is essentially a capacitor, one plate of which is the central wire. The other plate is the interior surface of the case. The two "plates" are separated by the polystyrene insulator.

With this dosimeter, as with the self-reading type, an auxiliary piece of equipment, called in this case a MINOMETER, is needed. One minometer will serve many pocket chambers. Its function is to place an original charge on the central wire; and, after the charge has been partially dissipated by ionizing radiations (gamma rays), to indicate the dosage in terms of the remaining charge.

A very sensitive electrostatic voltmeter in the minometer automatically indicates the amount of the exposure in milliroentgens when it is properly connected to the pocket dosimeter.

One type of dosimeter and minometer is shown in figure 11-18. Although the nonself-reading dosimeter cannot be read by the wearer as readily as the self-reading type, it has the advantage of costing only about one-tenth as much.

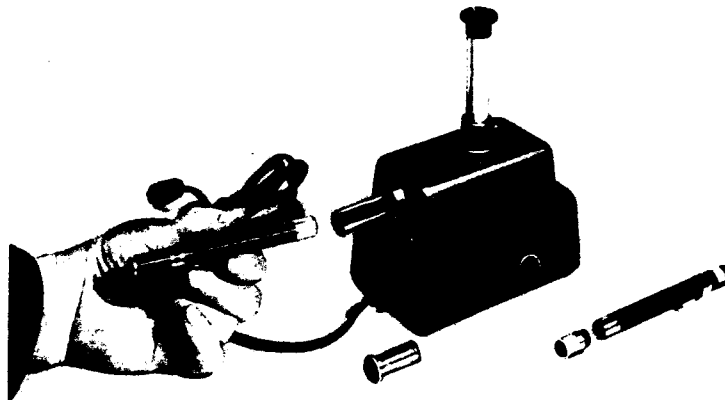


Figure 11-18.—Dosimeter and minometer.

One special use of the nonself-reading pocket meter is the measurement of thermal neutron radiation dosage. (Thermal neutrons are very slow neutrons.) In this case, the inside surface of the meter case is coated with a boron compound. The boron absorbs the thermal neutrons and gives up alpha particles as it converts to lithium. The alpha particles have high ionizing ability.

Ionization-Chamber Survey Meter

Thus far, the ionization-chamber type of instruments (dosimeters) discussed have been those that indicate the

cumulated dose, not the rate at which the dose is being acquired. Ionization-chamber instruments are also available that indicate intensity directly for survey operations.

A simplified circuit diagram of one type of ionization-chamber survey meter is shown in figure 11-19. The electrodes of the ionization chamber are kept at a constant potential by the battery. This potential is such that the ions, formed by the radiation passing into the ion chamber, will not attain velocities high enough to cause secondary ionization as they are accelerated toward the electrodes. The operation is then confined to region B of the curve in figure 11-12, B.

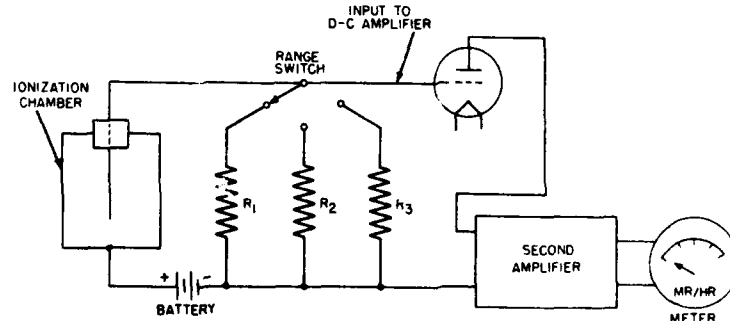


Figure 11-19.—Simplified circuit diagram of ionization-chamber survey meter.

The flow of current through R_1 , R_2 , or R_3 develops a voltage, which when amplified, is capable of activating a meter. The usual range of such instruments is between 25 and 50,000 mr/hr.

With this type of survey instrument, the meter gives a relatively steady reading of the rate at which ionizing events are taking place in the chamber, and therefore it is called a RATE METER.

The AN/PDR-T1B is an instrument employing the ion-chamber principle for the detection of gamma radiations.

PROPORTIONAL COUNTER

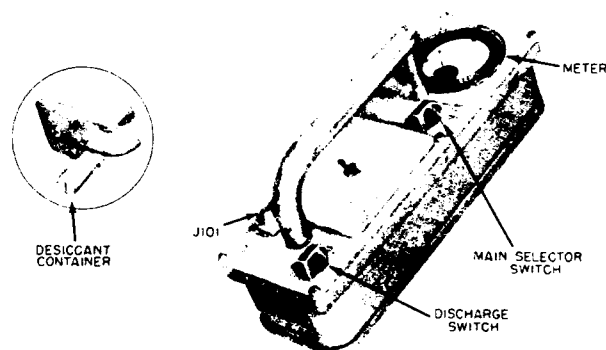
Purpose and General Description of the Equipment

Radiac Set AN/PDR-10C is a battery-operated proportional counter used by the Navy for detecting the presence and measuring the intensity of low-level alpha radiation. As the name suggests, it operates in the proportional region (region C) of figure 11-12, B. A view of the top of the instrument is shown in figure 11-20, A, and a circuit block diagram is shown in part B.

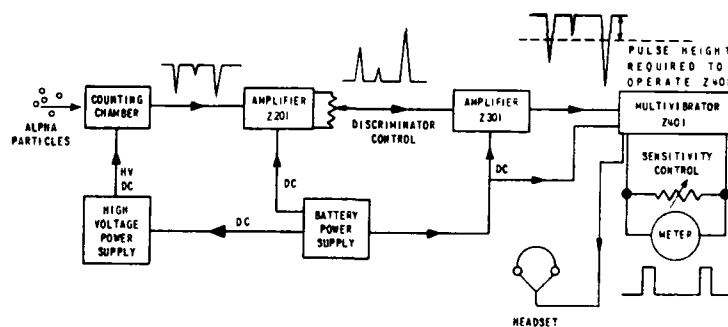
When radiation is to be monitored, the equipment is placed with its bottom surface against the surface emitting the alpha radiations. In this connection it should be emphasized that it is possible to contaminate the AN/PDR-10 when it is placed against an alpha-emitting surface. The alpha particles penetrate the thin aluminum foil window in the bottom of the equipment and ionize the air within the detecting chamber. A high voltage is applied between the electrodes of the chamber, and this voltage attracts the ionized particles with such force that each produces other ions by collision with molecules before striking the electrodes. The net result is a pulse many times the size of a pulse that would be produced by the alpha particle alone. The pulse is then fed to a rate meter circuit (amplifiers, multivibrator, and meter), which indicates the number of times per minute alpha particles enter the counting chamber.

Both visual and audible indication are provided by means of an internally illuminated meter and a detachable headset. A battery-test feature is also included as well as an alpha source for checking equipment operation. The radiacmeter is made airtight by means of rubber gaskets at all openings with the exception of the chamber. A protective cover plate is provided to protect the fragile window in the bottom of the equipment.

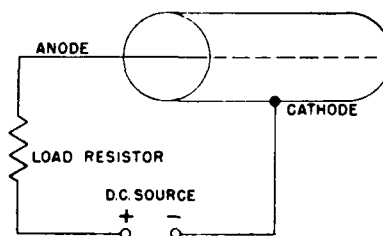
The counting chamber (fig. 11-20, B) is the detecting component of the system, and all of the remaining cir-



A TOP VIEW SHOWING CONTROLS AND DESICCANT CONTAINER



B CIRCUIT BLOCK DIAGRAM



C SCHEMATIC OF A COUNTING CHAMBER

Figure 11-20.—Radiacmeter AN/PDR-10C.

cuitry is used to supply power to it or to convert its output to a usable form and magnitude.

Circuit Operation

COUNTING CHAMBER.—As has been stated, the counting chamber is operated in the proportional counting region, C, of figure 11-12, B. Basically, it consists of an air chamber in which is mounted an anode (actually seven parallel wires); and the walls of the chamber act as the cathode.

A simplified schematic diagram of a cylindrical counting chamber is shown in figure 11-20, C. A potential is applied, as shown. When an alpha particle enters the counter it ionizes air molecules along its path (primary ionization), producing positive and negative ions. The positive ions drift toward the cathode and the negative ions (electrons) move rapidly toward the anode. The rapidly traveling electrons collide with gas molecules. If the electric field is sufficiently high, the electrons produced by primary ionization will gain enough energy between collisions to ionize additional air molecules, thus producing secondary ionization. The field is stronger near the anode and therefore the electrons gain more energy as they approach the anode.

In a proportional counter of this type the voltage is so adjusted that at about the tenth collision of the electron on its way to the anode it ionizes a molecule. The two electrons then move on to ionize two other molecules, thus adding two more electrons to the growing stream. After a number of such ionizing events, about 1000 electrons are produced by one initial electron. Thus, the amplification is 1000. This process is known as **GAS AMPLIFICATION**. The electrons collected by the anode flow through the load resistor and produce a voltage across it. This voltage is fed to the amplifiers, which are described later.

It is possible for alpha, beta, and gamma radiations to produce ionization in this instrument. However, alpha particles are by far the most effective in producing

ionization. As has been stated, the alpha particle is a helium nucleus with a double positive charge and produces a large number of ionizations per unit length of its path—about 3×10^4 ions/cm. The beta particle is a high-speed electron, producing about 300 ions/cm. Gamma radiation is very high frequency electromagnetic radiation, which produces hardly any ionization in air and only a very small amount on striking heavy metals.

Because the output of this counter is proportional to the number of ions produced initially, it is apparent that the pulse produced by the alpha particle is $\frac{3 \times 10^4}{300}$, or 100 times larger than that produced by the beta particle, and very much larger than that produced by gamma rays. This characteristic is used to discriminate against beta and gamma radiations.

AMPLIFIERS.—The two amplifiers, Z201 and Z301 (fig. 11-20, B) are conventional resistance-capacitance coupled amplifiers. The negative-going pulse from the counting chamber is fed to Z201, where it is amplified. In the output of Z201 is the discriminator control. This potentiometer may be adjusted by means of a screwdriver. It is used to discriminate against the small pulses produced by beta particles.

MULTIVIBRATOR AND METERING CIRCUIT.—The negative-going pulses from amplifier Z301 are fed to the multivibrator. This is a one-shot multivibrator that goes through one cycle of operation for each initiating signal. These pulses must have a certain minimum amplitude to cause the multivibrator to function. When the discrimination control is properly adjusted, beta-particle signals cannot trigger the multivibrator, but alpha particles are able to do so.

The meter is connected to the output of the multivibrator. The magnitude of the meter indication is determined by the number of pulses of current from the output of the multivibrator. Because all of the current pulses are of the same magnitude, the steady-state value

is an average of the number of pulses per unit of time, or, in other words, the counting rate.

HIGH-VOLTAGE POWER SUPPLY.—The high-voltage power supply contains a relaxation oscillator, which feeds a saw-tooth waveform to the grid of a pentode tube, the plate circuit of which contains a very large inductance. The sudden downward swing of the saw-tooth waveform cuts off the plate current of the pentode, and the collapsing field of the inductor produces a very high voltage (about 2500 volts) at the plate of the pentode. This voltage is rectified and applied to the counting chamber and to a 0.02 μ f charging capacitor in parallel with the counting chamber. The high positive charge established on the capacitor provides the electric field for the counting chamber. Once fully charged, the equipment will continue to read radiation for a long time without recharging. Thus, the relaxation oscillator, amplifier, and rectifier operate only during the charging time (approximately 5 seconds) when the main selector switch is in the CHARGE position.

PULSE-TYPE INSTRUMENTS

Purpose and General Description of the Equipment

A top view of a typical pulse-type instrument, Radiacmeter AN/PDR-27C, is shown in figure 11-21. It is a portable, watertight, battery-operated radiation detector and indicator. It is capable of detecting and measuring beta and gamma radiations together, or gamma radiations alone. The detector is normally carried in an external well on the radiacmeter and can be easily removed. When measuring gamma radiations, the detector can be used in or out of the well; beta radiations however, can only be detected when the detector is removed from the well and the beta shield (see inset) on the end of the probe is moved aside.

Geiger-Muller (G-M) tubes are used in the radiac set to detect beta and gamma radiations. When the tubes (two are used in the set) are exposed to such

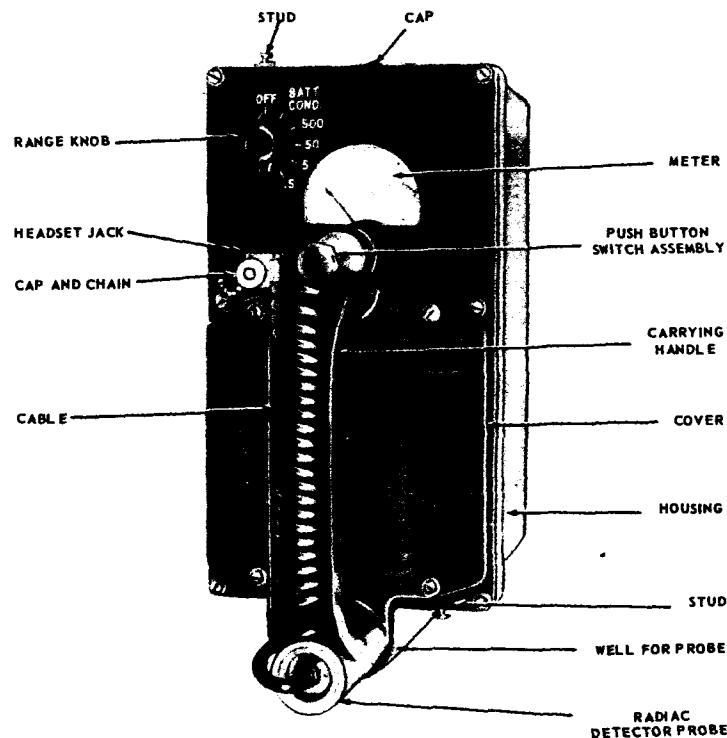


Figure 11-21.—Radiacmeter AN/PDR-27C.

radiations, they produce short-duration, d-c voltage pulses at an average repetition rate proportional to the average radiation field intensity in the vicinity of the tubes. These pulses, which are of random duration and random amplitude, are converted to pulses of equal duration and constant amplitude. These pulses are used to generate visual and aural indications of the average radiation field strength in the vicinity of the G-M tubes.

Visual indication is provided by a meter, the reading of which is proportional to the pulse reception rate; aural indication is provided by headphones in which a click is heard for each received pulse.

The range of field intensities capable of being detected by the radiacmeter is relatively broad and therefore four ranges are provided (0.5, 5, 50, and 500 mr/hr). The two more sensitive ranges (0.5 and 5) utilize a Navy type BS-1 G-M tube, which is contained in the probe. This tube has a mica end window covered by a removable metal beta shield. This shield can be moved aside to expose the beta window for beta-plus-gamma radiation readings, and is left in place for gamma radiation reading alone. The two less sensitive ranges utilize a Navy-type BS-2 G-M tube, which is contained inside the radiacmeter housing. Only gamma radiation field strengths can be measured on these two less sensitive ranges.

A radioactive test sample is provided so that the operator can ascertain the operating condition of the radiacmeter when no known radiation field is available. The radioactive sample consists of a plastic tube containing approximately 5 microcuries of cobalt 60 (a radium source is sometimes used). This substance is potentially dangerous and should be handled according to the instructions given in the instruction book.

Circuit Operation

A block diagram of Radiac Set AN/PDR-27G is shown in figure 11-22. The power is supplied by batteries, as indicated in the figure. The high-voltage power supply, employing a relaxation oscillator, converts the +135-volt, d-c power from the batteries into +700-volt, d-c power, which is fed to the G-M tubes.

DETECTOR CIRCUIT.—Two G-M tubes are used as radiation detectors. The more sensitive tube, V102, is used in the probe; the less sensitive tube, V101, is located in the body of the instrument. When the range switch is in any of the four range positions, V101 is connected to the radiacmeter. When the switch is in either the 0.5 or the 5 position, V102 is also connected to the radiacmeter.

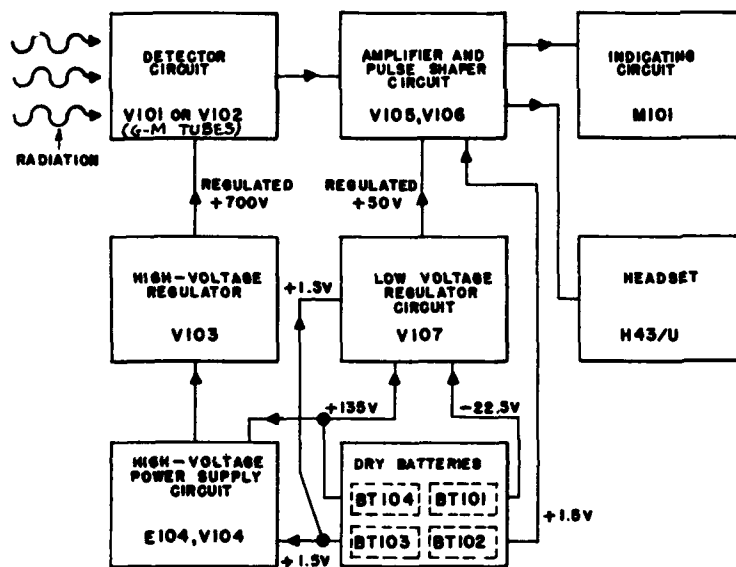


Figure 11-22.—Block diagram of Radiac Set AN/PDR-27G.

In any of the range positions, regulated 700-volt d-c power is applied through the anode load resistor (not shown in the figure) to the anode of the selected G-M tube. When the G-M tube conducts because of an ionizing event, a voltage pulse is developed across the load resistor. The voltage pulse is capacitively coupled to the input grid of V105 in the pulse-shaper and amplifier circuit. The output of the G-M tube is a series of negative-going pulses, one for each ionizing event that occurs within the tube.

AMPLIFIER AND PULSE SHAPER CIRCUIT.—This circuit converts the random-amplitude, random-duration pulses from the detector circuit into pulses of constant amplitude and constant duration by means of one-shot multivibrator action, and feeds them to the indicating circuit. The amplitude and duration of the output pulses are seriously affected by changes in the plate supply voltage. To eliminate this effect, the plate supply voltage for both tubes in this circuit is regulated.

INDICATING CIRCUIT.—The function of the indicating circuit is to convert the output pulses of the amplifier and pulse-shaper circuit into a relatively steady meter deflection proportional to the radiation intensity.

The average current through the meter depends on (1) the number of pulses per second received from the amplifier and pulse-shaper circuit, and (2) the amplitude and duration of each pulse.

Because the number of pulses per second is proportional to the radiation intensity, the average meter current will be proportional to the radiation intensity as long as the amplitude and duration of each pulse remains the same (that is, at any one position of the range switch). When ranges are changed, the amplitude and duration of the pulses change; consequently, the meter current per pulse also changes.

The meter deflection is proportional to the average meter current; this current is proportional to the number of pulses per second, and the number of pulses per second is, in turn, proportional to the radiation intensity for a given type of radiation. Consequently, the meter scale can be calibrated to indicate mr/hr directly.

SCINTILLATION COUNTERS

Purpose and General Description of the Equipment

Radiacmeter AN/PDR-18B is a typical scintillation counter currently being used by the Navy. It is used to detect and measure high-intensity gamma radiation. Alpha and beta radiations are eliminated because they cannot pass through the wall of the case. A top view of the instrument is shown in figure 11-23, A, and a functional block diagram is shown in part B.

The detection of gamma radiation is accomplished by means of a sensitive phosphor detector. Gamma radiation striking the phosphor causes it to fluoresce and thus to illuminate a photomultiplier tube. The d-c output of the photomultiplier tube is directly coupled to the grid of

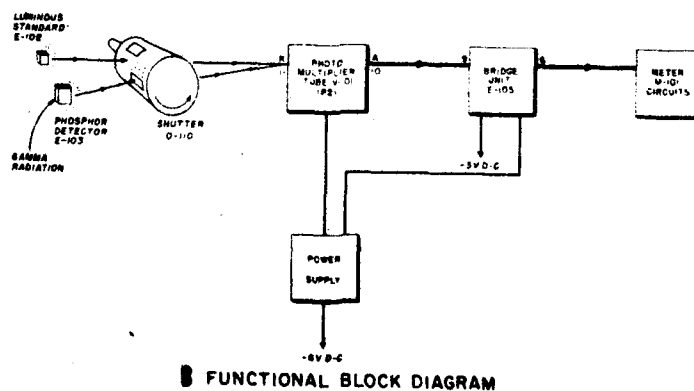
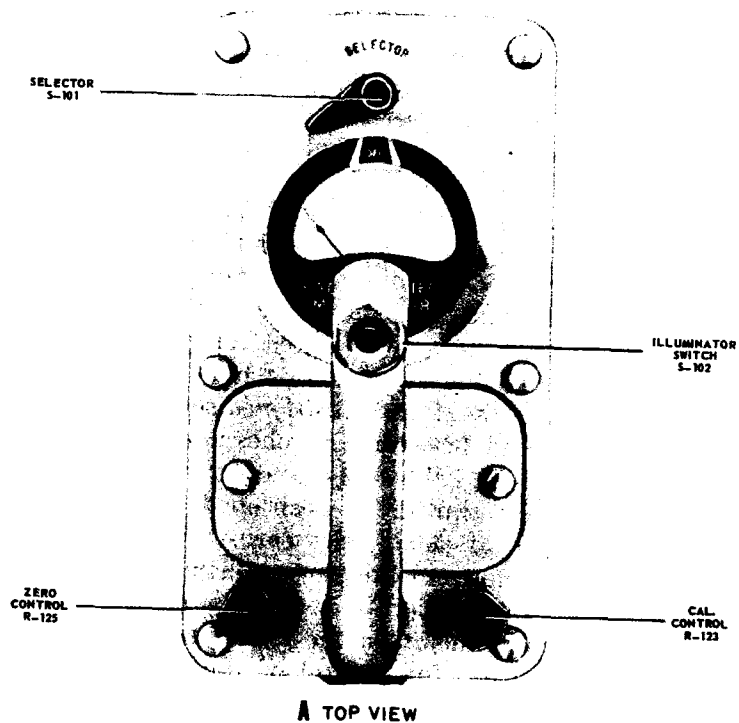


Figure 11-23.—Top view of Radiacmeter AN/PDR-18B and functional block diagram.

an amplifier tube, which is in one arm of a balanced bridge. The degree of unbalance of the bridge is proportional to the intensity of the gamma radiation being measured, and is indicated on a microammeter that is calibrated in roentgens per hour.

The shutter is a rotatable cylinder surrounding the photomultiplier tube. There are three apertures in the shutter. When the selector switch is in its CAL (calibrate position), the shutter is positioned so that its calibration aperture admits light from the luminous standard to the photomultiplier tube. Under this condition, the circuit may be adjusted for full-scale meter deflection. When the selector switch is in its 0.5, 5.0, or 50 position, the shutter is positioned so that its largest aperture is placed between the phosphor detector and the photomultiplier. When the selector switch is in the 500 position, the shutter is positioned so that a rectangular pattern of small holes forms the aperture between the phosphor and the photomultiplier tube.

The meter range-selector switch is located directly above the microammeter on the front panel (fig. 11-23, A). A push-button for control of the meter dial illumination is located on the handle. A knob for setting the microammeter to zero is located in the lower left-hand corner of the front panel; a similar knob for calibrating the microammeter is located in the lower right-hand corner. The meter ranges are 0.5 (yellow), 5 (orange), 50 (light magenta), and 500 (red) roentgens per hour. The meter scales are mechanically linked to the range selector switch so that only the calibration for the selected range appears on the dial of the microammeter.

Simplified Schematic Diagram

Because the photomultiplier tube has not been discussed in previous courses, a simplified schematic diagram of this tube and the associated circuitry is included, together with a brief description of its principle of operation.

Gamma radiation from the source causes the phosphor detector to glow. This light is directed through the shutter to the cathode of the photomultiplier tube (V-101), as indicated in figure 11-24.

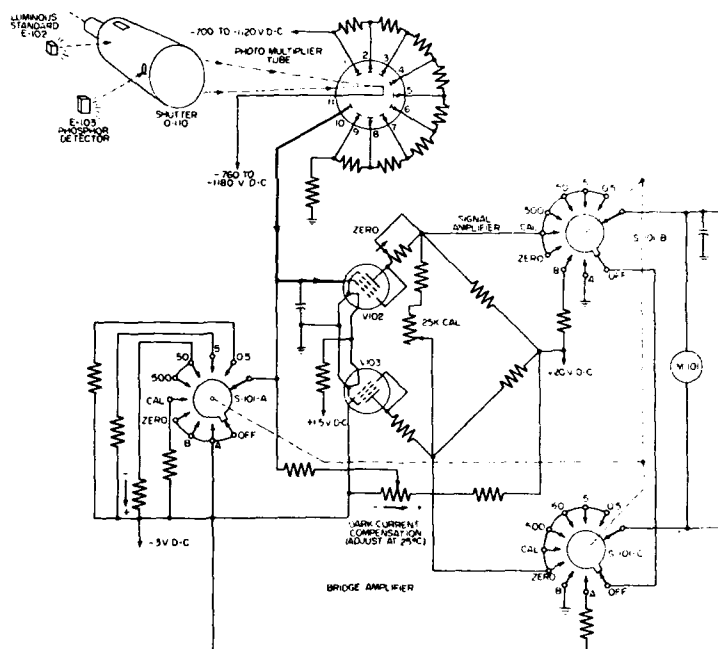


Figure 11-24.—Simplified schematic diagram of detection and bridge amplifier circuit.

The photomultiplier tube contains nine multiplying anodes and one collector anode. The nine multiplying anodes are called DYNODES. The potential of the cathode and each of the dynodes is negative with respect to ground; the cathode is more negative than the dynodes. The potential applied to the cathode is adjustable between -760 and -1180 , and the potential applied to the group of dynodes is adjustable between -700 and -1120 . In order to keep the sensitivity of the detection stage essentially constant, the potentials applied to the cathode

and dynodes must be adjusted when a photomultiplier tube is replaced. The maximum voltage between cathode and dynodes is 240 volts, and the minimum is 60 volts.

The light quanta striking the cathode of the photomultiplier tube causes it to emit a number of electrons, proportional to the value of the light quanta, in the direction of dynode 1. The electrons are accelerated toward dynode 1 because it is positive with respect to the cathode. Each electron striking dynode 1 releases a number of secondary electrons, which are drawn by the higher potential on dynode 2, thus multiplying the current. This process of multiplication is repeated throughout the nine stages of multiplication. The total gain is approximately one million.

The load resistor in the anode circuit is selected by selector switch S-101A. The signal voltage developed across the selected load resistance is applied to the grid of V-102 in the bridge circuit.

A small amount of current flows in V-101 even when it is not exposed to light. To counteract this effect, a variable positive bias is introduced into the grid circuit of V-102. This bias is controlled by the dark-current compensation potentiometer.

A detailed discussion of circuit operation, maintenance, and calibration is included in the instruction book that accompanies the equipment.

PHOTOGRAPHIC DOSIMETRY

General

Although a packet containing one or more types of photographic film is not in itself a radiac instrument, the detection and measurement of beta, gamma, X, and fast neutron radiations by the use of photographic film are very important in military establishments, laboratories, and industry. However, electronic devices are needed for interpreting the information accumulated by the film.

There are a number of problems involved in this method of detecting and measuring radioactivity. First

of all, suitable film emulsions must be chosen, and then the badge that will contain the film must be designed. Suitable film-developing procedures must be set up, and the necessary calibration standards and bookkeeping must be established.

The dosage to which a given film is exposed is determined by means of an instrument called a DENSITOMETER, which measures the extent of film darkening by beta, gamma, and X radiation. The effects produced in the film by fast neutrons are determined by means of a microscope.

Effects of Beta and Gamma Radiations on Photographic Emulsion

When beta radiations strike the photographic emulsion, some type of ionization (not well understood) takes place. The result is a blackening of the film, which becomes apparent when it is developed. The amount of blackening depends on the intensity of the incident radiations, the time of exposure, the sensitivity of the film, and on the way the film is developed.

Gamma rays affect the photographic emulsion in a different way. It is a common practice to cover a part of the film with a thin cadmium shield (lead is sometimes used when neutron-sensitive film is not included in the packet), which absorbs beta radiations but permits the gamma radiations to pass through and to produce a blackening of the film. Thus, the blackening of the film under the cadmium shield is caused largely by gamma radiations, while the blackening of the unshielded portion of the film may be caused largely by incident beta radiations. Soft gamma radiations (and X radiations also) will contribute to the blackening of the unshielded portion of the film, and therefore no accurate indication of beta radiations alone can be obtained.

Gamma radiations affect the emulsion under the shield in an indirect manner by freeing electrons or secondary beta particles in the metal shield around the film. These particles then cause ionization in the emulsion.

As was stated earlier, when a low-energy, gamma-ray photon interacts with an atom, an electron is ejected. This is the photoelectric effect. It is increased when the film is covered with the shield, and consequently the blackening of the film is increased. When the incident gamma photons have medium energy, there is elastic scattering (Compton effect). This process of absorbing radiation energy is effective when the lighter elements are the target. Because the film contains atoms of nitrogen and carbon, this effect adds appreciably to the blackening of the film. For gamma-ray photons of high energy, pair production may take place near the nucleus of the heavy atoms. The resulting electrons have high energy and can cause ionization in the film emulsion.

Two pieces of film of different sensitivities are often used together in a film badge in order to extend the range of radiation measurements that can be made.

Effects of Neutrons on Photographic Emulsion

Neutron-sensitive photographic film is used for measuring fast-neutron dosage. This film is often placed in the same film badge (discussed later) with the beta-gamma sensitive films.

The cadmium shield not only absorbs beta radiations but it also is a good absorber of slow neutrons. Fast neutrons, however, pass through the cadmium to the film where they may interact with the nuclei of hydrogen atoms in the film emulsion. The recoil of the hydrogen nucleus (a proton) leaves a trail of ions in the emulsion. These trails left in the emulsion are known as RECOIL PROTON TRACKS.

The neutron-exposed film is developed and read under a microscope by counting the recoil proton tracks in the emulsion. This reading procedure is obviously a painstaking operation.

The part of the film that is shielded by the cadmium shows the effects of fast neutrons; the part that is unshielded is affected by both fast and slow neutrons because both may pass through the portion of the film.

It is also possible to use film emulsions containing a boron compound for detecting neutrons. In this case the neutron is absorbed into the boron nucleus, which emits an alpha particle and becomes a lithium nucleus. The emitted alpha particle has high ionizing ability and causes a short but dense track in the emulsion.

Film Density

The stream of particles or radiation falling on (or penetrating) photographic film may be compared with the fall of rain in a given area. The INTENSITY of the rain may be described in terms of the number, size, and energy of the drops falling on the given area at a given time. The AMOUNT of rainfall involves time. If the intensity (the amount that falls in one unit of time) is multiplied by the total time during which the measurement is made, the amount can be determined. It is easy to see that a given amount of rain can be accumulated just as easily by having the intensity and the time short as by having the intensity low and the time long.

Essentially the same thing takes place when nuclear radiation is involved. Certain instruments (rate meters) measure the INTENSITY of radiation. Films indicate the AMOUNT of radiation entering the film during the time it is exposed, and this is an indication of the amount of radiation a person carrying the badge receives.

A formula relating the dosage, D (in roentgens), the intensity, I (in roentgens/hour), and time t (in hours) is

$$D = It.$$

As an example, assume that a film is exposed to an average intensity of 10 mr/hr for 8 hours, what is the cumulated dosage in roentgens? 10 mr/hr is the same as 0.01 r/hr .

$$D = It$$

$$D = 0.01 \text{ } r/hr \times 8 \text{ } hr$$

$$D = 0.08 \text{ } r$$

As another example, assume that after being developed and read, a film indicates an exposure of 2 r . If the

exposure time is 5 eight-hour days, what was the average intensity in mr/hr ?

$$D = It$$

$$I = \frac{D}{t}$$

$$I = \frac{2r}{40\ hr} = \frac{2000\ mr}{40\ hr} = 50\ mr/hr.$$

After being exposed and processed according to the manufacturers' instructions, the film must be compared with a standard to determine the amount of radiation that it has absorbed. The more radiation the film has absorbed the darker it will be.

If the film is placed in the path of a beam of light, the amount of light passing through the film will be inversely proportional to the darkness density, D of the film (and therefore to the amount of radiation absorbed by the film).

The OPACITY, O , of a film is the ratio of the intensity, I_0 of the light falling on the developed film to the intensity, I , of the light that passes through the film. Expressed as an equation,

$$O = \frac{I_0}{I}.$$

The eye responds to light in approximately a logarithmic manner. That is, if the illumination of an object is increased 100 times, to the eye the illumination would appear to be doubled. Because of this, it is convenient to compare the density of films by means of a scale based on the logarithm of the opacity. Of course, the greater the radiation exposure the greater the opacity of the film. Expressed as an equation,

$$D = \log_{10} \frac{I_0}{I}.$$

As an example of the use of this equation, assume that a certain type of film is exposed to one roentgen of gamma radiation. It is then developed and examined, and it is found that the film passes 50% of the incident light. What is the density, D , of the film.

$$\begin{aligned}
 D &= \log_{10} \frac{I_0}{I} \\
 &= \log_{10} \frac{100}{100 - 50} \\
 &= \log_{10} 2 = 0.301
 \end{aligned}$$

If several films from the same lot are exposed to various KNOWN amounts of radiation (for example, one film may be exposed to 10 *mr*, another to 50 *mr*, another to 100 *mr*, and so on), the densities of the individual films may be plotted against the exposure to form a characteristic curve for the type of film being used. One such curve is shown in figure 11-25. In this figure, log scales are used for convenience.

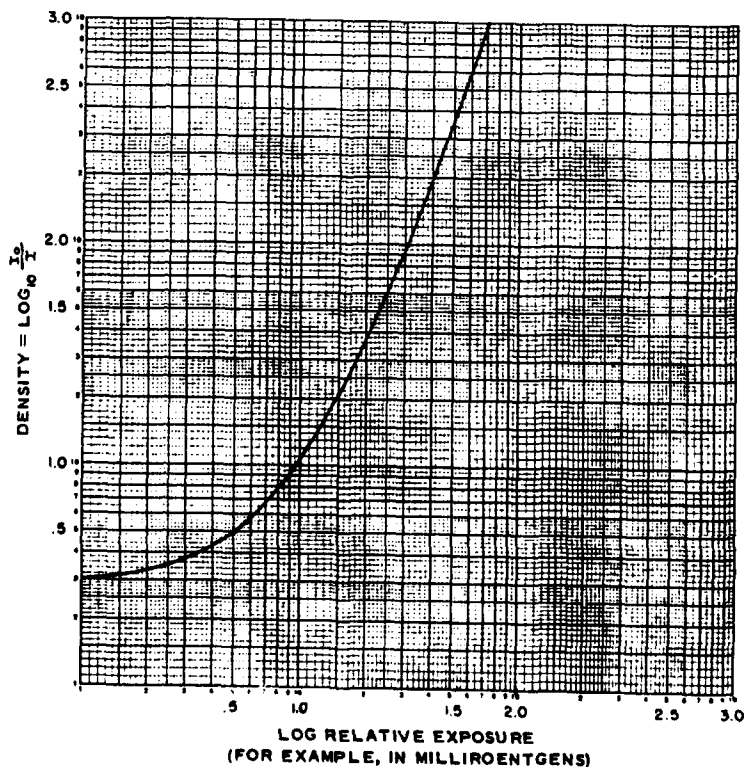


Figure 11-25.—Typical film characteristic curve.

Once the characteristic curve for a particular lot of films is established, the amount of exposure of any exposed film from the lot may be read from the curve, after the density has been determined by a densitometer. This instrument is described later. Only the straighter portion of the curve should be used because here there is the greatest change in density for a given change in exposure. This permits more accurate readings to be made.

If a different exposure range is required, a different type of film is used. Three types of useful film emulsions and their useful sensitivity ranges are given in table 22.

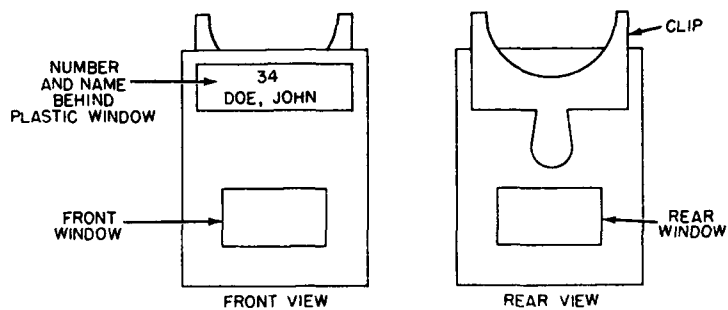
TABLE 23
TYPES OF FILM

Film Emulsion	Useful Sensitivity Range (Roentgens)
Type K-----	0.05 - 2.0
Type A-----	1.0 - 10.0
Dupont 552-----	0.06 - 10

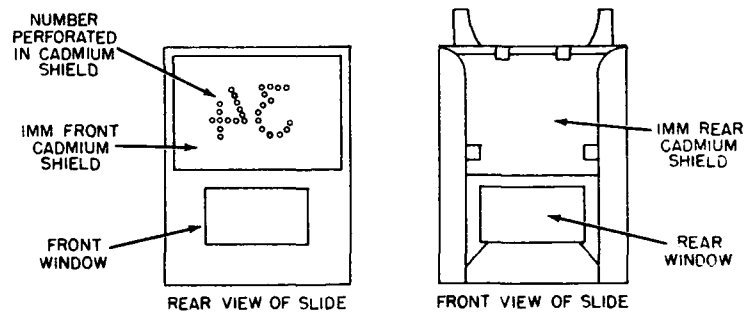
Film Badge

There are various types of film badges in use; however, the one shown in figure 11-26, A, is commonly used at Navy installations. The number of the badge and the name of the wearer are typed on a small card, which is placed behind the plastic window and in front of the cadmium shield. The front and rear windows permit beta rays to pass unimpeded into the film packets contained in the badge. The spring clip permits the badge to be fastened to the clothing of the wearer.

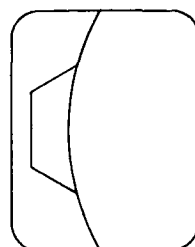
Views of the film badge and slide with the slide removed are shown in part B of the figure. Two cadmium shields are used, one in the slide and one in the case.



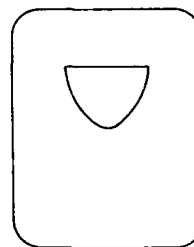
A FILM BADGE ASSEMBLED



B VIEW OF FILM BADGE WITH SLIDE REMOVED



DUPONT TYPE 552
(FOR BETA, GAMMA, &
X RADIATION)



KODAK TYPE NTA
(FOR FAST-NEUTRON
RADIATION)

C FILM PACKETS

Figure 11-26.—Film badge.

They shield both sides of the film packets from beta radiation, but permit gamma radiation to pass through to the packets. For the purpose of easy identification, the number of the film badge is perforated in the front cadmium shield. A brief exposure of the top part of the badge to soft X rays causes the number to appear on the developed film.

Representative film packets are shown in part C of the figure. These are used by the Health Physics Unit of the Naval Research Laboratory.

The Type 552 light-tight packet contains two pieces of film. One is more sensitive than the other. The packet is so placed that the more sensitive film is next to the front of the badge. The use of films of two different sensitivities affords a wider range of dosage indication than would be obtained by the use of only one film.

The Type NTA light-tight packet contains one piece of film that gives an indication of the amount of fast-neutron radiation absorbed in the film behind the shield. The emulsion contains many hydrogen atoms, which react (recoil) when they are bombarded by neutrons. The recoil tracks in the film are observed by means of a microscope. The Type NTA film packet is placed next to the rear of the film badge.

Densitometers

PURPOSE AND GENERAL DESCRIPTION OF THE EQUIPMENT.—The blackness, or density, of the exposed and developed film is determined by means of a densitometer. A simplified schematic diagram of a densitometer is shown in figure 11-27.

Light from the light source passes through the lens and the limiting diaphragm (which restricts the light to a small section of the film) and through the film to the photoelectric cell. The photoelectric cell produces a current proportional to the amount of light falling on it. This current passes through a microammeter, which is calibrated in units of density.

The scale of the instrument is arranged so that when the film is perfectly clear the pointer indicates zero density. If the film is perfectly black (so that no light passes through) the pointer indicates infinite density. At intermediate densities the needle indicates intermediate values.

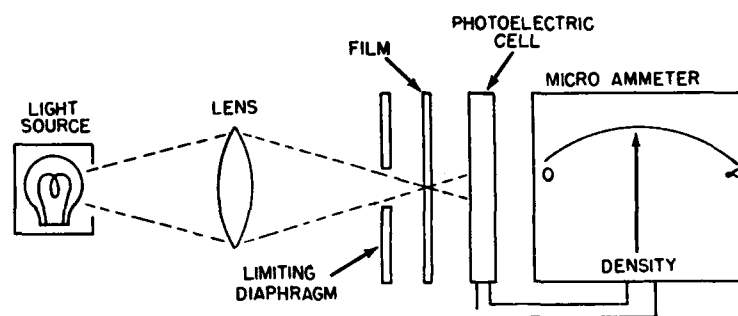
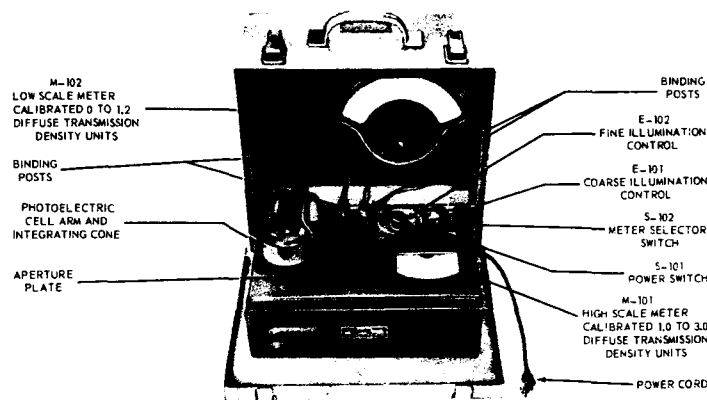


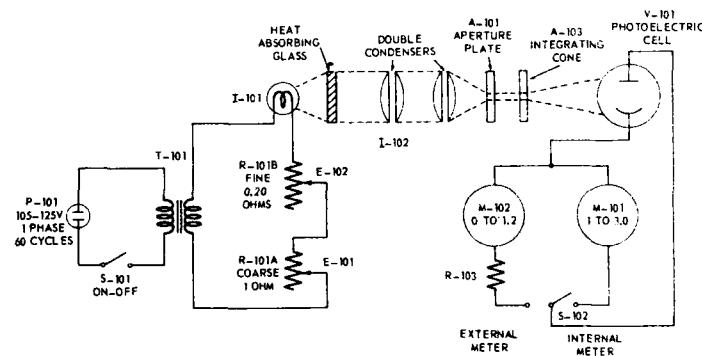
Figure 11-27.—Schematic diagram of a densitometer.

One type of densitometer, the PH-614/U, is shown in figure 11-28, A. The operating controls and the external features are labeled. A simplified schematic diagram of this instrument is shown in part B of the figure.

Transfer *T*-101 steps the input voltage down to approximately 5 volts for lamp *I*-101. Resistors *R*-101A (coarse control *E*-101) and *R*-101B (fine control *E*-102) permit adjustment of the lamp voltage (and the lamp brightness). The optical assembly, *I*-102, beams the light through the aperture plate above which is placed the film that is to be read. The integrating cone and the photoelectric cell are contained in the arm that is lowered to the film when a reading is made. Either of the two meters may be used, depending on the range of densities involved. The restoring system of each of the meters holds the pointer at the infinity mark on the scale when no current flows through the meter. This corresponds to the condition when a perfectly dark film is held over the aperture plate.



A OPERATING CONTROLS AND EXTERNAL FEATURES



B SIMPLIFIED SCHEMATIC DIAGRAM

Figure 11-28.—Densitometer PH-614/U.

USE OF THE EQUIPMENT.—This section gives a brief description of how the PH-614/U densitometer is used to obtain film-density readings. However, before the equipment is actually put to use, the operator must carefully study the instruction book that accompanies the equipment.

Film badges are usually delivered in lots of one thousand. From each lot, one or more badges are selected to

be used as CONTROL films and several are selected for CALIBRATION purposes.

The control film plays a very important role in determining film density. Without being exposed in any manner, the film is developed in exact accordance with the instructions provided by the manufacturer for developing that particular type of film. The developed control film is used to allow compensation for the fog level (the normal density of the unexposed film) of the batch of film from which it was selected.

This is the way the control film is used. With the equipment operating, and the external (more sensitive and more often used) meter in the circuit, the control film is placed over the aperture and the photoelectric cell arm is lowered until it is in contact with the film. The coarse adjustment (*E-101*) and the fine adjustment (*E-102*) are adjusted (in that order) to bring the meter indication to zero (maximum meter current). These adjustments compensate for the fog level of all of the film in the batch by making the light just bright enough to compensate for the normal fog in the film.

The calibration films also are extremely important because they permit the density readings to be interpreted by means of a graph in terms of the amount of radiation exposure.

The calibration films are exposed to different known levels of radiation, the levels being determined by the expected range of dosage to which the average film badge will be exposed in the field. When the calibration films have been developed and dried, the density readings (above fog level) are obtained with the densitometer and a characteristic curve of density versus dosage is plotted, as illustrated in figure 11-25.

Two calibration step wedges are supplied with the equipment for use in checking the operation of the two meters. These wedges, one of which is shown in figure 11-29 are used in the maintenance program. The method of using the wedges is relatively simple. Assume that

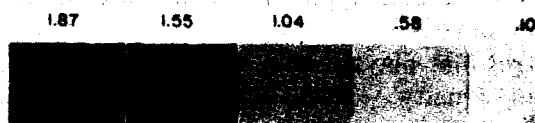


Figure 11-29.—Typical calibration film wedge.

the equipment is operating and that the external meter is being used. The photoelectric cell arm is depressed until it is in contact with the aperture plate through which the light is being emitted. Controls *E-101* and *E-102* are adjusted so that the meter reads zero (maximum current). A section of the wedge is then placed over the aperture and the photoelectric cell arm depressed until it is in contact with the wedge. The meter reading is then compared with the density printed on the wedge section. They should agree.

After the control negative has been used to correct for the fog level and the characteristic curve plotted by the use of calibration films, it is relatively easy to make a film badge measurement. The film badge negative is placed over the aperture and the photoelectric cell arm depressed until it is in contact with the film. The meter reading is then used to obtain the dosage from the characteristic curve for the lot of film in use.

CALIBRATION OF RADIAC INSTRUMENTS

Because of changes in tube and circuit characteristics, radiac instruments require recalibration from time to time. This is an extremely important part of radiac maintenance because defective equipment may result in radiation casualties. This type of work is done by experienced technicians at one of the radiac repair facilities provided by the Bureau of Ships.

In this chapter, only certain background information on calibration is given. More details will be included

as required in the advanced courses of study in the ET series.

The standard procedure for calibrating radiac instruments is to select certain intensity values (mr/hr) from each scale range of the instrument to be calibrated so that the intensity values will be evenly distributed throughout the entire range of the instrument. From the calibration formula (to be given), the distance (D) from the standard radiation source for each of the intensity values is computed. The instrument is then placed successively at these distances and readings taken. The computed and the actual readings should be essentially the same. If they are not, the proper calibration adjustments are made on the instrument.

The following calibration formula (for a standard radiation source) is frequently used.

$$D \text{ (in ft)} = \sqrt{\frac{9.04 \times \text{activity of source in millicuries}}{\text{intensity in } mr/hr}}$$

One millicurie is one milligram radium equivalent.

As an example, assume that a 100-millicurie source is used and that the desired intensity is to be 5 mr/hr , what will be the distance, D , from the source to the instrument for an intensity of 5 mr/hr .

$$D \text{ (in ft)} = \sqrt{\frac{9.04 \times 100}{5}}$$

$$D = \sqrt{181} = 13.4 \text{ ft (approximately)}$$

Other formulas, employing various units of distance and a standard source of radiation containing a given mass (in milligrams, mg) of radium, are

$$D \text{ (yd)} = \frac{mg}{mr/hr}$$

$$D \text{ (in.)} = \frac{1.3 \times mg}{r/hr}$$

$$D \text{ (cm)} = \frac{8.4 \times mg}{r/hr}$$

where mr/hr is the intensity in milliroentgens per hour and r/hr is the intensity in roentgens per hour.

If a large room is available, a calibration laboratory can be devised by marking the floor of the room with circles of various radii, as illustrated in figure 11-30. Several persons may work at the same time in such a room. Some such arrangement might also be made out-of-doors, especially in an emergency. The circles have a common center and the radioactive source (for example, radium) is suspended about 3 inches above the floor at the common center of the circles. The first three radii are a foot different in length; the others are a yard difference in length. The radial lines are drawn at 20-degree intervals. For making precise distance measurements between the radioactive source and the radiac-meter, accurate rulers or tapes are needed.

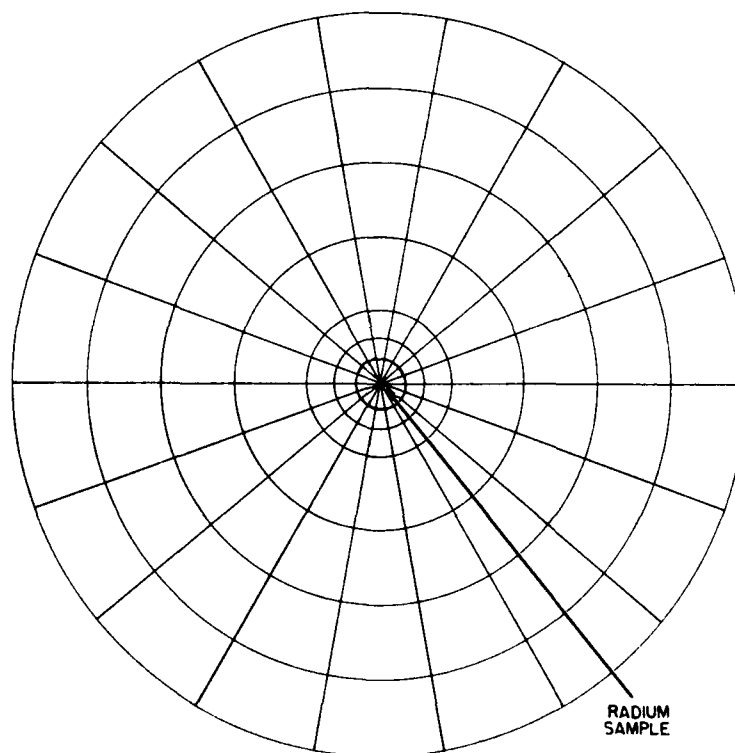
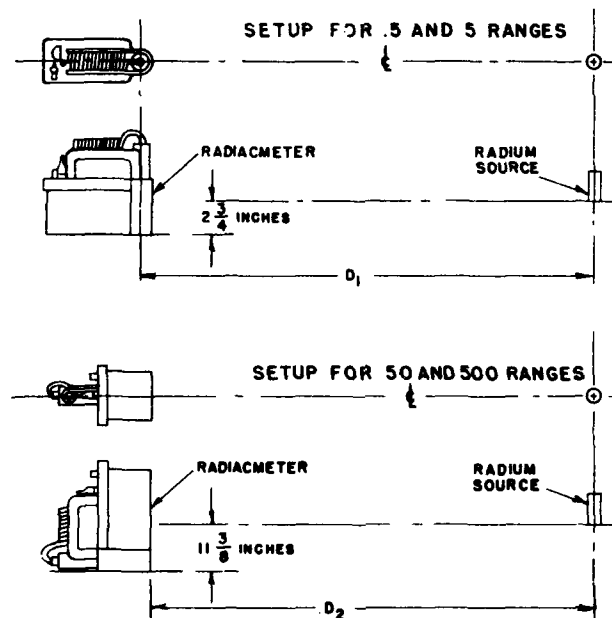


Figure 11-30.—Floor plan for room for calibrating radiac instruments.

Because a radioactive substance is involved, it is necessary to use due caution. All radiation safety precautions should be taken, and the calibration should be performed as quickly as possible to avoid prolonged exposure to the radiation.

Specific instructions for orientating the radiac instrument with respect to the radioactive source for calibration purposes is given in the instruction book that accompanies the instrument. Detailed instructions for the calibration procedure is also given.



CHECK	RANGE	D_1 INCHES	D_2 INCHES	ADJUST	TO READ MR/HR
1	.5	80.6	—	R-110	.40
2	5	25.4	—	R-104	4.
3	50.	—	8.06	R-106	40.
4	500.	—	2.54	R-108	400.

NOTE 1. ABOVE VALUES APPLY ONLY TO CALIBRATION BY 2-MILLIGRAM RADIUM SOURCE.

NOTE 2. RADIUM SOURCE MUST BE SET UP IN LINE WITH DIMPLE IN STEPS 3 AND 4.

Figure 11-31.—Calibration setup and values for the AN/PDR-27G.

The following steps are taken in calibrating the AN/PDR-27G Radiac Set with a 2-milligram radium source.

Step 1. The calibration port is removed to expose the calibration resistor controls. A check is made to see that the beta shield covers the end of the radiac detector, and the detector is placed in the well of the radiacmeter.

Step 2. The arrangement of the equipment is shown in figure 11-31. Each distance is measured carefully and the radiacmeter indication observed; if it differs by more than 10 percent from the specified value, as shown in the figure for that range, the proper calibration resistor is adjusted until the correct value is indicated on the meter.

If the mass of the radium is not 2 milligrams, or if it is desired to calibrate the radiacmeter at intensities not shown in figure 11-31, the following formula is used to find the relationship between meter indication and distance between radiacmeter and radium source

$$D = \frac{1.3 \times w}{r/hr}$$

where D is the distance in inches between radiacmeter and radium source, w is the mass of the radium source in milligrams, and r/hr is the radiation intensity in roentgens per hour. Roentgens are easily converted to milliroentgens.

Step 3. After all ranges are adjusted, the range switch is turned to OFF.

Step 4. If no other tests are to be made, the radium source is returned to a safe location.

Step 5. The calibration port is replaced.

QUIZ

1. What information is indicated by rate meters?
2. What information is indicated by dosimeters?
3. What are the four families of radioactive elements?
4. What are alpha particles?
5. What are beta particles?
6. How do gamma rays differ from light rays?
7. In figure 11-1, why are alpha and beta particles bent in opposite directions?
8. Most of the instruments discussed in this chapter utilize what effect to detect radiations?
9. What development has made the detection of radiations by scintillation increasingly important?
10. What are the two quantities measured by radiac instruments?
11. How many disintegrations does one milligram of pure radium undergo in one seconds?
12. What is the unit of dosage represented by 100 ergs absorbed in 1 gram of mass?
13. Starting with one gram of pure radium, what will be the remaining percentage of radium at the end of 4800 years?
14. What is meant by the term half-thickness of a shielding material?
15. How many ions are formed when one electron is dislodged from a neutral atom?
16. Why does the alpha particle cause a larger amount of ionization for a given distance of travel than does a beta particle?
17. What are the effects produced by gamma photons that cause them to be readily detectable?
18. In what three ways may the energy of gamma radiation be absorbed as it passes through matter?
19. In what type of collision (between ions) is there no change in momentum or kinetic energy?
20. In avalanche ionization, what is the gas amplification factor?
21. Why do the curves in region C of figure 11-12, B, slope upward?
22. In the direct-reading radiacmeter the quartz fiber is similar to what element in the gold-leaf electroscope?

23. What are the two functions of a minometer?
24. In what region of the curves in figure 11-12, B, does the ionization chamber survey meter operate?
25. What type of radiation is the most effective in producing ionization in the proportional counter (AN/PDR-10C)?
26. What is the purpose of the discriminator control in the AN/PDR-10?
27. What type of radiations may be detected and measured by Radiacmeter AN/PDR-27G?
28. What type of detector is used in Radiacmeter AN/PDR-18B (scintillation counter)?
29. The amount of blackening of photographic emulsion due to beta radiations depends on what four factors?
30. Why are two pieces of film of different sensitivities often used together in a film badge?
31. Assume that a film from a film badge indicates an exposure of 1 r that was acquired in 5 eight-hour days, what was the average intensity in mr/hr ?
32. What is the purpose of the control film used with a densitometer?
33. What is the purpose of the calibration films used with a densitometer?
34. Why should the calibration of a radiac instrument be performed as quickly as possible, consistent with accuracy?

CHAPTER

12

COMMON OPERATING ADJUSTMENTS: RADIO TRANSMITTERS AND RECEIVERS

INTRODUCTION

The ET 3 must know how to make many operating adjustments on a variety of electronic equipments. These equipments include communications transmitters and receivers (and associated TTY and FAX circuits), surface search and height finding radars and their associated repeaters (including IFF equipment), sonar, and electronic aids to navigation. Common operating adjustments include starting and stopping the equipment, tuning it, and selecting the operating frequency. Meter readings of current, voltage, and power must be taken; gain-control or intensity-control adjustments must also be made. The knowledge of how to perform these functions is basic to his knowledge of maintenance and repair because without it the ET 3 can do little to maintain or repair an equipment.

The common operating adjustments are made by means of external controls. Other chapters in this training course describe various electronic circuits associated with external controls and analyze their functions. The purpose of this and the following two chapters is to describe the common operating adjustments for three general classes of electronic equipments. These include radio communications, radar, and sonar.

The method of approach in treating each class of electronic equipment is to give, first of all, a picture of a typical equipment and a general description of its functions and how it is related to other equipments or components. Next, a block diagram of the equipment showing the major components and their interconnections, together with a description of their functions, is given. Finally, the common operating adjustments are described in detail.

This method of approach has the advantage of showing the ET 3 why certain adjustments are made rather than merely telling him how they are made. How to make adjustments on electronic equipment is spelled out in detail in the equipment instruction book.

In addition to making common operating adjustments on a variety of electronic equipments, the ET 3 must be able to perform the necessary switching operations at a switchboard to connect an equipment to a remote control point or to another equipment. The circuits for a variety of switching operations are analyzed in another chapter of this training course.

Necessity for Familiarity with External Controls

In modern warfare no commander can exercise control of more than a handful of men by his physical presence. To receive information upon which to base decisions, to transmit commands, and to keep his ship in all respects ready for combat, the commanding officer must rely upon communications. In this day of huge task forces and armadas of supporting aircraft, effective communications mean radio communications.

Communications equipments include low, high, and very high-frequency, and ultra-high frequency transmitters and receivers. The low- and high-frequency high-power transmitters are used for long range communications. The very high-frequency, low-power transmitters are used for short-range communications. Communications receivers are usually of the superheterodyne type

and are somewhat similar to broadcast radio receivers, except that the communications receivers have much greater selectivity and sensitivity and cover a greater band of frequencies. The receiver must be properly tuned, the gain control correctly adjusted, the BFO operating correctly, and many other adjustments made by means of the external controls in order to have satisfactory performance.

A transmitter or receiver not properly tuned may mean a break in a communications chain, the loss of a vital message, and the difference between success and failure of a mission. The ET 3 must back up the operators of electronic equipments and be prepared to lend a hand in making the necessary adjustments for top performance; this requirement is in addition to his other duties of troubleshooting, maintenance, and repair.

Common Adjustments and Controls

Before the ET 3 can ascertain that an equipment is working properly he must be able to perform the following actions: (1) starting and stopping the equipment, (2) tuning the oscillator by varying the inductance or capacitance in the oscillator tank circuit, (3) tuning the various r-f amplifier stages progressively from the stage next to the oscillator to the final power amplifier by varying the capacitance or inductance in the associated tank circuits, (4) tuning the antenna by varying the inductance or capacitance in the antenna tuning circuit, (5) matching the antenna to the antenna feed line by varying the mutual inductance in an auto-transformer coupling circuit, (6) varying the load on the transmitter by adjusting the coupling mutual inductance between the antenna feed line and the transmitter, (7) manual or machine keying the transmitter and (8) modulating the r-f carrier with voice or teletype signals.

Actions commonly performed by the ET 3 relating to communications receivers include (1) tuning the receiver by adjusting the capacitance in the r-f amplifier and

local oscillator resonant tank circuits, (2) band switching by changing the inductance in the r-f amplifier and local oscillator resonant tank circuits, (3) adjusting the r-f and a-f signal levels by varying the r-f and a-f gain control potentiometer, (4) switching on or off the beat frequency oscillator (BFO), (5) tuning the BFO by adjusting the capacitance in the associated tank circuit, (6) switching on or off the receiver silencer, and (7) adjusting the tone control circuits in the associated noise suppressors by varying the capacitance shunted across the audio circuits.

Necessity for Careful Study of Technical Manuals

Every electronic equipment aboard ship has an instruction book (technical manual) that completely describes the equipment. The first step in becoming acquainted with an electronic equipment, whether it be a communications transmitter or receiver, a surface search radar, or a scanning sonar, is to break out the technical manual for that particular equipment and study it carefully.

The technical manual contains valuable information, which is not always used to best advantage simply because it is not studied carefully. As mentioned in chapter 7, instruction books are usually arranged in sections beginning with a general description (section 1), followed by theory of operation (section 2), installation procedures (section 3), operational procedures (section 4), operator's maintenance (section 5), preventive maintenance (section 6), corrective maintenance (section 7), and a parts list (section 8). Detailed wiring diagrams and schematics are also included in the latter part of the instruction book. Frequently, simplified schematics are included with the discussion of theory of operation.

The arrangement and content of the technical manual should be closely observed. It is not necessary to memorize the data. However, make mental notes of the purpose and use of each section.

For example, there may be a data sheet containing

information about relay coils and contacts. Or, there may be a paragraph detailing the information that should accompany an order for a renewal part. Make a note of this, and the general nature of the data, for possible future use. The more familiar the ET 3 is with the instruction book, the easier his work will be and the more time he can save in an emergency.

The schematic and interconnection wiring diagrams should be studied carefully. Be able to identify any part that is illustrated. Parts that cannot be readily identified at first can be identified later by studying the parts list. The system of symbols used should be learned. This is particularly important when a symbol has been assigned to each pair of contacts on a relay or switch. Sometimes several devices operate from the same control; the method of showing this on the diagram should be noted. Determine the best use to which the schematic, wiring, and interconnection diagrams can be put.

Where circuit cabling is used, the individual leads are identified as they enter and leave the cable. For example, in one particular equipment the lead from terminal 3 of potentiometer R257B extends to jack J260D via a cable. Where the lead enters the cable it is marked J260D. Where it leaves the cable it is marked R257B.

Each technical manual of most currently used ship-board equipment is being supplemented with the Maintenance Standards Book, parts I and II described in chapter 6 of this training course under the heading of the POMSEE program. This book also indicates many of the common adjustments of the external as well as internal control points of the associated equipment.

RADIO TRANSMITTING SET AN/SRT-15

First, consider the Radio Communications Transmitting Set AN/SRT-15 (fig. 12-1). A general description of the major components is followed by a discussion of some of the common adjustments.

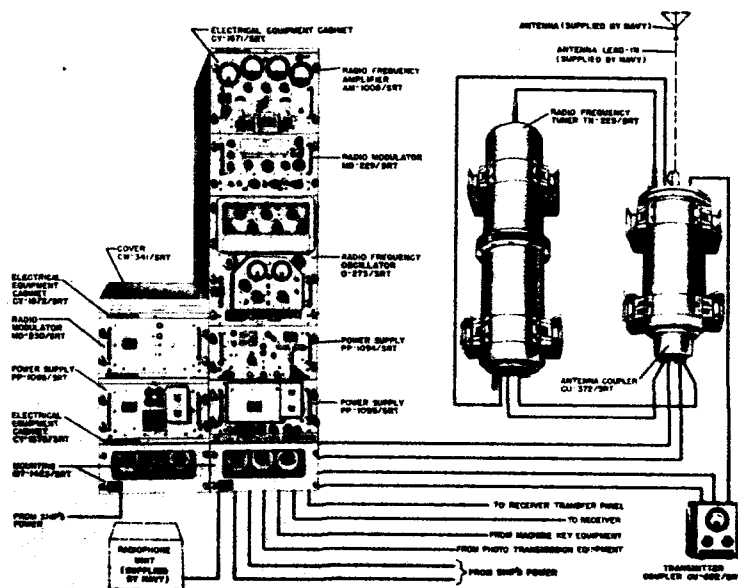


Figure 12-1.—Radio Transmitting Set AN/SRT-15.

The set may transmit an r-f carrier at either a 100-watt or a 500-watt nominal level. The r-f carrier may be amplitude modulated for radiophone (type A3 emission), or it may be ON-OFF c-w telegraphy (type A1 emission), either hand or machine keyed. Other modes of operation include telegraphy by frequency-shift keying (type F1 emission), using an FS machine key (teletype operation), and facsimile (type F4 emission), using frequency modulation.

Frequency selection is manually accomplished. A set of nine frequency selection control knobs located on the radio frequency oscillator provides a range of frequencies from 0.3 mc to 26 mc in 10-cycle steps.

Start-stop control, keying, and radiophone may be obtained from a remote location. Standard Navy six-wire radio transmitter control circuits are used for all remote-control operations.

The AN/SRT-15 with all accessories includes a 100-watt transmitter group and booster, antenna tuning equipment, antenna, and remote radiophone unit. The booster includes modulator-power units to accomplish 500-watt operation. The transmitter bay consists of the 100-watt transmitter group, a transmitter coupler, two mountings, and the radio modulator-power supply (booster).

The antenna tuning equipment includes an antenna coupler and r-f tuner.

The 100-watt transmitter group contains all circuits for generating the desired radio frequency and amplifying it to the 100-watt carrier level, and provides it either in amplitude or frequency-modulation communication, as previously described. The modulated r-f carrier output is fed through a 50-ohm coaxial cable to an adjustable autotransformer (transmitter coupler) for matching the output of the radio frequency amplifier to the input of the antenna coupler.

The transmitter group includes a cabinet holding five pull-out drawer-type chassis. From top to bottom these units are (1) the radio frequency amplifier (RFA), (2) the low-level radio modulator (LLRM), (3) the radio frequency oscillator (RFO), (4) the low-voltage power supply (LVPS), and (5) the medium-voltage power supply (MVPS).

The functional block diagram of Radio Transmitting Set AN/SRT-15 is shown in figure 12-2. The r-f carrier originates in the radio frequency oscillator and is amplified in the radio frequency amplifier. The output of the radio frequency amplifier is fed to the antenna via the load adjusting unit and the antenna coupler. For 100-watt operation the output of the low-level radio modulator is fed directly to the radio frequency amplifier. For 500-watt operation the output of the low-level radio modulator is fed to the high-level radio modulator and the output of the high-level radio modulator is fed to the radio frequency amplifier. The radio modulator power supply (in the booster) provides the necessary

additional power to increase the r-f carrier output from 100 to 500 watts.

It should be noted that where references are made to the low-level radio modulator or the high-level radio modulator, they should not be interpreted as meaning the technique of modulation known as grid modulation as opposed to plate modulation, but rather as referring to the operating power level of 100 or 500 watts.

Radio Frequency Amplifier

The radio frequency amplifier (fig. 12-3) amplifies the r-f signal received from the radio frequency oscillator to either the 100- or 500-watt nominal level. It consists of three stages of amplification, which include (1) the buffer, (2) the intermediate power amplifier (IPA), and (3) the power amplifier (PA).

The output of the radio frequency oscillator drives the tuned buffer stage. This stage also receives keying signals from the low-level radio modulator to key the output of the RFA ON and OFF during hand-key, machine-key,

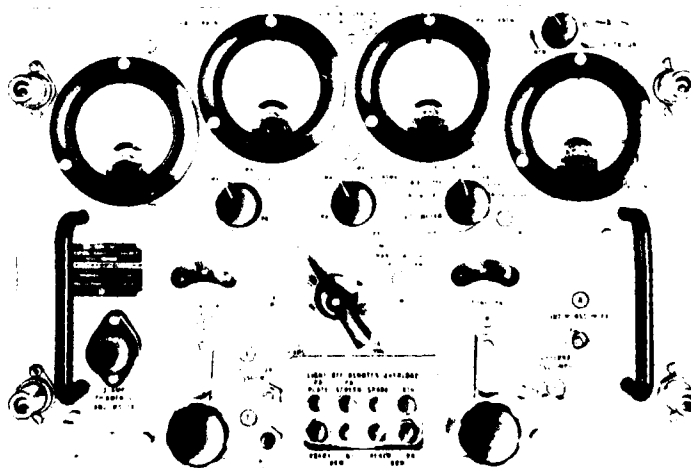


Figure 12-3.—Radio Frequency Amplifier AM-1008/SRT.

and phone operation. The tuned IPA stage, which follows, uses a beam power tetrode.

The final stage is the power amplifier, employing a tetrode with forced-air cooling. In phone operation, an audio modulating signal is received from either the low-level radio modulator (100-watt operation) or the high-level radio modulator (500-watt operation) to amplitude modulate the output of the RFA.

The RFA is manually tuned by the adjusting of three front-panel controls (the band switch, the tune IPA control, and the tune PA control). In both the IPA and the PA stages of amplification there is a tuned plate tank circuit that is affected by these controls. The first of the tuning controls is a six-position band switch that connects a tank circuit to each of the three stages in accordance with the band of frequencies in which the selected transmission frequencies lie. The second control tunes the buffer and IPA stage tank circuits and the third control tunes the PA stage. The second and third controls vary the capacity of the tank circuits to bring them into resonance at the desired frequency.

In addition to the tuning controls, there is a control (excitation control) for regulating the input level of the signal from the radio frequency oscillator. The RFA front panel contains four meters used for tuning indicators and as test meters for various operating voltages and currents. A set of indicator lamps is provided to indicate overload conditions and operating conditions of the carrier.

A pushbutton switch, which is used to place the set in nominal 500-watt operation, is mounted on the RFA front panel. A second pushbutton is used to restore the set to the 100-watt level.

Low-Level Radio Modulator

The low-level Radio Modulator MD-229/SRT is illustrated in figure 12-4. This unit accepts voice, telegraphy (hand or machine key), frequency shift (teletype), or

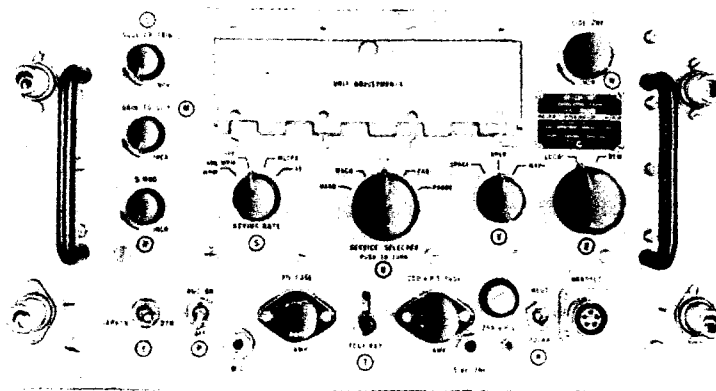


Figure 12-4.—Radio Modulator MD-229/SRT (low-level radio modulator, LLRM).

facsimile signals. It contains audio-amplifying and modulating circuits for amplitude modulation of the r-f carrier at the 100-watt level. For 500-watt operation the low-level radio modulator feeds the high-level radio modulator (HLRM) that boosts the signal to the required level. Peak limiting and noise suppression (squelch) circuits are provided in the audio circuits. Either carbon or dynamic microphones may be used.

An electronic keyer circuit provides the keying voltage to control the radio frequency amplifier during c-w telegraph (hand-key and machine-key operation) and to control the radio frequency oscillator in frequency-shift telegraphy. The keying circuits are suitable for speeds from hand keying to 600 words per minute. Facsimile signals are connected through the low-level radio modulator to the frequency-shift circuits in the radio-frequency oscillator drawer. An audio oscillator (200-cycle output) is included in the LLRM to phase-modulate the transmitter signal to overcome selective fading in frequency-shift transmission; in c-w telegraphy the oscillator has a 1000-cycle output used for aural monitoring of the keying signals.

The front panel of the LLRM has controls for select-

ing the mode of transmission, receptacles for a local carbon or dynamic microphone, gain controls, and a squelch circuit control. A test key is provided for carrier control.

Radio Frequency Oscillator

The radio frequency oscillator (fig. 12-5) is the source of the r-f carrier signal. It consists of 15 sections: 14 removable units (holding the electron tube circuits) and a mounting to which these units are attached. The 15 sections have official standard item name and symbol designations but are usually referred to by their common name or unit number.

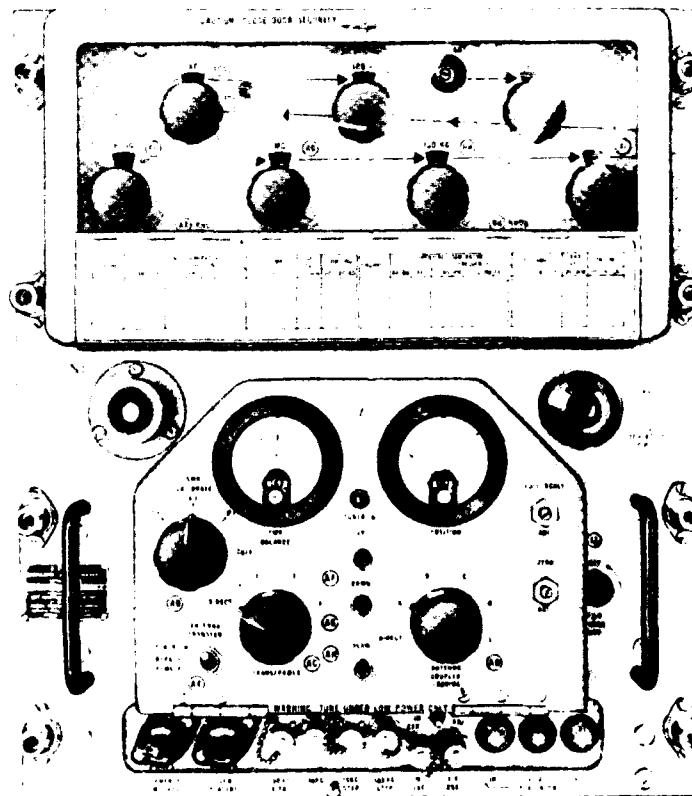


Figure 12-5.—Radio Frequency Oscillator O-275/SRT (RFO).

The output stage of the RFO is divided into three separate units (11a, 11b, and 11c) each of which covers a portion of the total frequency range of the radio transmitter.

Units 1 through 12 are equipped with multiple pin-type connectors that mate with receptacles on unit 14. Radio-frequency connections are made through connectors and jumper cables. On each subchassis, test points are provided at r-f input or output points. By using a test cable, any subunit can be examined in detail with each part readily accessible.

There are three individual oscillators in the RFO. Unit 1 is the crystal oscillator, which generates the basic frequency of 100 kc with an accuracy of 1.5 parts per million over the temperature range of -4°F to $+122^{\circ}\text{F}$. Unit 3 is the interpolation oscillator used to obtain the 10-cycle steps. Unit 12 is the frequency-shift oscillator. The 100-kc carrier frequency of this oscillator is capable of being shifted from +2000 to -500 cycles about the 100-kc value. The frequency-shift oscillator is used in the mixing sequence only when service selector control, U, on the LLRM (fig. 12-4) is set in one of the frequency-shift positions, FSK or FAX.

The 100-kc signal from the crystal oscillator controls several frequency multipliers that generate a high order of frequencies for the mixing stages. Locked to the crystal oscillator are 10-kc, 100-kc, and 1-mc step generators, each of which provides 10 frequency increments used in the mixing sequence. The independent interpolation oscillator is used to obtain 10-, 100-, and 1000-cycle steps. This interpolation can be checked readily against the crystal oscillator and may be adjusted to maintain its accuracy. Several frequency converters mix the signals from the crystal oscillator, interpolation oscillator, and step generators to provide an r-f signal in steps of 10 cycles over the frequency range of 0.3 to 26 mc.

The front panel of the RFO (fig. 12-5) has all the controls for setting up any frequency within the fre-

quency range. Nine knobs are provided for manually setting a frequency.

An electron-ray tube is provided for checking the frequency-shift oscillator or the interpolation oscillator against the standard crystal oscillator. A set of test receptacles is provided on the front panel; these bring out important signals in the RFO for monitoring with a standard test oscilloscope.

The Antenna Control Indicator C-1352/SRT is mounted on the face of the FRO front panel and is considered as a component of the RFO. The control indicator has all the controls and indicators required to accomplish the manual tuning of the antenna coupler and r-f tuner.

A set of three pushbutton switches controls the UP and DOWN movement of the shorting ring on the main tuning coil in the r-f tuner. One toggle switch is used to control the action of the bypass switch in the antenna coupler, enabling the antenna tuning equipment to be placed in the antenna line or to be completely bypassed. One rotary switch controls the loading switches in the antenna coupler, selecting various values of capacitive or inductive reactance loading in conjunction with the main tuning coil. Another rotary switch controls the action of a switch in the r-f tuner, which switches an impedance-matching transformer in or out of the transmission line. An indicator is provided to show the standing-wave ratio on the transmission line. The indicator has an associated switch that is used to set the range of the indicator. A second indicator shows the position of the shorting ring on the main tuning coil in the r-f tuner.

Low-Voltage Power Supply

Power Supply Unit PP-1094/SRT (fig. 12-6) is commonly called the low-voltage power supply (LVPS) to distinguish it from other power supplies in the transmitting set. It includes three conventional full-wave rectifiers employing electron tubes and the associated filter circuits. A metallic full-wave rectifier provides

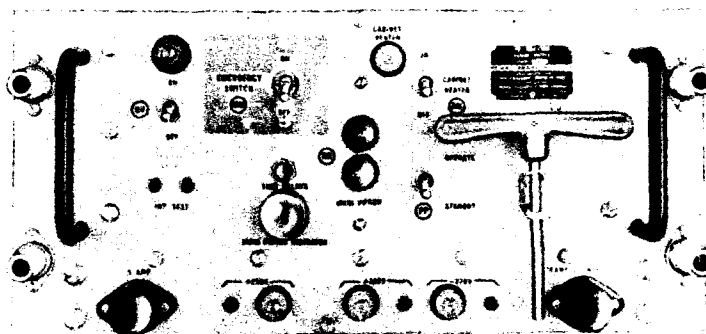


Figure 12-6.—Low-voltage Power Supply (LVPS) PP-1094/SRT.

a separate -24-volt supply for control circuit functions. One plate-filament transformer supplies all voltages for the rectifier circuits. The primary a-c input is 110 volts, 60 cycle, single phase.

The two controls for turning power on and off in the 100-watt transmitter group are located on the front panel of this unit. A cabinet heater switch controls heaters provided to raise the equipment temperature under some conditions. The standby operate switch may be used to put the equipment in a "ready" or "standby" condition. The front panel indicator lights show the proper operation of controls and circuits of this unit.

Medium-Voltage Power Supply

Power Supply Unit PP-1095/SRT (fig. 12-7) is commonly called the medium-voltage power supply (MVPS). It contains the necessary power transformers, rectifier tubes, filter components, and miscellaneous parts to provide outputs of +500 volts and +1050/1300 volts for the IPA and PA tubes of the RFA and portions of the low-level radio modulator. This unit is energized by operating the appropriate controls on the front panel of the low-voltage power supply. The +500-volt supply is used when the equipment is operating at the 100- and 500-watt levels, but the +1050/1300-volt supply is used

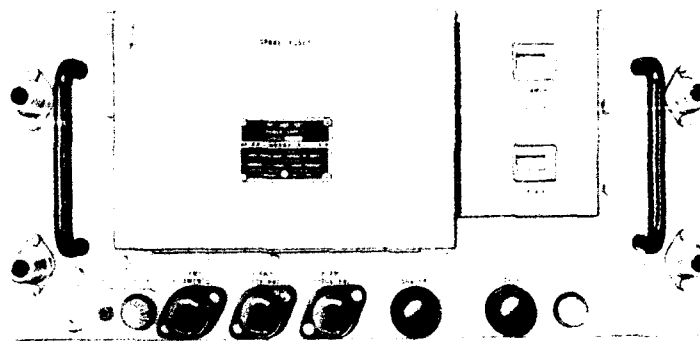


Figure 12-7.—Medium-voltage Power Supply (MVPS) PP-1095/SRT.

only at the 100-watt level. The +1050-volt output is used with phone service only; whereas, the +1300-volt output is used with all other modes of transmission. The elapsed time meters on the front panel are provided for logging transmitter-group tube hours (filament and plate).

Transmitter Coupler

The load adjusting unit (fig. 12-8) is Transmitter Coupler CU-402/SRT. This unit has a mounting bracket to permit independent mounting. The unit includes an autotransformer with four taps and a standing-wave ratio monitor circuit. An input switch and an output switch, each with four positions that connect to the four taps of the autotransformer, are also components of this unit.

The r-f output of the radio frequency amplifier is connected by interconnecting cabling to the standing-wave ratio monitor and then to the input switch and one of the taps of the autotransformer, which acts as an impedance-matching device. The output from the autotransformer (from the tap selected by the output switch) is fed to the antenna coupler.

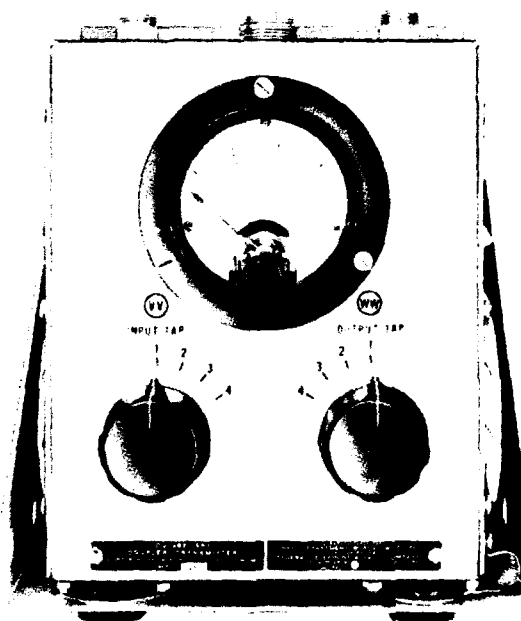
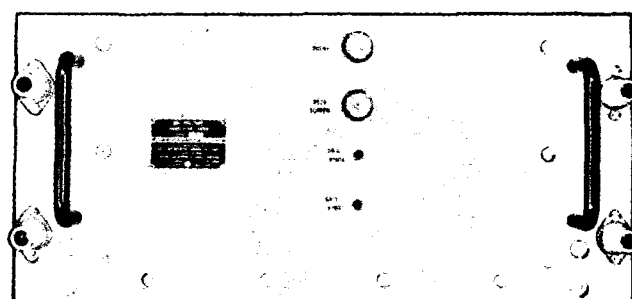


Figure 12-8.—Transmitter Coupler CU-402/SRT (load adjusting unit).

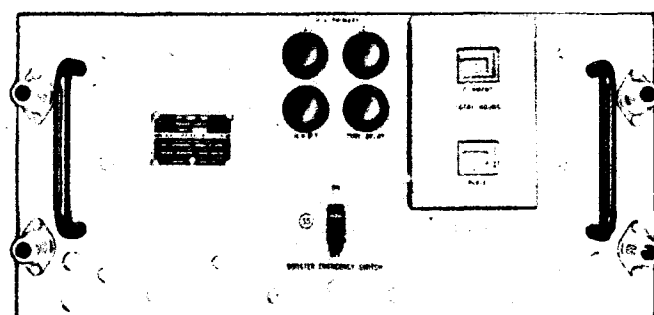
Radio Modulator Power Supply

The Radio Modulator Power Supply OA-685/SRT (booster) (fig. 12-9) provides additional audio and plate power to increase the r-f carrier output of the 100-watt transmitter group to 500 watts. Limitations within the transmitter and antenna tuning equipment make it impracticable to obtain 500-watt carrier operation on the lower frequencies from 0.3 mc to 2 mc. With this exception, all features of the 100-watt transmitter are retained when 500-watt operation is used. Transmitter and antenna tuning is performed at the 100-watt level; high power is applied only when tuning has been completed.

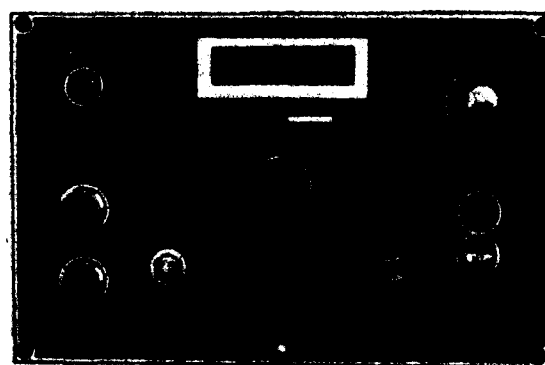
The booster includes (1) Radio Modulator MD-230/SRT (high-level radio modulator) (fig. 12-9, A), and



A HIGH LEVEL RADIO MODULATOR



B HIGH VOLTAGE POWER SUPPLY



C REMOTE CONTROL UNIT

Figure 12-9.—Radio Modulator Power Supply OA-685/SRT (booster) and Radio Phone unit Navy Type 23500.

(2) Power Supply PP-1096/SRT (high-voltage power supply) (fig. 12-9, B). The mechanical construction of the booster components is similar to that used in the 100-watt transmitter group. The high-level radio modulator and the high-voltage power supply are of the pull-out drawer design and are housed in individual cabinets equipped with slide and rail arrangement.

The high-level radio modulator (HLRM) modulates the r-f amplifier during phone service at the 500-watt power level. A push-pull, high-level audio power amplifier consisting of two tetrodes operating in class AB2 provides plate modulation for the final r-f amplifier stage. The low-level radio modulator (LLRM) supplies 6 watts of power to drive the HLRM.

The control that energizes the HLRM is located on the RFA front panel.

The high-voltage power supply (HVPS) consists of six hot cathode gas rectifier tubes in a three-phase, full-wave rectifier circuit with choke input filter. It provides an output of either +2400-volt or +3000-volt d-c power, as required for the plate of the power amplifier tetrode in the RFA. The +2400-volt output is used for phone service only; whereas, the +3000-volt output is used with all other modes of transmission. By means of links the input connections of the HVPS may be changed to use either 220- or 440-volt, 3-phase, 60-cycle primary power.

An emergency switch on the front panel of the HVPS controls the 3-phase input power. Filament power is applied to the HVPS (and the HLRM) when the booster emergency switch is on. Application of plate power is controlled by a time delay element and a pushbutton switch on the front panel of the RFA. Indicator lights are also provided on the front panel of the HVPS to show power-on and time-delay status.

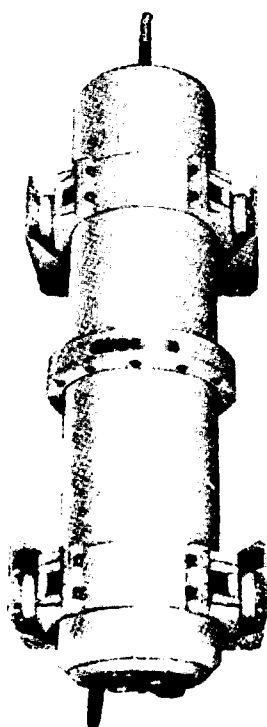
Remote Control Unit

To operate the transmitting set from a remote location requires a remote-control unit. A typical remote-control

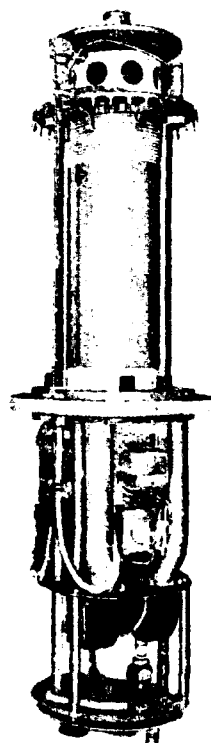
unit is Navy type 23500 (fig. 12-9, C). This unit contains a start-stop switch for turning the transmitter on or off, jacks for connecting a handset, chest set, or hand key, a volume control for the earphones, and indicator lamps for transmitter-on and carrier-on indications.

R-F Tuner

The function of the antenna tuning equipment (fig. 12-10, A) is to match the impedance of the r-f transmission line (50 ohms) to the antenna input impedance over the entire frequency range. The principal tuning



SIDE VIEW,
COVER ON



SIDE VIEW,
COVER OFF

Figure 12-10.—Radio Frequency Tuner TN-229/SRT (r-f tuner).

romponent to accomplish this match is the main tuning coil found in the r-f tuner (fig. 12-10, B). This coil is a helically wound length of transmission line whose length can be varied by the position of a concentric sliding short circuit. A single coupling coil concentric with the main coil is mounted on the sliding short. The sliding short is positioned by a drive motor and associated gear train; the drive motor is controlled from the control indicator mounted on the face of the RFO panel. An impedance matching transformer is also located in the r-f tuner. The transformer can be inserted or removed from the transmission line by a motor-driven switch that, in turn, is controlled at the control indicator. The transformer is required at the low frequencies to match the very low antenna impedance to the 50-ohm transmission line.

A blower is provided for heat dissipation in the r-f tuner. A thermostatic switch that is normally closed and a blower centrifugal switch that is closed only when the blower is rotating are provided as safety devices when the equipment is operated at the 500-watt level. If either or both of these switches are open, the transmitter can function only at the 100-watt level.

The r-f tuner is a sealed moisture-proof unit equipped with valves and a pressure gauge to permit pressurizing the unit to a pressure of 20 pounds per square inch with dry nitrogen gas.

Antenna Coupler

The Antenna Coupler CU-372/SRT (fig. 12-11) has two basic functions: (1) to switch various inductive or capacitive reactance components into the transmission line to extend the range of tuning of the main tuning coil, and (2) to provide a switch that permits the antenna to be connected through the tuning components to the transmitter r-f output or to connect the antenna directly to the transmitter r-f output.

To extend the tuning range of the main coil in the r-f

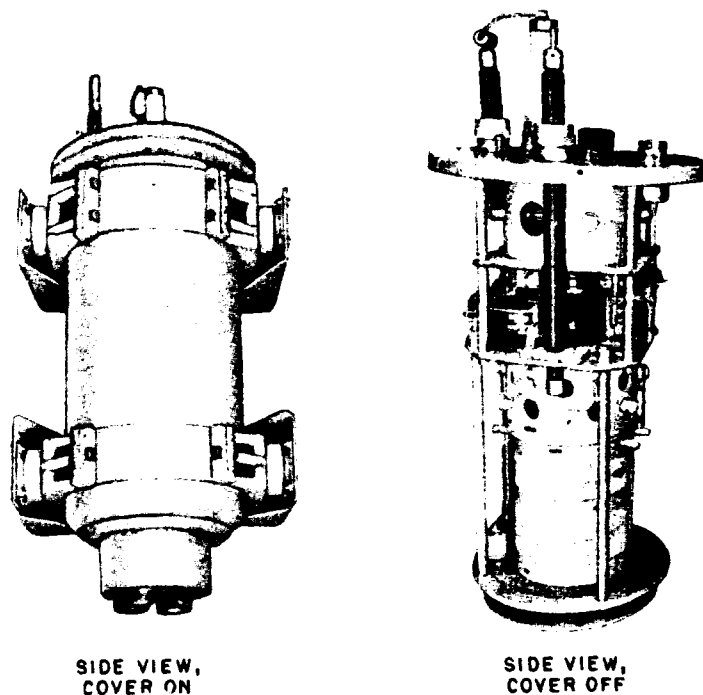


Figure 12-11.—Antenna Coupler CU-372/SRT.

tuner, three capacitors and two coils are in the antenna coupler that can be inserted in various combinations in series, or in shunt with the main tuning coil. A motor-driven switch selects the component desired; the switch is controlled from the control-indicator on the front panel of the RFO in the transmitter bay (fig. 12-5). This switch also has a position in which no loading components are added, leaving the main tuning coil in the r-f tuner as the only tuning component in use.

The switch to either bypass the tuning components or insert them on the transmission line is motor driven. It has two positions and is manually controlled at the control indicator (fig. 12-5).

The antenna coupler, like the r-f tuner, is a sealed unit with similar provisions for charging with dry nitrogen gas.

The transmitting set is designed to work into a 35-foot whip antenna, Navy type C66047, or into a 60 to 130-foot single wire with a 40-foot downlead.

Common Adjustments

Common adjustments for Radio Transmitting Set AN/SRT-15 include starting and stopping the equipment for 100- and 500-watt operation, selecting the types of service (mode of transmission), selecting a frequency, tuning, and remote operation.

As an example of common operating adjustments, the sequence of operations is given for starting and stopping the equipment for 100- and 500-watt operation.

All the controls for starting and stopping the equipment for 100-watt operation are located on the LVPS (fig. 12-6).

To start the transmitter for 100-watt operation:

1. Turn the emergency switch, MM, on.
2. Depress the start pushbutton of the main power switch, RR. When the main power is on, the following events take place:
 - a. The main power indicator light on the LVPS is energized.
 - b. The blower motor in the RFA (fig. 12-3) starts to operate.
 - c. The -12- and the +250-volt regulated power supplies in the LLRM (fig. 12-4) are energized, and the 250-volt power supply indicator light in the LLRM comes on.
 - d. The filament supplies in all units are energized.

Approximately 25 to 30 seconds after the main power is on the following actions occur:

1. The LVPS time delay expires and the time delay indicator light on the LVPS energizes.

2. The +250-v and -220-volt indicator lights on the LVPS are energized, thereby denoting the presence of the corresponding supply voltages.

3. The carrier 100-watt ready indicator on the RFA (fig. 12-3) energizes.

4. The blower motors in the mounting start operating.

If the standby operate switch, PP, in the LVPS is in the STANDBY position, there will be no plate power and nothing further will happen. Set the standby-operate switch, PP, to OPERATE. If the service selector, U, in the LLRM (fig. 12-4) is set to HAND, the following actions will occur:

1. The +500-volt and the +1050/1300-volt supplies together with the 500-volt primary, 500-volt output, 1300-volt primary, and 1300-volt output indicator lights in the MVPS (fig. 12-7) will energize.

2. The +300-volt indicator light in the LVPS will energize, denoting the presence of this supply voltage.

3. The carrier 100-watt ON indicator light in the RFA (fig. 12-3) will energize.

The actions indicated in items 1 through 2 will occur when the service selector, U (fig. 12-4) is in the MACH, FSK, and FAX positions only if the keying line is closed. If the service selector is in the PHONE position, these actions will occur only when the press-to-talk button on the phone is depressed.

Power in the 100-watt transmitter group may be turned off by depressing the stop pushbutton on the main power switch, RR, on the LVPS (fig. 12-6), or by throwing the emergency switch, MM, to the OFF position. The latter control removes all power; whereas, the former removes all power except that to the mounting heaters.

The radio modulator power supply (booster) is energized only when it is desired to have the AN/SRT-15 transmitting set operate at the 500-watt level. To energize the booster, the transmitter group must be energized, and the standby operate switch, PP, on the LVPS

(fig. 12-6) must be in the STANDBY position. The booster now may be energized as follows:

1. Set the booster emergency switch, SS, on the high-voltage power supply (HVPS) (fig. 12-9, B) to ON. After a 30-second time delay, the time delay indicator light is energized.

2. Depress the push for 500-watt button, E, on the RFA (fig. 12-3) to initiate the following action:

- a. The carrier 500-watt ready indicator light on the RFA will energize. At this time filament power has been applied to the booster but there will be no plate power. The equipment is now in the operate condition. Assume that the service selector, U, in the LLRM (fig. 12-4) is set to the HAND position.

- b. The +1050/+1300-volt supply in the MVPS (fig. 12-7) is deenergized and the 1300-volt primary and 1300-volt output indicator lights in the MVPS will be extinguished.

- c. The O1, O2, and O3 high-voltage primary indicator lights on the HVPS (fig. 12-9, B) are energized.

- d. The 3000-volt and 350-volt screen indicator lights on the HLRM (fig. 12-9, A) are energized, thereby denoting the presence of these supply voltages.

- e. The carrier 500-volt on indicator in the RFA (fig. 12-3) is energized.

To turn off the booster, depress the disable 500-watt pushbutton, F, on the RFA. This action disables plate power only in the booster. Turning the booster emergency switch, SS, on the HVPS (fig. 12-9, B) to OFF removes both filament and plate power in the booster. If the 100-watt transmitter group power is turned off while booster power is still on, plate power will be removed from the booster also.

Figure 12-12 illustrates, by functional block diagrams, the sequence of operation of the control circuits. Figure 12-12, A, shows the operation through "-24 volt after time delay," which is the same for either 100- or 500-watt operation. Figure 12-12, B, continues the se-



A



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quence for 100-watt operation; figure 12-12, C, shows the sequence for 500-watt operation.

The main power input (top block of figure 12-12, A) is 117-volt, 60-cycle, single-phase power received from the ship's supply. Emergency switch MM controls the power input to the transmitter bay. When switch MM is closed, power is delivered to the cabinet heater switch, NN, and to the main power switch, RR.

When the start button of switch RR is depressed, the master control relay is energized, which distributes a-c power for the following purposes: to distribute a-c power throughout the transmitter bay, to energize all filament supplies in the transmitter bay, to energize the blower in the RFA, to energize the main power indicator, to turn on the +250-volt regulated and -12-volt power supplies in the LLRM, and, through the interlocks, to energize the LVPS time delay. After the time delay, the "-24-volt after time delay" supply is energized, which is a control voltage. With "-24 volt after time delay" the -220-volt and the +250-volt unregulated supplies in the LVPS are energized.

The following sequence applies with the service selector, U, on the LLRM set at the HAND position.

At this point for 100-watt operation (fig. 12-12, B) with the standby operate switch, PP, in STANDBY, the carrier 100-watt ready indicator will be energized. If a different frequency is desired from the last previous transmission, the manual settings of the new frequency by adjustment of the control knobs on the RFO are made at this point in sequence followed by the corresponding manual band switching in the RFA, the readjustment of the initial setting of the two switches on the load adjusting unit (transmitter coupler), and then readjustment of the initial antenna tuning by the manual controls on the control indicator.

Placing the standby operate switch, PP, in OPERATE energizes the +500-volt and +1050/+1300-volt supplies in the MVPS and energizes the 100-watt carrier on in-

indicator. Energizing the +500-volt supply allows the +300-volt supply in the LVPS to energize. Placing the transmitter in a "key down" condition will now energize the carrier, and manual tuning of the IPA and PA stages of the RFA is performed. The final fine antenna tuning adjustments are now made at the control indicator. Further adjustment of the switches on the load adjusting unit will be required only if satisfactory tuning is not accomplished with the switches in their initial setting.

For 500-watt operation (fig. 12-12, C) after LVPS time delay, and with the standby operate switch, PP, in STANDBY, frequency selection, if required, takes place as previously described. The sequence now takes one of two paths, depending on whether or not tuning is required.

If tuning is required, it should be done with the transmitter energized at the 100-watt level (path 1), which gives the same sequence of operation as for 100 watts, as previously described. After tuning is complete, the booster emergency switch, SS, which controls power input to the booster, is turned on.

This action supplies either 220- or 440-volt, 60-cycle, three-phase power to the booster, energizing the HVPS time delay. After the time delay is over, the push for 500-watt button, E, is depressed, energizing the +2400/+3000-volt supply and the carrier 500 watt on indicator. Concurrently the 100-watt indicator and the +1050/+1300-volt supply are deenergized.

If no tuning is required (path 2), the booster emergency switch, SS, is placed in the ON position. When switch SS is closed, the booster receives either 220- or 440-volt, 60-cycle three-phase power from the ship's supply, energizing the HVPS time delay. After the time delay is over, the push for 500-watt button, E, is depressed, energizing the carrier 500-watt ready indicator. Placing the standby operate switch, PP, in OPERATE energizes the +2400/+3000-volt supply in the HVPS, the +500-volt supply in the MVPS, the carrier 500 watt

on indicator (when the +500-volt supply is energized), and it allows the +300-volt supply also to energize. Placing the transmitter in a "key down" condition will now energize the carrier.

RADIO RECEIVING SETS AN/SRR-11, 12, 13

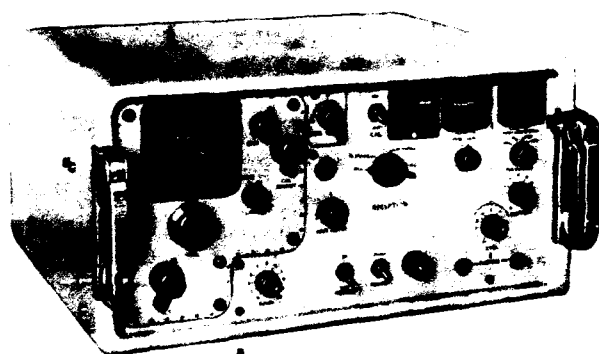
Radio Receiving Sets AN/SRR-11, 12 and 13 (fig. 12-13 are representative communications receivers designed for general application in all types of vessels of the U. S. Navy. The AN/SRR-13A receivers is illustrated in figure 12-13A. They are companion receivers to the previously described transmitting sets, AN/SRT 14, 15, and 16, and cover frequencies between 14 kc and 32 mc. A general description of these sets is given to acquaint the ET 3 with the nature of the circuits and components with which the external operating controls are associated. An explanation of the common operating adjustments on the AN/SRR-11 receiver is then given, and this is concluded with a summary of operating procedures.

General Description

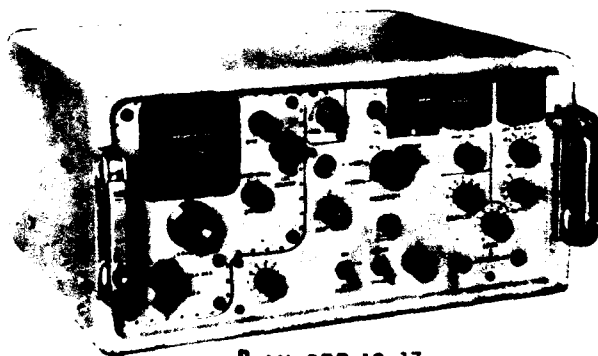
The AN/SRR-11, 12, and 13 receivers are designed for table-top mountings. Each is selfcontained in a metal case with operating controls, switches, meters (tuning and output), phone jack connectors, and main tuning dial assembly mounted on the front panel. The receiver chassis is mounted on rails in the receiver cabinet and can be withdrawn and positioned 45 or 90 degrees (up or down) for ease in servicing.

The frequency range of each receiver is divided into five bands. Continuous tuning is available throughout each band. The frequency range of the AN/SRR-11 receiver is from 14 to 600 kc (low frequency), that of the AN/SRR-12 receiver is from 0.25 to 8 mc (medium frequency), and the range of the AN/SRR-13 receiver is from 2 to 32 mc (high frequency).

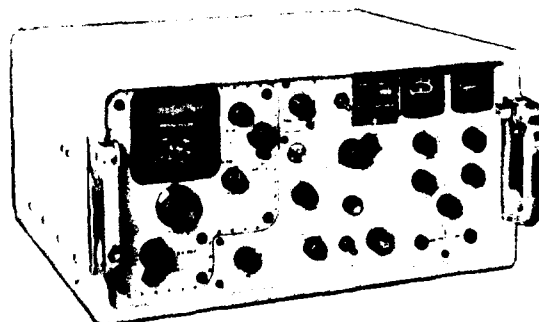
The AN/SRR-11 receiver is provided with circuits



A AN/SRR-11



B AN/SRR 12-13



C AN/SRR 13 A

Figure 12-13.—Radio Receiving Sets AN/SRR-11, 12, 13, and 13A.

and switching to receiver A1 (c-w telegraphy) signals, A2 (m-c-w telegraphy) signals, and F1 (telegraphy by frequency-shift keying) signals. In addition, the AN/SRR-12 and 13 receivers are capable of receiving A3 (radiophone) emissions.

A functional block diagram of the AN/SRR-11 receiver is illustrated in figure 12-14.

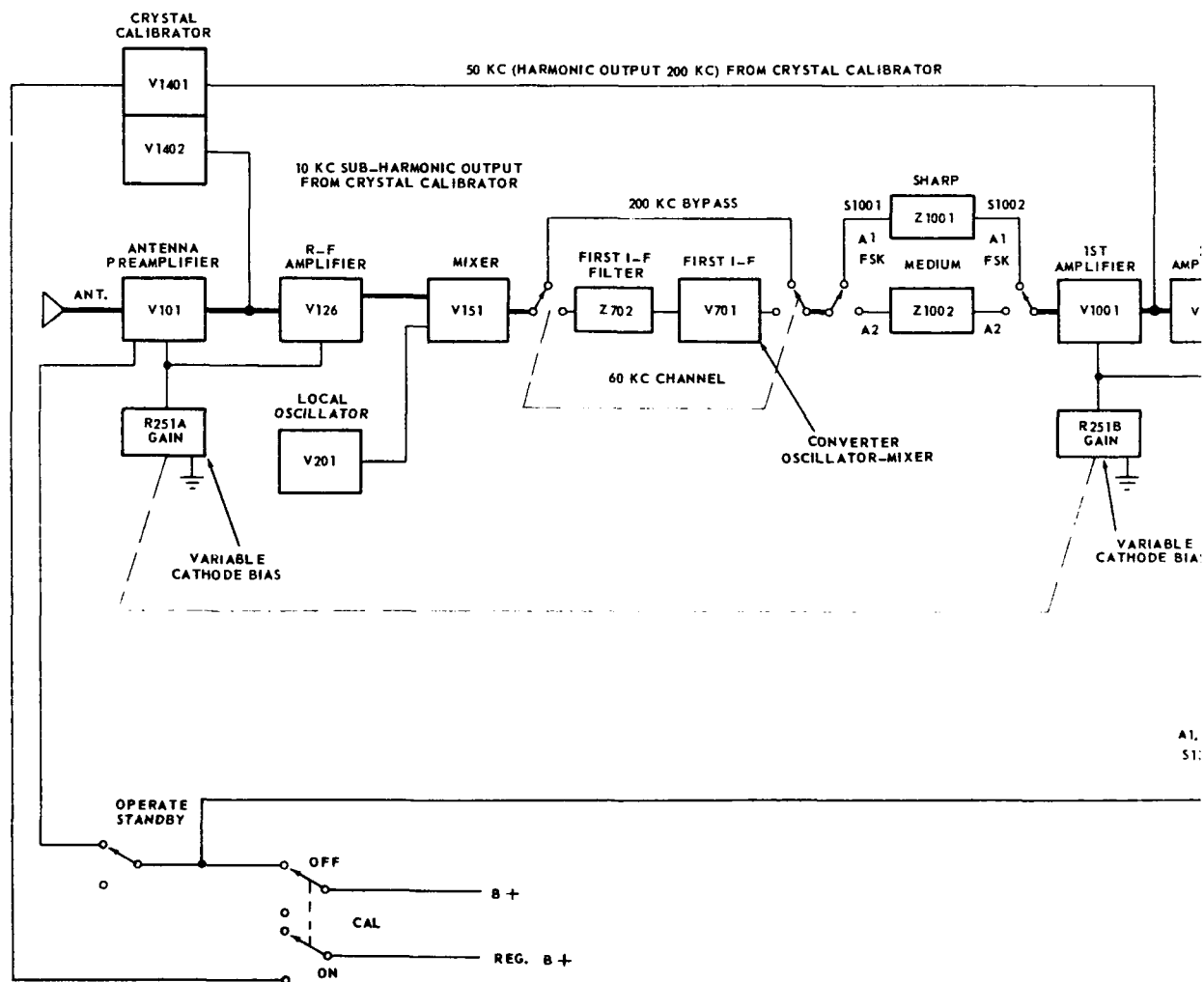
The basic receiver represented by the AN/SRR-11, 12 and 13 sets is a double superheterodyne having two stages of r-f amplification ahead of the first mixer and oscillator.

A first intermediate frequency amplifier (which is essentially the second converter) follows, and its output is fed to the second i-f assembly. Signals of A2 (m-c-w) and A3 (phone) emissions are rectified in a diode detector. The diode detector is bypassed when the receiver is switched to c-w or frequency-shift reception. Such signals are heterodyned in a beat frequency oscillator mixer stage with those from a BFO to produce a difference frequency in the audio range. A manual gain control or delayed automatic gain control circuit (depending upon the setting of the reception control) is provided to reduce the gain of the r-f and second i-f amplifiers when strong signals are received.

Audio frequencies are amplified through a four-stage amplifier, which feeds a balanced audio line and an unbalanced line for phone jack connections.

Circuits from the antenna stage through the first i-f amplifier are designed so that they will have different characteristics in order to provide for optimum reception on the several bands of frequencies covered by the low-, medium-, and high-frequency receivers.

In the AN/SRR-11 receiver the signal is fed from the antenna through the first and second r-f amplifiers, V101 and V126, to a mixer, V151, in which it is combined with the output of a local oscillator, V201. The output of the mixer has a frequency of 60 kc (bands 1 and 4) and passes through a band-pass filter, Z702, to a first i-f



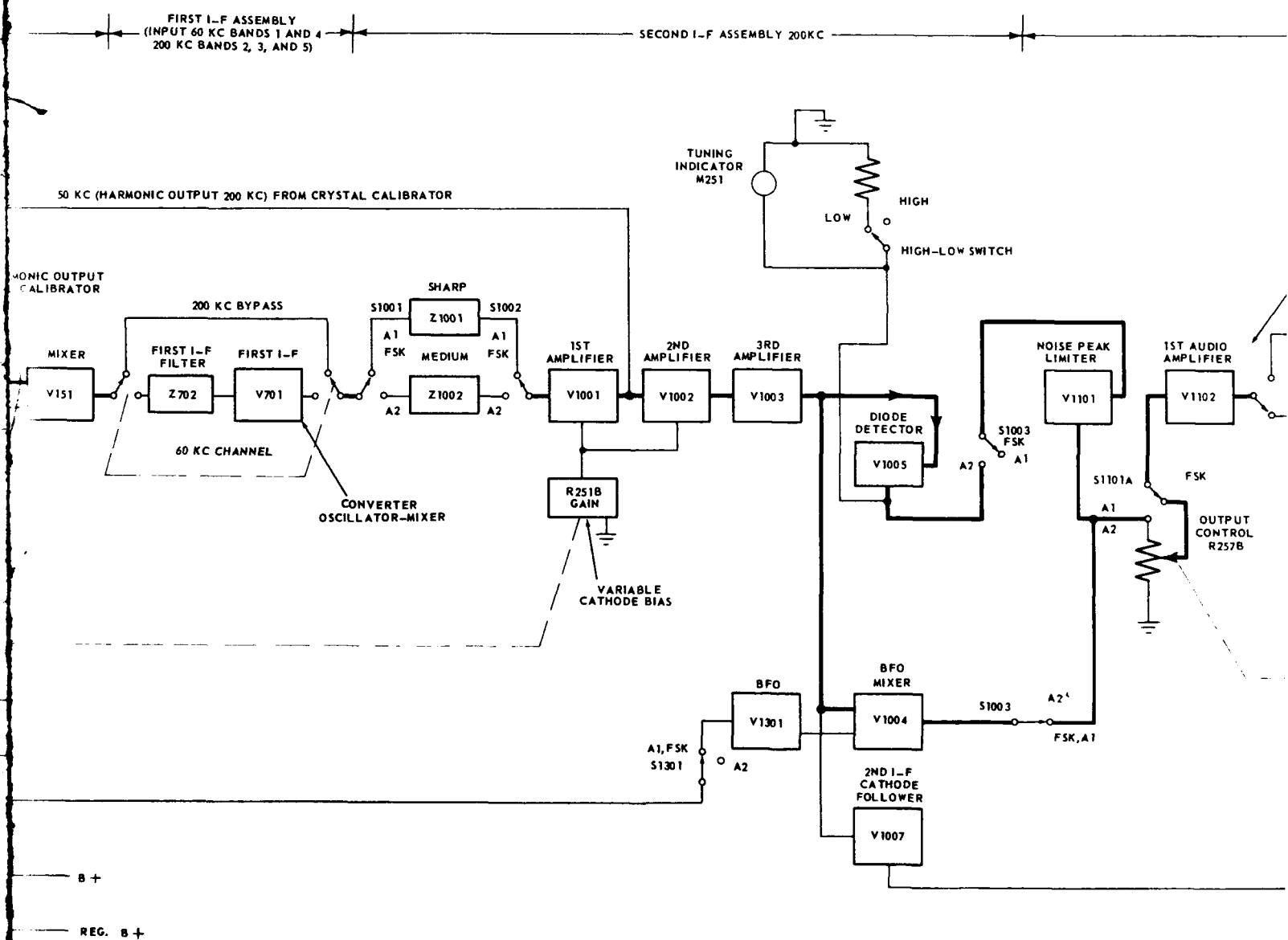
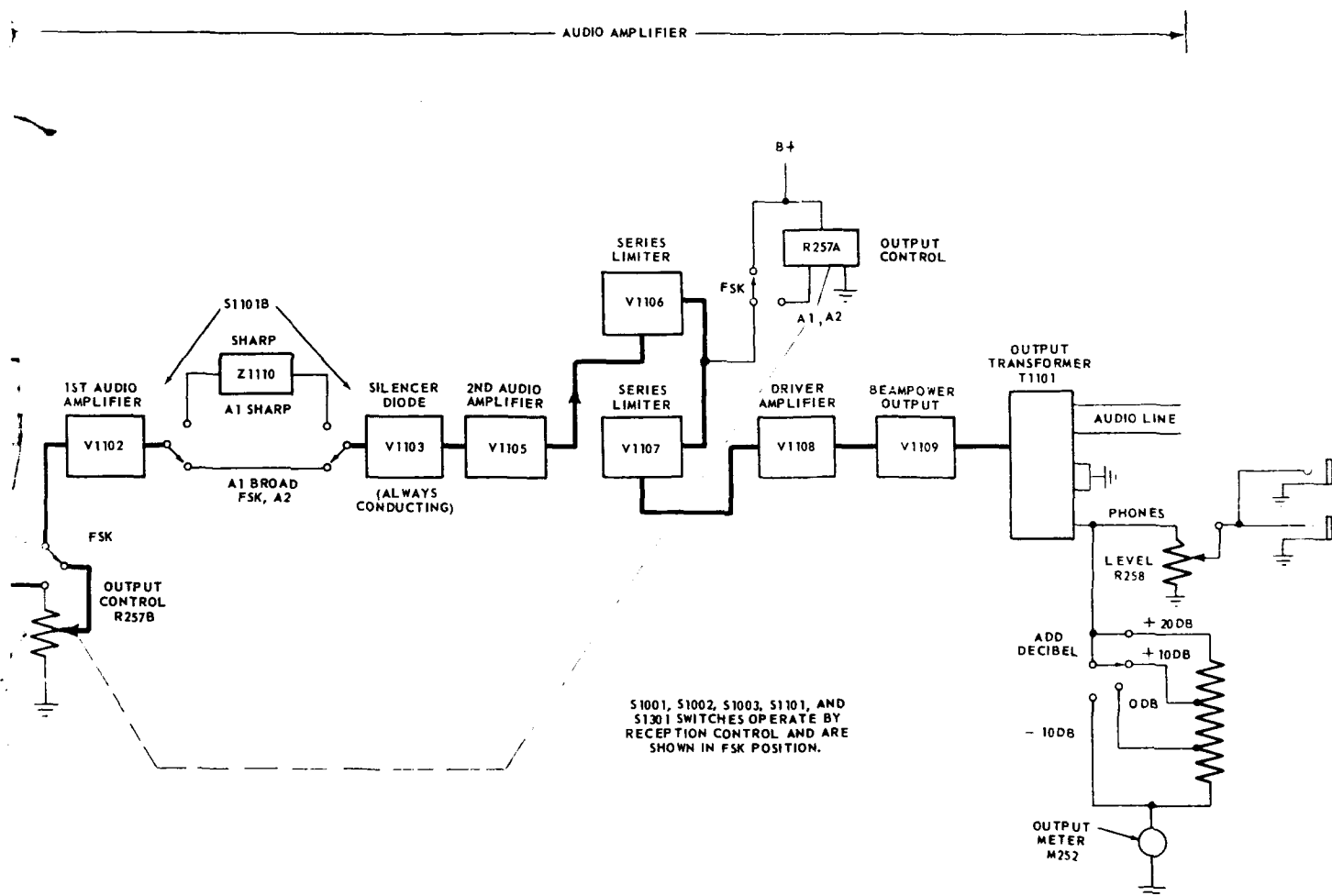


Figure 12-14.—Block diagram of AN/SRR-11 receiver.





IF

stage, V701, where it is converted to a frequency of 200 kc. This action is accomplished in a dual purpose tube, V701, which operates both as a crystal-controlled heterodyning oscillator (140 kc) and as a mixer. The 200-kc output is transformer coupled to the second i-f input assembly. This assembly includes filters Z1001 and Z1002; three stages of i-f amplification (V1001, V1002, and V1003) at 200 kc; a BFO mixer, V1004; diode detector, V1005; and a cathode follower, V1007 used to supply i-f signals to a frequency-shift converter or other accessory equipment.

The 200-kc input to the second i-f assembly is filtered before it is applied to the first amplifier, V1001. The filter selected depends on the position of wafer switches S1001 and S1002, which are actuated by the reception control. When this control is set at FSK, A1 broad, or A1 sharp, signals are fed through the "sharp" filter, Z1001, which provides a pass band of approximately 3.2 kc centered about 200 kc. When the reception control is set at A2 broad, the "medium" filter, Z1002, is used, which provides a pass band of approximately 8 kc centered about 200 kc.

On bands 2, 3, and 5 the first i-f input from the output of the mixer, V151, is 200 kc. On these bands the signal is bypassed around the first i-f filter, Z702, and the first i-f converter (oscillator mixer), V701. Plate and screen voltages are removed from X701, thereby rendering this stage inoperative.

The second i-f, power supply, beat frequency oscillator, and audio amplifier are similar for the AN/SRR-11, 12, and 13 equipments.

A crystal-controlled calibrator circuit is incorporated in each receiver to provide crystal check points. These check points are spread uniformly over the tuning range of the receivers and occur at 10-kc intervals for the AN/SRR-11, at 50-kc intervals for the AN/SRR-12, and at 200-kc intervals for the AN/SRR-13. The frequency check points are used in conjunction with the

CAL adjust knob on the receiver front panel to calibrate the tuning dial.

External connections are furnished from the AN/SRR-12 and 13 receivers to provide an AGC voltage and circuit connection to a common external diode load, so that these receivers may be operated with a companion receiver in a dual diversity reception system.

External connections are also furnished for feeding a frequency-shift converter of either the i-f or audio type. An additional external connection on the AN/SRR-12 and 13 is provided to supply i-f signals to a panoramic adapter.

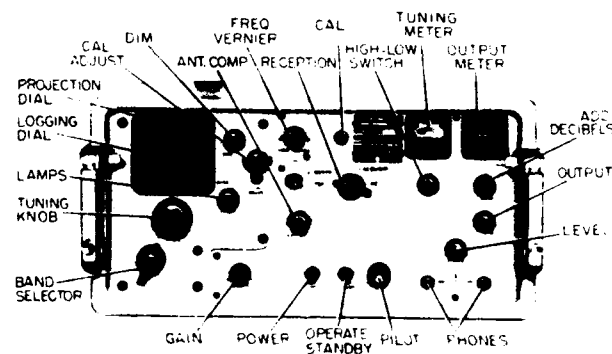
The frequency to which the receiver is tuned appears projected on a translucent screen (tuning dial) located at the upper left of the front panel. The dial is calibrated in kilocycles on the AN/SRR-11 and in megacycles on the AN/SRR-12 and 13. The projection system consists of a glass disk on which the tuning range of the receiver is calibrated in five scales. A light source is mounted in a housing behind the tuning dial. A portion of one of the optical scales on the glass disk is projected through a system of lenses and onto a mirror that reflects the image of the scale back upon the translucent screen. The glass disk is rotated by gears as the tuning knob is turned. When the setting of the band switch is changed, the dial light and lens housing are moved up or down by a cam driven from the band switch gears to align the lens system with the corresponding frequency scale on the glass disk.

The CAL adjust knob and locking screw located to the right of the tuning dial provide a means of shifting the frequency scale on the translucent screen when recalibrating the receiver in conjunction with the crystal controlled calibrator. This action is accomplished by a slight horizontal movement of the lens system.

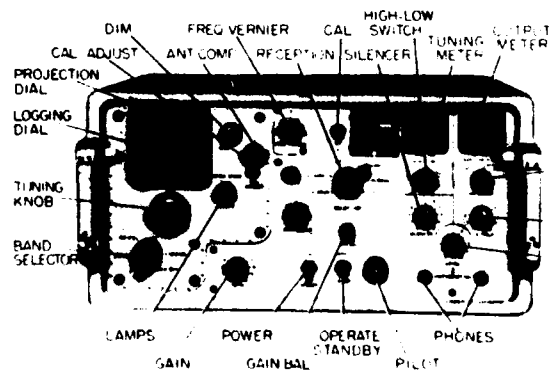
Common External Adjustments

All operating controls and switches necessary for the operation of the three receiver types (AN/SRR-11, 12,

and 13) are mounted on the front panel of the receivers together with two meters to be used when tuning and reading the output level. The functional name of each control and meter is marked on the panel near the particular control, as illustrated in figure 12-15. Figure 12-15, A, illustrates the front panel controls for the AN/SRR-11 receiver, and figure 12-15, B, illustrates the front panel controls for the AN/SRR-12, and 13 receivers.



A AN/SRR 11



B AN/SRR 12 13

Figure 12-15.—Radio Receiving Sets AN/SRR-11, 12, 13 (front panel controls).

Before operating the receivers, make sure that the chassis is firmly placed in the receiver cabinet. If the chassis is not firmly placed in the cabinet, no power will be applied to the receiver.

The on-off power switch applies primary power when in the ON position. When the operate standby switch (not included on the AN/SRR13A) is at STANDBY, plate voltage is removed from the antenna preamplifier. The pilot light is energized when high voltage is applied to the set.

The gain control, R251 A, and B (fig. 12-14) operates in the r-f and i-f stages. Maximum gain in these stages occurs when the control knob is turned fully clockwise. In this position the cathode bias, for example that of V101, V126, V1001, and V1002 in the AN/SRR-11 receiver is a minimum, and the m_{μ} of these tubes is a maximum. (Refer to the training course, *Basic Electronics*, NavPers 10087, chapter 2, for a discussion of variable m_{μ} , or remote cutoff tubes.) The gain control is inactive when the reception control on the AN/SRR-12 and 13 is positioned at A3 sharp, A3 broad, or FSK.

The Ant Comp (antenna compensating) control (not shown in the block diagram) provides a tuning adjustment for the antenna preamplifier to compensate for variations in the antenna impedance. This control actuates an air-dielectric trimmer capacitor in shunt with the tuned grid circuit of the first r-f amplifier. A fixed mica capacitor is also connected in series with the antenna input lead. This capacitor is shorted by a micro-switch operated by a cam on the shaft of the antenna compensating control for 180 degrees of rotation of the control, designated low. In this case, the primary circuit capacitance is that of the antenna. The switch is open for the second 180 degrees rotation of the control, designated high, and the fixed capacitor is inserted in series with the antenna. In this case, the total capacitance of the antenna and fixed capacitor is reduced to match that of the primary input circuit.

The band selector provides selection of the tuning

range of the receiver in any one of five bands. The five-band selector switches comprising this control are mechanically linked and arranged to connect the appropriate transformer coil group for each frequency band to the tuning capacitors. Sections of these switches are arranged to short out certain unused portions of the transformer coil groups to prevent absorption of the signal.

The tuning knob is used to tune the receiver to the desired frequency. The indication of this frequency appears on the translucent screen above the tuning knob, as previously described. A four-section, air-dielectric, ganged tuning capacitor is mechanically linked to the tuning knob. The four sections are connected across appropriate transformer coil groups in the grid circuits of the first and second r-f amplifiers, the mixer, and the local oscillator. The linear scale below the translucent screen is a logging dial used to log stations. It is mechanically linked to the tuning knob control and is used as a convenient method of quickly locating a station.

The dim control knob is turned to vary the intensity of the dial light.

The lamp switch connects a spare dial light in the event of failure of the operating light.

The output control, potentiometer *R257B* (fig. 12-14) for the AN/SRR-11 receiver adjusts the signal level, for FSK signals, before the signal is applied to the grid of the first audio amplifier, *V1102*. For *A1* and *A2* signals, potentiometer *R257A* varies the voltage applied to limiter diodes *V1106* and *V1107*. These diodes are combined to clip equally on positive and negative portions of the audio cycle when *S1101A* on the reception is set for *A1* or *A2*.

The reception control on the AN/SRR-11 receiver is a four-position switch used to select the appropriate circuits for the type of signal being received. The FSK position provides circuits for receiving *F1* (frequency-shift) signals when a suitable converter is connected to the receiver; a beat note is provided. The *A1-broad* setting is used for receiving c-w (unmodulated) signals;

a beat note is also provided. The A1 sharp setting is used to separate c-w signals by narrowing the frequency response; a beat note is also provided. The A2 position provides for the reception of m-c-w signals; no beat note is provided. In addition to the four signal positions on the AN/SRR-11 reception control, the corresponding switches on the AN/SRR-12 and 13 receivers have two additional settings. These are designated A3 sharp and A3 broad. Both settings provide circuits for the reception of voice-modulated signals.

The silencer (AN/SRR-12 and 13 only) provides for the reduction of background noise when the reception control is set at A3 sharp or A3 broad, and the desired station is not transmitting. The silencer diode is in series with the signal circuit between the first and second audio amplifiers. When a strong carrier is present, this tube conducts and the signal is amplified. In the absence of a carrier the diode plate is negative with respect to the cathode, and the tube is cut off, thereby preventing noise from being further amplified by the succeeding a-f stages.

The frequency vernier varies the pitch of the beat note when the reception control is in the A1 broad, A1 sharp, and the FSK positions.

When CAL switch is in the ON position, frequency check points are provided.

The CAL adjust control is used to reset the projection dial after the desired check point frequency has been zeroed.

The tuning meter reads up scale (toward the right) when the desired signal is tuned to a maximum. The meter reads down scale (toward the left) when the desired station is detuned. The tuning meter is used in conjunction with the high-low switch.

The high-low switch normally is in the LOW position. In this position the tuning meter is protected by a resistor.

When the tuning meter reads on the lower part (left

side) of the scale in the LOW position of the switch, use the HIGH position and tune the receiver slightly for an up-scale reading on the meter. The HIGH position of the switch is spring loaded; when released the switch will return to the LOW position.

The output meter reads the output power level between -20 db and +25 db when used in conjunction with the add decibel switch. Zero db is equivalent to 6 mw in a 600-ohm load.

The add decibel switch provides attenuation for the output meter circuit. The +10 decibel position should be used for checking strong output levels. The zero-decibel position is used to measure weak levels, and the -10 decibel position is used for a momentary reading of weak levels. The add decibel switch should be in the +20 decibel position when not using the output meter.

Summary of Operation

When starting the equipment (1) make sure the receiver chassis is firmly in the cabinet, (2) turn the power switch to ON, (3) adjust the dial illumination by turning the dim control (turn the dim control fully counterclockwise to extinguish the dial light; should the dial light fail, switch the lamp knob to the SPARE position and replace the burned out light), (4) turn add decibel switch to the +20 position, (5) turn the standby switch to OPERATE (note that the pilot light glows except when the knurled ring around the light is turned clockwise), (6) make sure that the CAL switch is in the OFF position, and (7) plug one or two pairs of headsets into the jacks marked, phones. Two pairs of headsets can be operated poerated from the receiver at the same time. Low-impedance phones (600 ohms nominal) similar to Navy type 49507 should be used. The level control regulates the gain through the headphones.

In order to tune a signal:

1. Turn the gain and output controls up (clockwise) until background noise is heard. Turn the silencer control fully counterclockwise. This control is only effective

when the reception control is set at A3 sharp or A3 broad. (The silencer control is not included on the AN/SRR-11.)

2. Select the appropriate frequency band using the band selector control.

3. Calibrate the receiver at the nearest frequency check point.

To calibrate the receiver, turn the CAL switch on. Set the tuning dial at the nearest calibration marker (designated by an inverted V on the frequency scale). Rock the tuning knob slightly on both sides of the chosen frequency until a beat note is heard. Zero beat should occur at the calibration marker chosen. If zero beat does not occur at this marker, adjust the tuning knob until zero beat is indicated.

Then loosen the thumb screw holding the CAL adjust knob (turn counterclockwise) and turn CAL adjust knob until the nearest calibration marker is under the hairline on the projection screen. Tighten the thumb screw over the CAL adjust knob. Turn the CAL switch to OFF.

Tune in the desired station by setting the desired station's frequency under the hairline index on the projection screen by means of the tuning knob. Turn the antenna compensating control until the signal is the loudest. This control will have the most effect at the high end of each frequency band. Adjust the signal to maximum, as indicated on the tuning meter.

As the station is tuned in, the tuning meter reads up scale. When below $\frac{1}{4}$ scale on the low setting of the high-low switch, hold the switch in the HIGH position and readjust the tuning knob for an up-scale indication of the tuning meter. (Never hold the high-low switch in the HIGH position when the tuning meter is at full scale with the high-low switch in the LOW position as this action would remove the protection afforded by the resistor.) Use of the tuning meter is optional for c-w signals (A1 broad or A1 sharp positions of the reception control).

To use the logging dial, the receiver should be calibrated, as previously described, and tuned to the desired station. The logging dial includes a fixed index and two movable scales immediately below the tuning projection dial. The logging dial is not affected by the CAL adjust knob. When the receiver is tuned to the desired station, record the settings of the two movable scales, using the index mark on the middle segment, as in the following example. The top scale reads between 200 and 300. The bottom scale reads 63. The setting of the logging dial is 263. By resetting this figure (263) on the logging dial for the same band-selector position, the previously received station can be returned quickly. The logging dial should always be set approaching from the same direction (clockwise rotation of the tuning knob).

Other tuning procedures will vary, depending on the position of the reception control and the class of emission of the desired signal.

When the receiver is supplying signals to a frequency-shift converter of the i-f type (similar to Navy Model CR-57/URR), tune the receiver to the desired station by means of the tuning knob and adjust the antenna compensating control for maximum signal, as indicated on the tuning meter.

When the receiver is supplying audio signals to a frequency-shift converter similar to Navy Model CV-60/URR, tune the receiver to the desired station by means of the tuning knob and then adjust the output and frequency vernier controls, as required for the operation of the frequency-shift converter.

LORAN RECEIVING EQUIPMENT

The principle of operation of the loran system of obtaining navigational fixes is described briefly in chapter 1 of this training course. A loran receiver located aboard ship is used to determine the difference in time required for pulsed radio signals to arrive from a pair of syn-

chronized transmitters (master and slave stations simultaneously pulsed) installed on shore several hundred miles apart.

Receiver Unit in the DAS-4

The model DAS-4 receiver-indicator (fig. 12-16) is one type of loran set that may be installed aboard ship. The signals from the master and the slave stations are displayed on the indicator cathode-ray tube.

The receiver in the DAS-4 is a conventional superheterodyne type, except that it has no variable tuning. Instead, the receiver is preset to four different frequencies corresponding to four loran channels. The channels are selected by means of a channel switch located on the front panel of the receiver (left-hand side of figure 12-16).

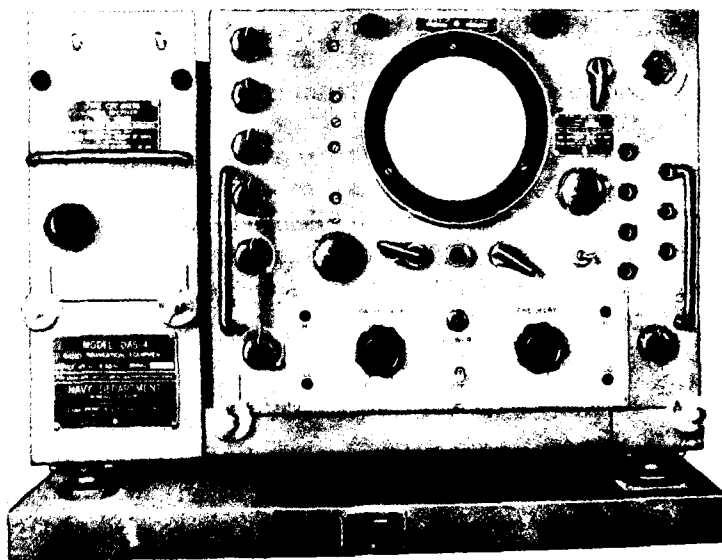


Figure 12-16.—DAS-4 receiver indicator.

The signal from the antenna is developed across a resonant tank in the grid circuit of the r-f amplifier. The channel switch connects the correct antenna, converter, and oscillator coils for the selected channel. The output of the r-f amplifier is fed to the grid of the converter. The local oscillator is tuned to 1050 kc above the incoming signal. The output of the converter is amplified by three i-f amplifiers before being fed to the diode detector. The output of the diode detector is fed to the video amplifier via a filter, which may be switched into the circuit to reduce interference. The output of the video amplifier is fed to the vertical deflection plates of the cathode-ray tube (fig. 12-17).

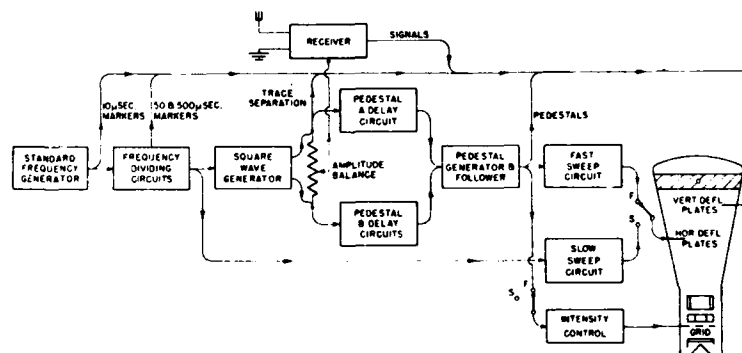


Figure 12-17.—Simplified block diagram of the DAS-4.

Operation of the DAS-4

The indicator unit is used to measure the time difference between a pulse from the master station and a pulse from a slave station operating at the same pulse repetition rate (PRR). The signal from the master station appears on one trace, and the signal from the slave station appears on the other trace (fig. 12-18). This pattern appears when the sweep speed switch is set at SLOW, the fast speed switch at 3, and the receiver switch at the ON-1 position. The markers appearing downward from the traces are at 500-microsecond intervals. Every

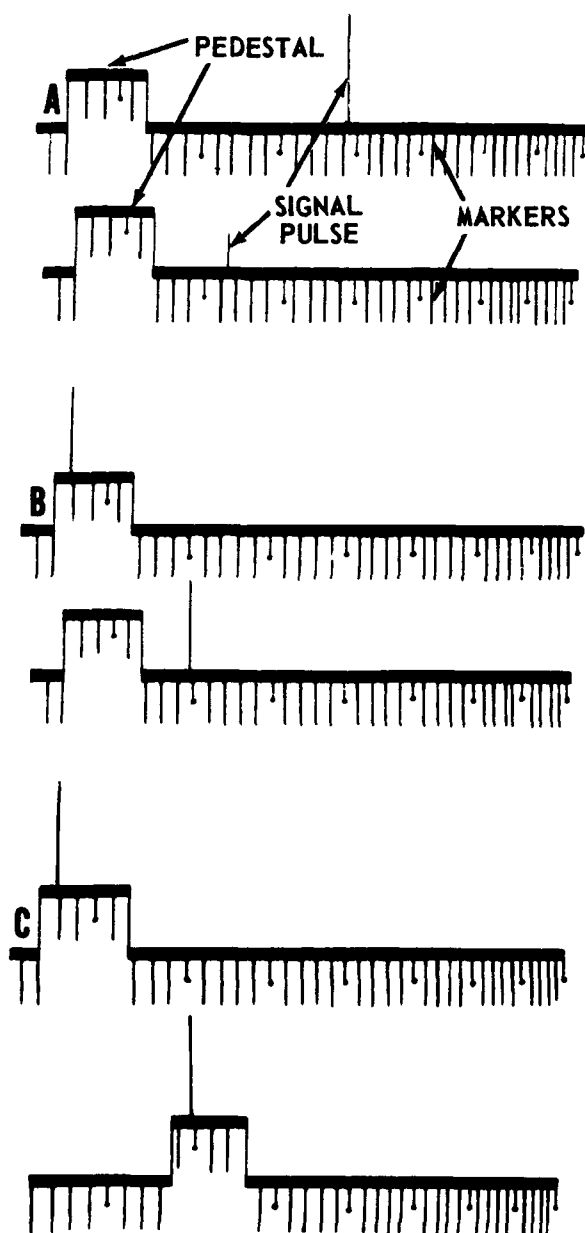


Figure 12-18.—Signals appearing on the indicator. A, Before adjustment of the amplitude balance control; B, after adjustment of the amplitude balance control; C, pulses placed on the pedestals.

fifth marker is made shorter for ease in counting. After selecting the channel (the basic PRR and the specific PRR, subdivisions of the basic PRR), you may see the signals anywhere along the traces (fig. 12-18, A). The master station pulse is always to the left of the slave pulse. Thus the master station pulse is on the lower trace in figure 12-18, A.

The amplitude balance control is adjusted until the amplitudes of the two pulses are equal (fig. 12-18, B). This action is accomplished automatically by periodically decreasing the gain of the third i-f amplifier in the receiver either during the upper trace or during the lower trace. Then by using the left right switch, the pulses are moved along the traces until the pulse from the master station is on the upper pedestal (fig. 12-18, B). The coarse delay and the fine delay controls are now used to move the pedestal on the lower trace until the slave signal appears on the lower pedestal (fig. 12-18, C).

The coarse delay exercises control in steps of 500 microseconds over a time delay range of 0 to 10,000 microseconds. The fine delay exercises continuous control over a time delay range of 0 to 650 microseconds.

When the sweep speed is turned to FAST, the tops of the pedestals enlarge until they cover the entire width of the screen (fig. 12-19, A). To obtain this pattern the sweep speed switch is set at FAST, and the fast sweep switch at 3. The delay controls are then adjusted until the slave pulse appears directly under the master pulse. The pulses are moved by the left-right switch until they are within the first 500-microsecond interval at the left end of the screen (fig. 12-19, B).

The left ends of the traces up to the first 500-microsecond marker are made to cover the full width of the screen by changing the fast sweep switch to position 2 (fig. 12-20). The slave pulse is brought under the master pulse by using the fine delay control. The pulses are moved to the left ends of the traces by the left-right switch.

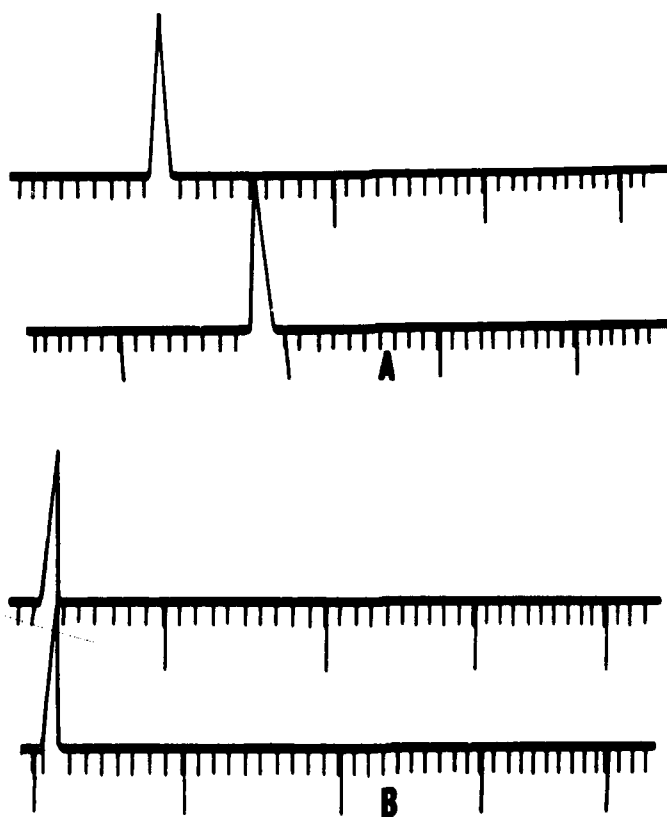


Figure 12-19.—Aligning the master and slave pulses. A, Pulses roughly aligned; B, pulses aligned and moved to the left end of the traces.

Turning the FAST SWEEP switch to position 1 enlarges the portions of the traces appearing to the left of the fourth 50-microsecond marker. The pulses appear in a pattern similar to that shown in figure 12-21.

Moving the receiver (RECVR) switch to the ON-2 position eliminates the trace separation and the markers. The two pulses appear to be on the same trace (fig. 12-22). For this pattern the sweep speed switch is set at FAST and the fast-sweep switch at 1 (fig. 12-22, A).

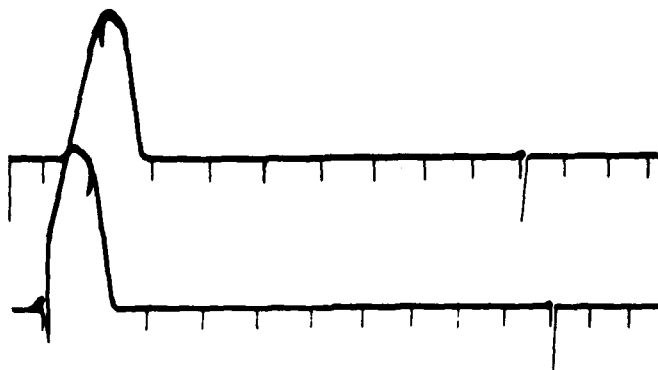


Figure 12-20.—Pulses appearing on indicator when the sweep speed switch is at FAST and the fast sweep switch is at position 2.

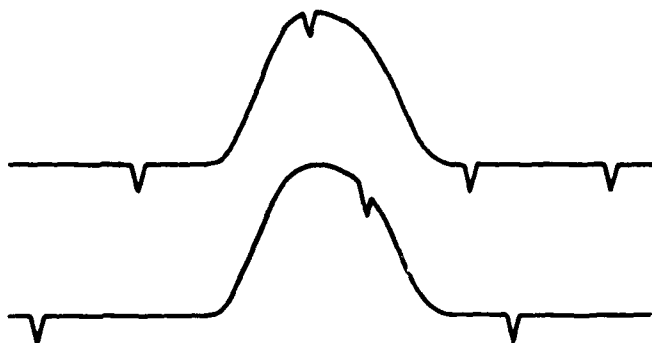


Figure 12-21.—Pulses appearing on the indicator when the sweep-speed switch is at FAST and the fast-sweep switch is at position 1.

The two pulses are then superimposed (fig. 12-22, B) by adjusting the fine delay control. The pulses will not coincide exactly. Correct adjustment is reached when the leading edges of the two are matched. After the pulses have been superimposed, the delay controls must not be disturbed until the time difference is read.

The time difference reading is made in three steps. The controls are left in the same position as they were

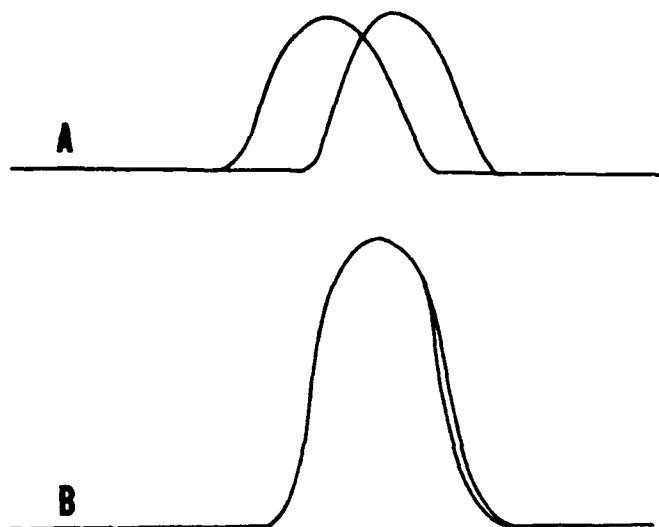


Figure 12-22.—Matching the pulses. A, Upper and lower traces superimposed; B, both traces and pulses superimposed.

for superimposing the pulses, except that the receiver switch is moved to the OFF position. The pattern illustrated in figure 12-23, A, will appear. From one of the downward projecting 50-microsecond markers on the lower trace, count the number of upward markers to the right of the 50-microsecond marker to a point directly below the next 50-microsecond marker on the upper trace. The small upward markers are at 10 microsecond intervals. The reading is 35 microseconds. This completes the first step.

Next turn the gain control to its extreme counter-clockwise position and the fast sweep switch to position 2. Place the receiver switch at the ON-1 position. Turn the trace separation control until the traces are about half an inch apart (fig. 12-23, B). Count the number of 50 microsecond markers from the right side of the 500-microsecond marker on the lower trace to a point directly beneath the 500-microsecond marker on the upper trace. In figure 12-23, B, there are eight 50-

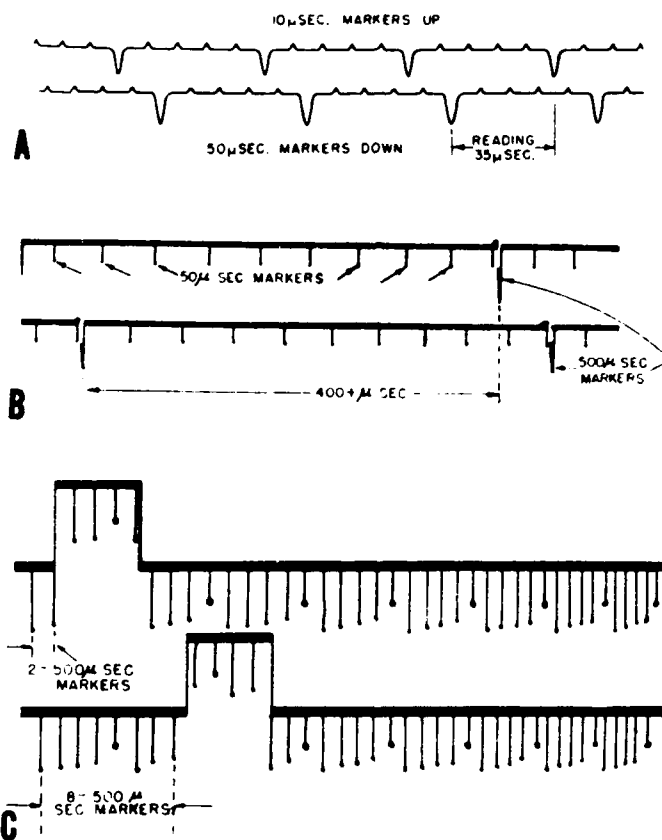


Figure 12-23.—Reading the time difference. A, Reading 35 microseconds; B, reading 400 microseconds; C, reading 3000 microseconds.

microsecond markers and the reading is 400 microseconds. This completes the second step.

The pattern illustrated in figure 12-23, C, is obtained when the sweep-speed switch is set at SLOW and the fast-sweep switch is turned to position 3. Count the number of 500-microsecond markers to the left of the pedestal on the lower trace. In figure 12-23, C, the number is 8. The corrected reading is taken from the left edge of the upper pedestal to the left edge of the lower pedestal. Because the left of the upper pedestal is always fixed

at the second marker on the upper trace, two markers must be subtracted from the number counted on the bottom trace. In figure 12-23, C, the number is 6, which corresponds to 3000 microseconds. This completes the third step. Adding the readings obtained in the three steps gives a total time difference of $35 + 400 + 300 = 3,435$ microseconds between the master station and the slave station.

Turn the gain control clockwise and the amplitude balance control to the center of its range. Set the channel, PRR, and station-selector switches to another pair of transmitters to secure a reading from them. Usually the other pair will operate on the same channel and the PRR switch settings. If this is the case, only the setting of the station selector switch need be changed.

QUIZ

1. How is a radio transmitting antenna matched to its antenna feed line?
2. How is the load on the radio transmitter varied?
3. What value in the r-f amplifier and local oscillator resonant tank circuits is changed when band switching takes place?
4. What is the first step in becoming acquainted with an electronics equipment?

The following questions pertain to the AN/SRT-15 transmitter.

5. In what major unit are included modulator power units to accomplish 500-watt operation?
6. What is the purpose of the transmitter coupler?
7. What are the three front-panel tuning controls on the radio frequency amplifier?
8. Into what unit does the low-level radio modulator feed for 500-watt operation?
9. What is the function of the autotransformer in the transmitter coupler?
10. What is the purpose of the interpolation oscillator?
11. Limitations within the transmitter and antenna tuning equipment make 500-watt operation impracticable on what range of frequencies?

12. What is the function of the antenna tuning equipment?
13. On what part of the equipment are located the controls for starting and stopping the equipment for 100-watt operation?
14. What are the two ways of removing power from the 100-watt transmitter group?
15. The booster is energized only under what circumstances?
16. When the emergency switch, MM (fig. 12-6) is on, power is supplied immediately to what two other switches?
17. When the master control relay is energized through the main power switch, power is then distributed to what portions of the transmitter?
18. Tuning is accomplished with the transmitter energized at what level?

The following questions pertain to Radio Receiving Sets AN/SRR-11, 12, 13.

19. What is the frequency range of each of the three receivers?
20. What types of emission may be received by these receivers?
21. During FSK reception, how is a signal frequency in the audio range developed?
22. On what setting of the reception control is (a) the sharp filter and (b) the medium filter used?
23. What provides signals for the crystal check points?
24. What is the function of the antenna compensating control?
25. What is the function of limiter diodes V1106 and V1107 (fig. 12-14) when A1 or A2 signals are being received?
26. What is the function of the add decibel switch?
27. In what positions of the reception control will the silencer be effective?

CHAPTER

13

COMMON OPERATING ADJUSTMENTS: TELETYPE AND FACSIMILE

TELETYPE EQUIPMENT

Teletype replaces the operator for changing plain language into code and code into plain language. To transmit a message with teletype the operator presses keys on a keyboard similar to a standard typewriter. As each key is pressed, mechanical cams and linkages cause a sequence of mark and space signals to be cut on tape. The signal on the tape activates the transmitter at speeds set up independently by the operator.

At the receiving end, each received signal sequence actuates selector magnets in a teletypewriter similar to the machine used at the transmitting end and causes the character transmitted to be printed on a paper and the carriage to be advanced one space. At the end of each line a special sequence of impulses causes the paper to be advanced one line.

In the teletype code each character consists of five impulses composed of marks and spaces, as described in chapter 1 of this training course. The sequence of impulses can be used to key a transmitter through suitable converters.

In frequency-shift keying the frequency shift is usually 425 cycles below the assigned carrier frequency for a

space and 425 cycles above the carrier for a mark. The radio receiver changes the r-f carrier into an audio tone by means of the beat frequency oscillator. The carrier shift then becomes an audio frequency shift of the same number of cycles.

In tone-modulated keying the r-f carrier is modulated with two tones (perhaps 500 and 700 cycles), one for a mark and the other for a space. With suitable receiving equipment, the tone-modulated signal may be used to activate a teletypewriter. Both the carrier frequency-shift system and the tone-modulated system are treated briefly in chapter 1 of this training course.

Basic Components

TRANSMISSION.—The basic components for converting the mark and space pulses of a teletypewriter into carrier frequency-shift (CFS) signals at the output of a radio transmitter may be incorporated in a frequency-shift keyer similar to Navy Model KY-75/SRT, or they may be incorporated in the transmitter itself (for example, Transmitting Set AN/SRT-15). Frequency-Shift Keyer KY-75/SRT is described later in this chapter in connection with facsimile equipment. Transmitting Set AN/SRT-15 is described in chapter 12 of this training course in connection with common operating adjustments of radio transmitters and receivers.

Controls that are used in connection with CFS teletype transmission in the AN/SRT-15 Transmitting Set include a neutral polar switch, R, of the LLRM (fig. 12-4) and also the keying rate switch, S, and the space-operate-mark control, V. The RFO (fig. 12-5) also contains controls that are used with CFS teletype transmission. These include the FS oscillator zero adjust control, Z, the FS deviation control, KK, and FSK phase modulation control, LL.

The neutral-polar switch, R (fig. 12-4) must be set according to the position of the service selector control, U, and the type of input signal available. With control

U in HAND, FAX, or PHONE, the position of the neutral-polar switch, R, is immaterial. In the NEUTRAL position, the keying circuit accepts a keying voltage that varies from zero during a space signal to a positive value for a mark signal. In the POLAR position the circuit accepts a keying voltage that varies from a negative value for a space signal to a positive value for a mark signal. In the MACH and FSK positions of the service selector, U, the setting of the neutral-polar switch, R, will depend upon the nature of the incoming keying signal from the machine keying equipment, which can be either neutral or polar as described.

The keying rate switch, S, has four positions: TT, MULTIFLEX, 200 WPM, and 400 WPM. The proper setting of the keying rate switch should be made in hand-key, machine-key, or FSK operation. The TT (teletype) position is used for hand- or machine-key speeds up to approximately 60 words per minute. Multiplex is used for multiplex transmission from 60 to 150 words per minute.

This control is provided to minimize sideband frequencies. To maintain an optimum keying pulse wave shape, the amount of capacitance in the circuit is varied with the keying speed. Failure to put this control in the proper position will not prevent the keying operation, but it will affect the wave shaping and therefore the band width required for transmission.

The space-operate-mark control, V, is normally in the OPERATE position, which allows regular keying signals from hand- or machine-key equipment to energize the keying circuit of the LLRM. Placing this control in either space or mark makes it possible to test the action of the keying circuit without causing r-f output. This testing can be performed regardless of the position of the service selector, U.

Placing the zero adjust control, Z, on the RFO (fig. 12-5) in the FS OSCILLATOR position connects the output of the frequency-shift oscillator into the zero beat indicator circuit where it is compared with the standard

100-kc signal from the crystal controlled 100-kc oscillator. The output of the FS oscillator can be regulated by the FS oscillator zero adjust control. The electron-ray tube zero beat indicator gives the indication of the variance in frequency between the standard and the FS oscillator signal.

The FS deviation control, KK, in the RFO is set according to the degree of frequency shift desired between a space and a mark. The combined dial reading gives (in cycles per second) the shift of the carrier frequency above and below the nominal frequency for FSK operation. For example, consider the frequency selection knobs set to provide a carrier frequency of 20.000000 megacycles and the FS deviation control set so that the dials read 4 on the inner dial and 50 on the outer dial (450 cps). The service selector, U, in the LLRM (fig. 12-4) is set at FSK. A space keying signal will shift the carrier to $20.000000 - 0.000450$ or 19.999550 megacycles, and a mark signal will shift the carrier to $20.000000 + 0.000450$ or 20.000450 megacycles. When control KK is set to its mid position 500, a 1000-cycle, space-to-mark frequency shift, corresponding to a 500-cycle deviation on either side of the carrier is provided. The deviation is adjustable to any value between zero and 500 cycles of the carrier for mark and space telegraph signals.

The FSK phase modulate control regulates the degree of phase shift applied to a 200-cycle signal generated in the LLRM and fed to the frequency-shift oscillator in the RFO. The purpose of the 200-cycle signal is to phase modulate the output of the frequency-shift oscillator to combat the effect of selective fading. Phase modulation spreads the energy of the signal over a wider frequency band, thereby providing a means for achieving a certain amount of frequency diversity. By using phase modulation during periods of selective fading, complete loss of the signal becomes less probable.

RECEPTION.—The basic components for converting an

r-f frequency-shift signal into a signal for controlling the d-c loop of a teletype printer are illustrated in the top row of the simplified block diagram of a frequency-shift converter in figure 13-1.

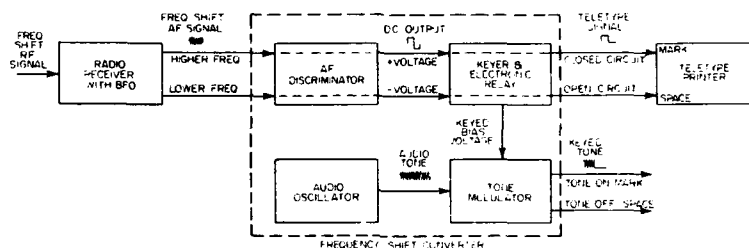


Figure 13-1.—Simplified block diagram of a frequency-shift converter.

The frequency shift of the r-f signal is converted in the radio receiver at the second detector (by the heterodyne action of the BFO) into either a high audio tone (mark) or a low audio tone (space). These signals are converted in the a-f discriminator into d-c pulses. The d-c pulses are fed into a keyer and electronic-relay circuit, which opens and closes a d-c loop circuit of an associated teletype printer, causing the mark-space characters to operate the teletype printer.

The lower blocks in figure 13-1 represent the circuits for a keyer-tone output. This output is used to operate remotely located telegraph or teletype terminal equipment over wire lines or radio links. A tone generated by the audio oscillator is fed to the tone modulator. The bias of this unit is controlled from the keyer and electronic relay. For space signals, the pushpull output stage is biased beyond cutoff so that the audio tone is blocked from the output. For mark signals from the keyer the bias is decreased to that of a normal pushpull amplifier so that the audio tone is amplified in the tone modulator and delivered to the output circuit.

The frequency versus mark-space relations shown in figure 13-1 are for typical operation. For this case the

higher radio frequency represents a mark and the lower represents a space. However, the opposite arrangement is sometimes used in which the lower radio frequency represents a mark and the higher represents a space. A reversing switch (not shown) following the discriminator provides a means of changing the polarities of the d-c output voltages so that the higher frequency will produce a negative voltage (space signal) and the lower frequency will produce a positive voltage (mark signal). The radio receiver is tuned to the desired signal, and the output and frequency vernier (BFO) controls are adjusted for the desired output to the converter.

Diversity Reception

Because of fading and interference over long distances, diversity reception is employed. In space diversity two receivers are tuned to the same frequency but the receiving antennas are spaced more than one wavelength apart. In frequency diversity the two receivers are tuned to separate frequency-shift carriers (of different frequencies), which are simultaneously carrying the same mark-space characters. The output of each receiver is connected to its associated frequency-shift converter, which converts the frequency shift characters into d-c pulses. These mark-space pulses are fed to the comparator where an automatic circuit selects and uses the better of the two signals to ultimately control an automatic teletype printer and to produce a keyed output tone for remote telegraph or teletype operation, as previously described.

Converter-Comparator Group

The Frequency-Shift Converter-Comparator Group AN/URA-8B comprises two Frequency-Shift Converters, CV-89A/URA-8A, and one Comparator, CM-22A/URA-8A, as illustrated in figure 13-2. In diversity reception the audio outputs of two standard Navy receivers (like the AN/SRR-12) are fed to their associated frequency-

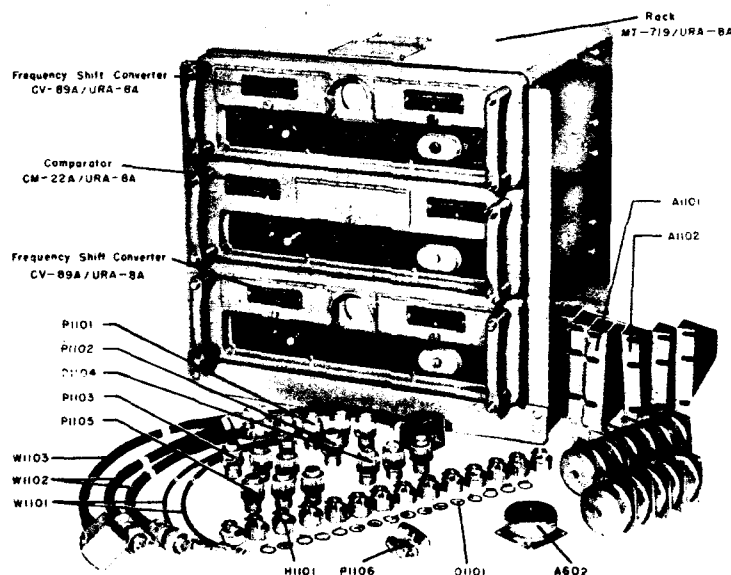


Figure 13-2.—Frequency-Shift Converter-Comparator Group AN/URA-8B.

shift converters, as shown in the block diagram of figure 13-3. The d-c signals from the discriminator circuits of the two frequency-shift converters are compared in the mark-space selector that automatically selects the better mark and the better space pulse for each character. The second frequency-shift converter is identical to the first and is represented by a single block for simplicity. The receivers may be operating on space diversity (if shore based) or frequency diversity (if aboard ship) on any radio frequency within their ranges. The frequency-shift converter is described first. The comparator is then described briefly, and common operating adjustments are emphasized last.

FREQUENCY SHIFT CONVERTER.—Two Frequency-Shift Converters, Navy Model CV-89A/URA-8A, are used in the Converter-Comparator Group AN/URA-8B. Each

subunit, (2) oscillator-keyer subunit, (3) monitor subunit, (4) power-supply subunit, (5) cable-filter assembly, (6) blower subunit, and (7) chassis-panel assembly.

The discriminator subunit contains wide-shift (200 to 1000 cycles) and narrow-shift (10 to 200 cycles) filters, a discriminator circuit, slow-speed (60 words per minute or less) and fast-speed (more than 60 words per minute) filters, and an axis (bias) restorer circuit. The discriminator converts frequency shifts into corresponding voltages, as illustrated in figure 13-4.

The filters attenuate spurious signals above the frequency of the pulse-rate circuit to prevent faulty operation due to noise, harmonics, and so forth.

The axis restorer maintains the optimum axis, or bias, for keying nonsymmetrical signals. It produces an optimum output signal when the received signal is weighted

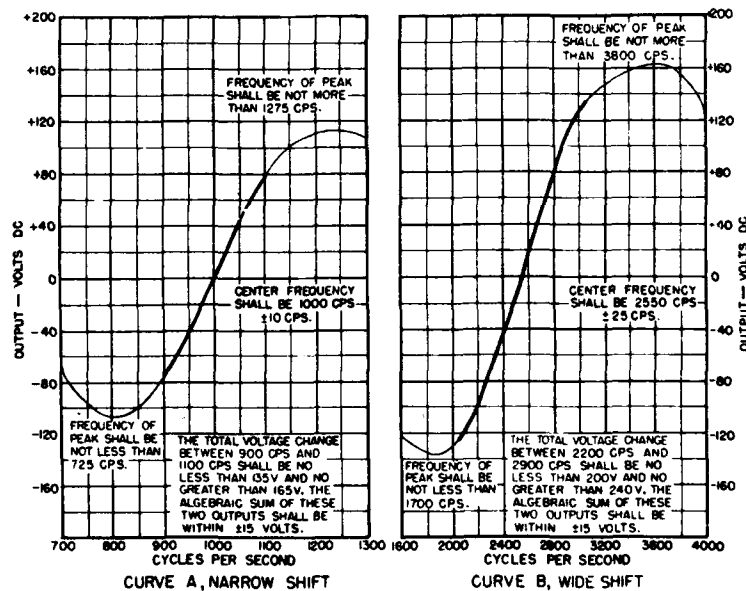


Figure 13-4.—Discriminator frequency response curves.

heavily on one side or the other, either mark or space. It will lock up (close the loop circuit) the teletype circuit when a prolonged mark or space signal condition develops. The setting of the threshold control affects the time required to lock up the teletype loop circuit.

The oscillator-keyer subunit contains the circuits for keying the teletype d-c loop and operating the teletype printers. It also provides a keyed-tone output by keying a self-generated tone, which may be selected as any one of eight audio frequencies. Provision is made for the use of an external tone, if desired.

This circuit is used in single receiver operation; but in diversity reception the signal from the converter is taken directly from the low-pass filter (after the discriminator) and fed to the comparator without using the tone and output circuits of the oscillator-keyer subunit. These are available, however, if it is desired to use the signal from one channel of the system while operating in diversity reception.

The monitor subunit includes a 2-inch cathode-ray oscilloscope used as a monitor for indicating proper tuning of the receiver, for checking the approximate width of the frequency shift of the signal, and for observing the polarity of the mark-space characters and other details of the signal. It employs a 60-cycle, sine-wave sweep. The vertical amplifier gain control is calibrated in cycles of shift, which are represented by a full pattern between horizontal lines marked on the screen window. The customary oscilloscope controls are provided. An external connection is provided for using a remote monitor or test oscilloscope.

The power supply subunit furnishes all the power required by the other subunits of the frequency-shift converter and is designed to operate from a power source of 105/115/125 volts, 50 to 60 cycles, single phase. A link connector is provided for selecting the correct transformer tap for the particular voltage being used.

The cable filter assembly carries all the connections

to the circuits of the chassis-panel assembly and its subunits. On the rear of the cable-filter assembly are ten connectors: one for blower power, and nine extending (in a row) out through the back of the case for accommodating all input and output connections to the frequency-shift converter.

The cable filter assembly removes extraneous noise and other signals, which might cause errors in keying. It includes r-f filters for the a-c input, the teletype output, the tone output, and the external tone input circuits.

The blower subunit is mounted on the rear of the case. It forces air through the unit for ventilation when the equipment is being used in high-temperature spaces. The motor operates on 110 volts, 60 cycles, and receives its power by way of a connector on the cable filter assembly. The air intake opening of the cast aluminum housing is covered by an air cleaner, which has an aluminum colth filter pad. Just inside this opening is a thermostatic switch, which automatically closes to start the motor when the temperature exceeds approximately 49° C.

The chassis-panel assembly consists principally of the front panel and a skeleton chassis into which the four previously described subunits are plugged and mounted. It has cabled wiring carrying the circuits between the receptacles for the subunits and cable filter assembly and to the electrical components on the front cable. The front panel components include the a-c power switch, the pilot light, and two monitor jacks. Other controls and indicators are described under "operation."

COMPARATOR.—The Comparator CM-22A/URA-8A includes (1) a selector subunit, (2) a power-supply subunit, (3) a cable-filter assembly, (4) a blower subunit, (5) a chassis-panel assembly, and (6) a case.

The selector subunit contains the circuit that compares the simultaneous signals from the two frequency-shift converter units and selects the best mark pulse and best space pulse for each character in the signals. The portion

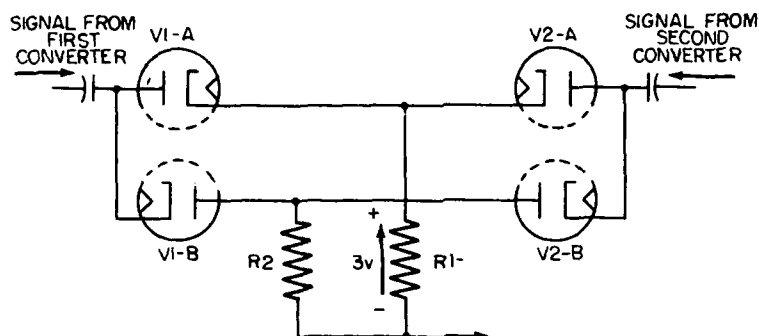


Figure 13-5.—Portion of selector subunit in Comparator CM-22A/URA-8A.

of the selector subunit in which this action occurs is illustrated in figure 13-5.

For example, assume that the first converter delivers a 3-volt positive pulse with respect to ground at the same time that the second converter delivers a 2-volt positive pulse. The 3-volt positive pulse will pass through V1A with negligible drop and develop 3 volts across R1. (Assume that the lower end of R1 is at or near ground potential.) This action makes the cathode of V2A 3 volts positive to ground; but the signal from the second converter is only 2 volts positive to ground. Hence V2A is cut off (its plate is negative with respect to its cathode), and only the diode with its plate positive with respect to its cathode will pass the signal. Thus in this example the signal from the first converter is selected by the comparator. The same selection occurs for the negative pulses at V1B and V2B; these pulses have R2 as their common load resistor.

When the signals from the two comparators have equal magnitudes, there is some combining due to phase difference, but otherwise the circuits pass only the stronger mark (positive) or the stronger space (negative) pulse. The selection is instantaneous even to the selection of parts of poorly shaped pulses.

Following the mark-space selector is an axis restorer similar to that in the frequency-shift converter, after

which the keying, tone, and output circuits are identical to those in the frequency-shift converter. The selected mark-space pulses are used by these circuits to key the teletype d-c loop and produce the keyed tone output.

The power supply unit supplies the power required to operate the selector subunit and, like the power supply in the frequency-shift converter, is designed with a link for adjusting the transformer to operate from 105/115/125 volts, 50 to 60 cycles, single phase.

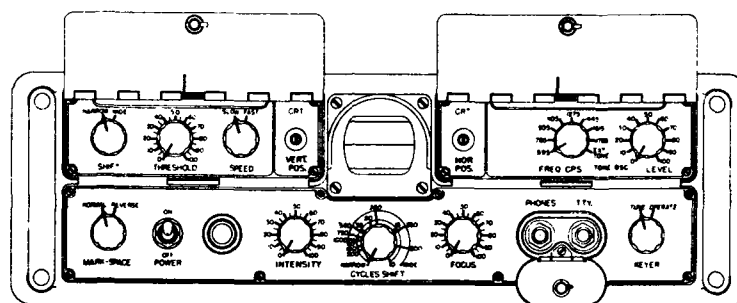
The cable filter assembly of the comparator is nearly identical to the corresponding assembly of the frequency-shift converter. The individual filters in the comparator cable filter assembly are duplicates of those in the frequency-shift converter, filtering the a-c input, the teletype and tone outputs, and the external tone input circuits.

The blower subunit on the rear of the comparator is identical to the one on the frequency-shift converter.

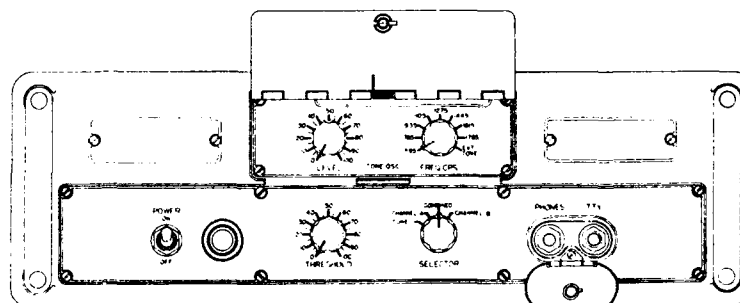
The chassis-panel assembly of the comparator consists principally of the front panel and a skeleton chassis into which the two subunits are plugged and mounted. Its general construction is similar to that of the frequency-shift converter chassis-panel assembly. Cabled wires carry the comparator circuits in the chassis panel assembly between the subunit and cable-filter receptacles and to the electrical components on the front panel. The front panel components include the a-c power switch, the pilot light, and two monitor jacks. Other controls are described under "operation."

OPERATION.—The operating controls of Frequency-Shift Converter CV-89A/URA-8A are illustrated in figure 13-6, A, and those for Comparator CM-22A/URA-8A are illustrated in figure 13-6, B. The associated monitor oscilloscope patterns are illustrated in figure 13-6.

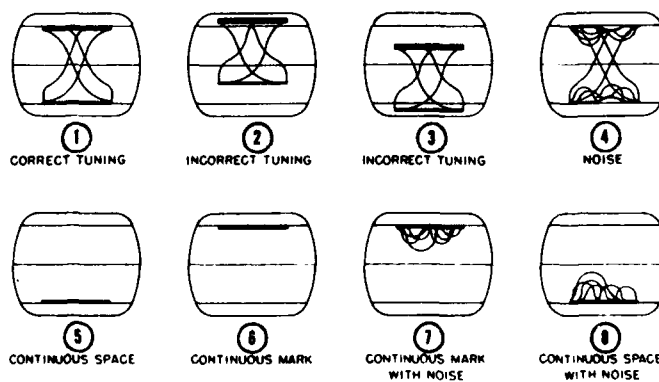
In order to obtain optimum performance of the converter-comparator group, it is necessary for the ET 3 to have a basic understanding of the receivers that are



A FREQUENCY SHIFT CONVERTER CV-89A/URA-8A



B COMPARATOR CM-22A/URA-8A



C MONITOR OSCILLOSCOPE PATTERNS

Figure 13-6.—Operating controls and monitor oscilloscope patterns for Converter-Comparator Group AN/URA-8B.

used with this equipment. The specific technical manual for the radio receivers being used should be available to the ET 3 to provide complete instructions.

When frequency-shift signals using narrow-shift operation are to be received, the BFO at the receiver should be adjusted to produce a beat note having an average center frequency of 1000 cycles (curve A, fig. 13-4). For wide-shift signals the BFO should be adjusted to produce a beat note having a center frequency of 2550 cycles (curve B, fig. 13-4). Where the BFO is not capable of producing this frequency, it may be obtained by slight detuning of the receiver, provided the selectivity is not too sharp.

When employing the higher frequency receivers (AN/SRR-12 and 13) on wide-shift signals, optimum operation is usually obtained with medium selectivity. However, under adverse noise and very weak signal conditions, improved operation can be obtained by using sharp selectivity, provided the BFO can be adjusted to be 2550 cycles higher or lower than the receiver intermediate frequency.

The operating controls for the frequency-shift converter include:

1. Threshold (adjusts bias (axis) to keyer grid).
2. Level (adjusts level of tone output).
3. Cycles shift (adjusts height of oscilloscope pattern and indicates cycles shift).
4. Vertical position (adjusts vertical position of oscilloscope pattern).
5. Horizontal position (adjusts horizontal position of oscilloscope pattern).
6. Intensity (adjusts brightness of oscilloscope pattern).
7. Focus (adjusts sharpness of oscilloscope trace lines).
8. Shift (adjusts discriminator circuits for narrow- or wide-shift input).
9. Mark space (reverses polarity of discriminator output).
10. Speed (selects fast- or slow-keying speed filters).

11. Frequency cps (selects frequency-determining elements for tone oscillator).

12. Keyer (for locking up, or closing of teletypewriter circuit during tuning of the receiver).

13. Power (switches a-c power input on and off).

The operating controls for the comparator include:

1. Threshold (adjusts bias (axis) to keyer grid).

2. Level (adjusts level of tone output).

3. Selector (selects input to comparator).

4. Frequency cps (selects frequency determining elements for tone oscillator).

5. Power (switches power on and off).

For diversity operation (fig. 13-3):

1. Set the comparator selector control to TUNE.

2. Turn the comparator threshold control to ZERO.

3. Throw all power switches to ON and allow sufficient time for the receivers to stabilize.

4. Set the shift control on each converter to the WIDE position; or if the shift width of the signal is known, set the shift control to the corresponding position.

5. Turn the cycles shift on each converter to approximately 800 on the wide range. If the cycles shift of the signal to be received is known, set the cycles shift to the corresponding position on the narrow or wide range.

6. Adjust the other oscilloscope controls as required. These adjustments are summarized at the end of this discussion.

7. Set the speed control on each converter to the SLOW position for keying speeds of less than 60 words per minute or to the FAST position for keying speeds in excess of 60 words per minute. However, under unusual conditions, operation is sometimes improved by switching to the FAST position when receiving less than 60 words per minute.

8. Set the comparator frequency cps to the desired tone output frequency and turn the level control to the required output level when tone output is used.

9. Tune the receivers to their respective r-f carriers and adjust the tuning so as to center the signal pattern on the oscilloscope, as shown in figure 13-6, C (1). The tuning of the receivers affects the vertical position of the pattern. The cycles shift control on the converter adjusts the vertical size of the pattern. Aural reproduction of the audio output of the receiver is recommended to aid the operator to identify the signals. If the AN/SRR-12 or 13 receivers are being used, the add decibels switch should be set on +10 and the level control adjusted until the output meter reads 0 db. For this condition, the signal power is equal to $0 + 10$ or 10 db. (Because zero db is equivalent to 6 mw into 600 ohms, 10 db is equivalent to a 60 mw output signal from the receiver.)

For dual diversity reception using two AN/SRR-12 or two AN/SRR-13 receivers, links are provided in the diode detector and AGC circuits that make these circuits common to the two receivers by means of receptacles, jacks, and suitable cabling. The gain of both receivers must be balanced. This action is accomplished by regulating the amount of amplification in the first two stages of the second i-f amplifier assembly of each receiver through adjustment of the diversity gain balance control. This control is a recessed screwdriver adjustment on the front panel.

With a common AGC circuit for both receivers, r-f input signals to both receivers (local and remote) will affect both AGC circuits simultaneously. For example, if the r-f input signal to the local receiver becomes stronger than the r-f input signal to the companion receiver, the AGC bias in both receivers will increase. This action decreases the gain of the r-f and i-f stages of both receivers, thereby decreasing the relative magnitude of the output signal of the companion receiver with its relatively weaker input signal. This action facilitates the selector action in the comparator by emphasizing the difference in voltage between the two receiver output signals.

The oscilloscope on each frequency-shift converter functions as a monitor for tuning its associated receiver to the r-f carriers, as previously described. When the receiver is tuned correctly and the cycles shift is properly adjusted, the pattern on the oscilloscope of each converter should coincide with the upper horizontal line for a mark pulse and the lower horizontal line for a space pulse, as illustrated in figure 13-6, C (1). If the receiver is not correctly tuned, the oscilloscope patterns will resemble patterns (2) and (3) in the figure. Under bad noise conditions the patterns will resemble (4), (7), and (8). A correctly tuned steady space and steady mark signal is shown at (5) and (6) respectively.

10. The width of shift being received is indicated on the cycles shift wide or narrow scale when the oscilloscope mark space pattern is adjusted between the upper and lower calibrating lines, as shown at (1). The scale to read is the one that corresponds to the setting of the shift control (fig. 13-6, A).

11. Set the comparator selector (fig. 13-6, B) to channel A (upper converter unit, fig. 13-2).

12. Turn the comparator threshold control clockwise until the teletype printer starts to print.

13. Try the channel A converter mark-space selector in both normal and reverse positions (fig. 13-6, A) and leave it in the position that gives correct copy on the teletype printer. In the correct position the characters are of the right polarity to control the teletype printer, but in the other position the characters are reversed and will not synchronize the control mechanism of the teletype printer. The latter condition results in no intelligence in the printed copy.

14. The teletype printer should now print correct copy (except in the low parts of a fading signal), indicating that channel A is ready for diversity operation.

15. Set the comparator selector to channel B (lower converter (fig. 13-2).

16. Turn the comparator threshold control clockwise until the teletype printer starts to print.

17. Try the channel B converter mark-space selector in both normal and reverse positions, as described for the channel A converter under item 13 (fig. 13-6, A). Leave the selector in the correct position, as described in item 13.

18. The teletype printer should now print correct copy (except in the low parts of a fading signal), indicating that channel B is ready for diversity operation.

19. Set the comparator selector to COMBINED (fig. 13-6, B).

20. Adjust the comparator threshold control to the highest scale reading that does not allow noise pulses to cause errors in the copy. A practical way to find this setting is to detune both receivers slightly off their respective r-f carriers to a position where noise alone is received. Then turn the threshold control clockwise to allow the noise to key the teletype printer. Finally turn the threshold control counterclockwise (back it off) to the position where the threshold bias is just enough to prevent the noise from keying the teletype printer.

21. Retune each receiver to its respective r-f carrier (as it was before detuning).

The frequency-shift converter-comparator group is now adjusted for diversity operation, either continuous or intermittent. Except for occasional retuning of the receivers and readjusting for changing conditions, the equipment should require little attention by the ET 3.

With experience in the use of this equipment the art of tuning and adjusting can be developed to the point where the proper settings can be readily recognized from the teletype printer copy and the monitor oscilloscope pattern. Under conditions of bad noise, it is frequently possible to obtain satisfactory teletype copy in diversity operation from signals that audibly are hardly distinguishable from the noise.

When placing the frequency-shift converter-comparator group into operation for the first time, it is necessary to

make four initial adjustments on the oscilloscopes associated with each of the converters. Two of these adjustments are semipermanent and need only be checked periodically after they are once set. The other two are panel controls that may have to be readjusted according to light conditions in the room in which the equipment is located.

To make these adjustments on the oscilloscope, (1) turn the receiver off and adjust the intensity and the focus on the converter (fig. 13-6, A) to give a clear, fine trace on the screen with the desired brightness; (2) adjust the converter screwdriver adjustment marked, VERT POS, to make the horizontal trace coincide with the horizontal centerline on the face of the oscilloscope; and (3) adjust the converter screwdriver adjustment marked, HOR POS, to center the horizontal trace on the screen.

After making these adjustments, turn the receiver on and proceed with the operation of the equipment. During operation the intensity and focus controls should be readjusted whenever necessary to give the clearest possible presentation.

Tone Converter AN/SGC-1A

Another method of teletype communications employs tone modulation for short range (UHF and VHF) transmission, as mentioned in chapter 1 of this training course. Tone modulation employs a tone converter, one type of which is included in Radio Teletype Terminal Set AN/SGC-1A, as illustrated at the center of figure 13-7. Other associated equipment includes a radio receiver and transfer panel, a radiophone transmitter and transfer panel, and a teletypewriter and panel. The blocks indicate that any suitable standard Navy components may be used.

In tone modulation transmission, the teletypewriter pulses are converted into corresponding audio tones, which amplitude modulate the voice-frequency transmitter. Conversion of the audio tones is accomplished by an audio oscillator in the tone converter, which op-

erates at 700 cycles when the teletype loop is in a closed-circuit (mark) condition and at 500 cycles when the loop is in an open-circuit (space) condition.

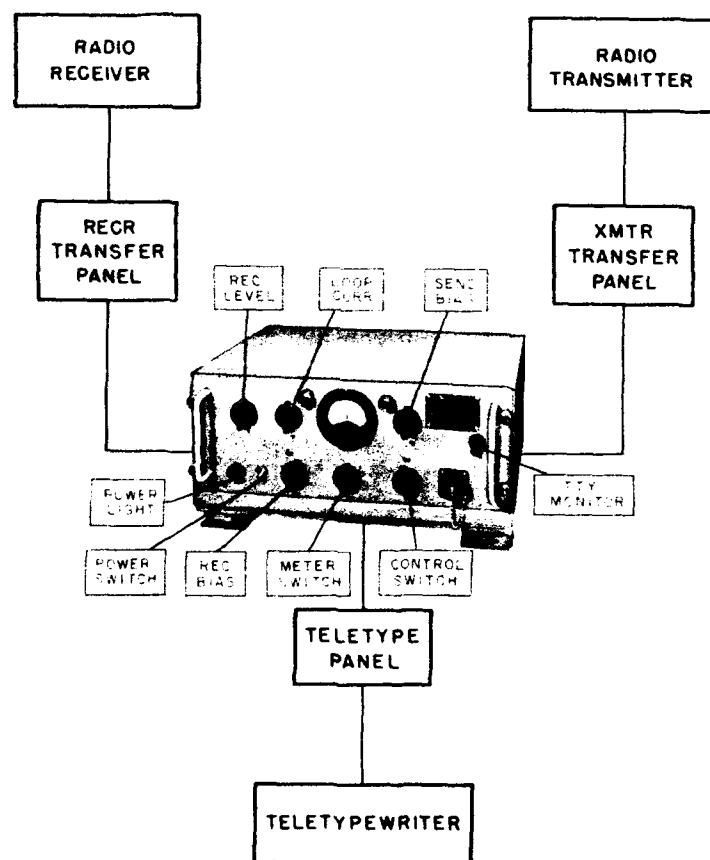


Figure 13-7.—Teletype Terminal Equipment AN/SGC-1A.

An internal relay in the tone converter closes a control line to the radio transmitter, which places the unit on the air when the operator begins typing a message. The control line remains closed until after the message has been transmitted.

When receiving messages, the tone converter accepts the mark and space tones coming in from an associated radio receiver and converts the intelligence of the tones to the make and break contacts of a relay connected in the local teletypewriter d-c loop circuit. This action causes the local teletypewriter to print in unison with the mark and space signals from the distant teletypewriter.

The receive level calibrated attenuator is located at the upper left side of the front panel on the tone converter. This control permits adjustment of the level of the incoming tone signals from the receiver. The loop current rheostat is next to the receive level control, and is adjusted to 60 ma when the teletype loop is in the mark, or closed circuit condition. A central zero meter indicator is located at the upper middle portion of the front panel. An associated switch is located directly below the meter. It has several positions to permit measurements to be taken in all the necessary portions of the circuit.

Two indicator lights flank the upper part of the meter. One light indicates the receive condition and the other indicates the transmit condition. Both lights are off when the tone converter is in the standby condition.

The send bias rheostat is located at the right of the meter. This control permits correction of any teletype distortion (for example, unequal length of mark and space signals) in the local teletypewriter loop when sending a teletype message.

At the far right is a jack marked, TTY monitor. A test or monitoring teletypewriter may be patched into this jack, thereby placing it in series with all other equipments in the loop. NOTE: headphones must not be plugged into this jack.

The power indicator light is located at the lower left side of the front panel of the tone converter. The power ON-OFF switch is located next to it.

The receive bias potentiometer is located at the right of the power switch. This control enables correction of

distortion (unequal length of mark and space tones) in the receiving tone circuit.

The control switch is located at the right of the meter switch. The position of the control switch determines the function of the tone converter to either receive or to transmit teletype signals.

A 115-volt, 60-cycle convenience outlet is provided at the lower right of the front panel. It bypasses the power switch.

A block diagram of the tone converter is illustrated in figure 13-8. Typical oscilloscope patterns are included. The attenuator is located at the input of the receive circuit to permit adjustment of the level of the incoming 2-tone signal. The band-pass filter passes all frequencies in the band from 400 to 800 cycles and rejects all other frequencies. The amplifier limiter stages have a constant-output level. The frequency discriminator filter selects the fundamental frequencies of 500 cycles and 700 cycles and routes them via separate germanium rectifiers to corresponding d-c amplifiers (in the d-c amplifier block) and associated relay coils in the receiver relay block. A 700-cycle signal causes the receive relay to close the teletype d-c loop; a 500-cycle signal causes the relay to open the loop. Thus, corresponding mark and space signals are developed in the teletype loop circuit.

In sending, the mark and space signals in the d-c loop cause the send relay to apply either a d-c voltage or no d-c voltage respectively to the two-tone oscillator. A mark signal causes the oscillator to operate at 700 cycles; a space signal causes it to operate at 500 cycles.

The output of the oscillator passes through a level-controlling potentiometer (not shown in the diagram) to the amplifier stage. The output of the amplifier passes through a band-pass filter to the ship's radio transmitter.

The control switch and its associated circuits permit the tone converter to function in several ways. When the switch is on AUTO, the tone converter may be in one

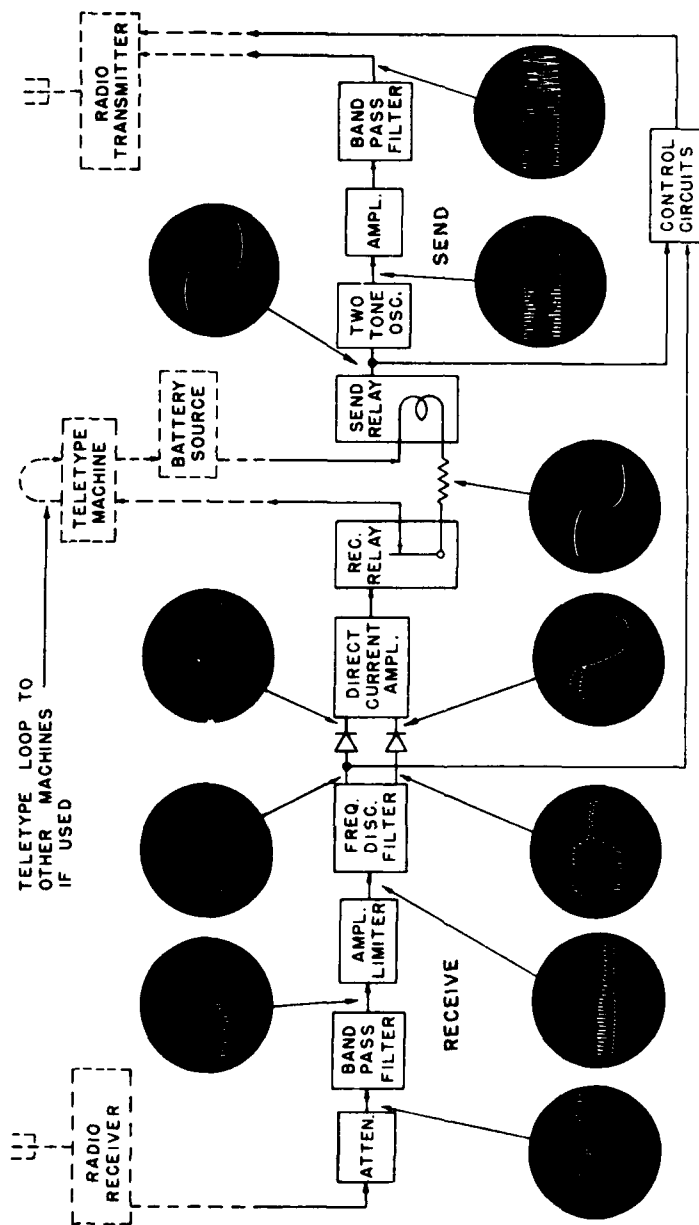


Figure 13-8.—Block diagram of tone converter.

of three conditions: receiving, transmitting, or standby. When in the standby condition, the reception of an incoming mark tone causes the control circuit to change to receiving. Following the end of the incoming message, the circuits shift back to standby.

When in the standby condition, the operation of the local teletypewriter causes the circuits to change to transmit. After the last letter is keyed, there is a time delay of about 3 seconds and then the circuits shift back to standby. The interlocking functions prevent the equipment from shifting directly from transmit to receive, or vice versa.

Thus an incoming signal will not interrupt an output signal nor will keying the local teletypewriter, when receiving, cause the circuit to shift to transmit.

The control circuits also, when shifted to transmit, cause the control contacts of the transmit control relay to the radio transmitter to close, thereby placing the transmitter carrier on the air.

When placing the tone converter in operation, proceed as follows (fig. 13-7).

1. Turn the power switch to ON.
2. Turn the control switch to TRS (transmit position). If the transmitter power has been turned on, the transmitter will send out a continuous tone; however, this does not matter for a few moments. If desired, the transmitter power may be left off until certain other adjustments have been made.
3. Turn the meter switch to LOOP CURRENT. Adjust the control marked, LOOP CURR, until the meter reads 60 on the upper scale. If the meter reads zero, the source of loop current may not be energized.
4. Turn the control switch to AUTO. Then hold down the space bar on the teletypewriter and turn the meter switch to SEND BIAS. The meter should read zero on the upper scale. If not, correct the reading to zero by means of the send bias control. Turn the meter switch to OFF before releasing the space bar.

5. The radio transmitter may be turned on if it was left off. When a teletype message is received from a distant station, turn the meter switch to RECEIVE LEVEL and adjust the receive level control until the meter reads, 0 dbm (lower scale).

6. The last adjustment is the receive bias control adjustment for which an incoming teletypewriter signal is required from a distant station. The ET 3 should request that a distant operator hold down his teletype space bar for a minute. While he is holding down the space bar, turn the meter switch to RECEIVE BIAS and adjust the receive bias control until the meter reads zero on the upper scale. Then return the meter switch to the OFF position.

The equipment is now adjusted for operation with its associated teletypewriter, receiver, and transmitter for communication with other stations similarly equipped.

The control switch is used for changing from one operating condition to another. Usually, for one-way reversible communication, this switch is set at the AUTO position. In auto condition, operators at two or more stations having this equipment may engage in full communication. After a station has completed sending its message, it is ready for reception of any return message after a three-second time delay.

In carrying on communications, the equipment should not be operated with the control switch turned to TRS because the equipment is then locked in the transmit condition and cannot receive any message until released by turning the control switch to one of the other two operating positions.

If it is desired to prevent the sending of a message by the teletypewriter, the control switch may be turned to REC/STDBY. Then the equipment cannot change to the transmit condition even though the teletypewriter is operated, but it can receive messages or remain in the standby condition.

The fourth position of the control switch is ADJUST FREQUENCY. This position is never to be used during

operating periods. It is for maintenance use only.

Because a small time delay is incurred in the operation of the control circuits of the local and distant terminals, the first character transmitted is usually lost. Therefore, the first character typed should be the "letters" key.

A summary of the operating procedure for the tone converter is indicated in table 24.

TABLE 24
OPERATION SEQUENCE

Check	Notes or Cautions	Control Switch Position	Meter Switch Position	Meter Read- ing	Control to Adjust
Loop Current---		TRS	LOOP CURR	60 upper scale	LOOP CURR
Send Bias---	Before turning meter switch to send bias depress space bar and keep it depressed until this ad- justment is made and switch turned to off.	AUTO	SEND BIAS	0 upper scale	SEND BIAS
Receive Level----	This adjustment requires the reception of a teletype sig- nal.	AUTO	REC LEVEL	0-dbm lower scale	REC LEVEL
Receive Bias-----	This adjustment requires that the distant operator de- press his space bar during the adjustment.	AUTO	REC BIAS	0 upper scale	REC BIAS

Teletype Panel TT-23/SG

The use of teletype panels similar to Teletype Panel TT-23/SG facilitates the interconnection and transfer of teletype equipment aboard ship with various radio adapters, such as frequency shift keyers (where they are not a part of the transmitting set) and frequency shift

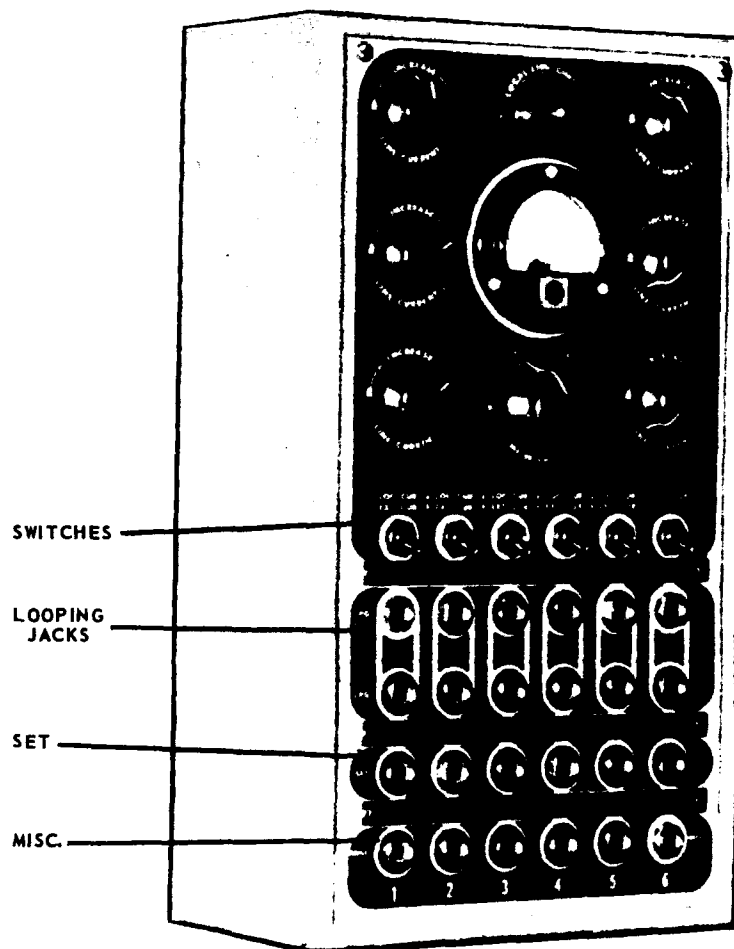


Figure 13-9.—Teletype Panel TT-23/SG.

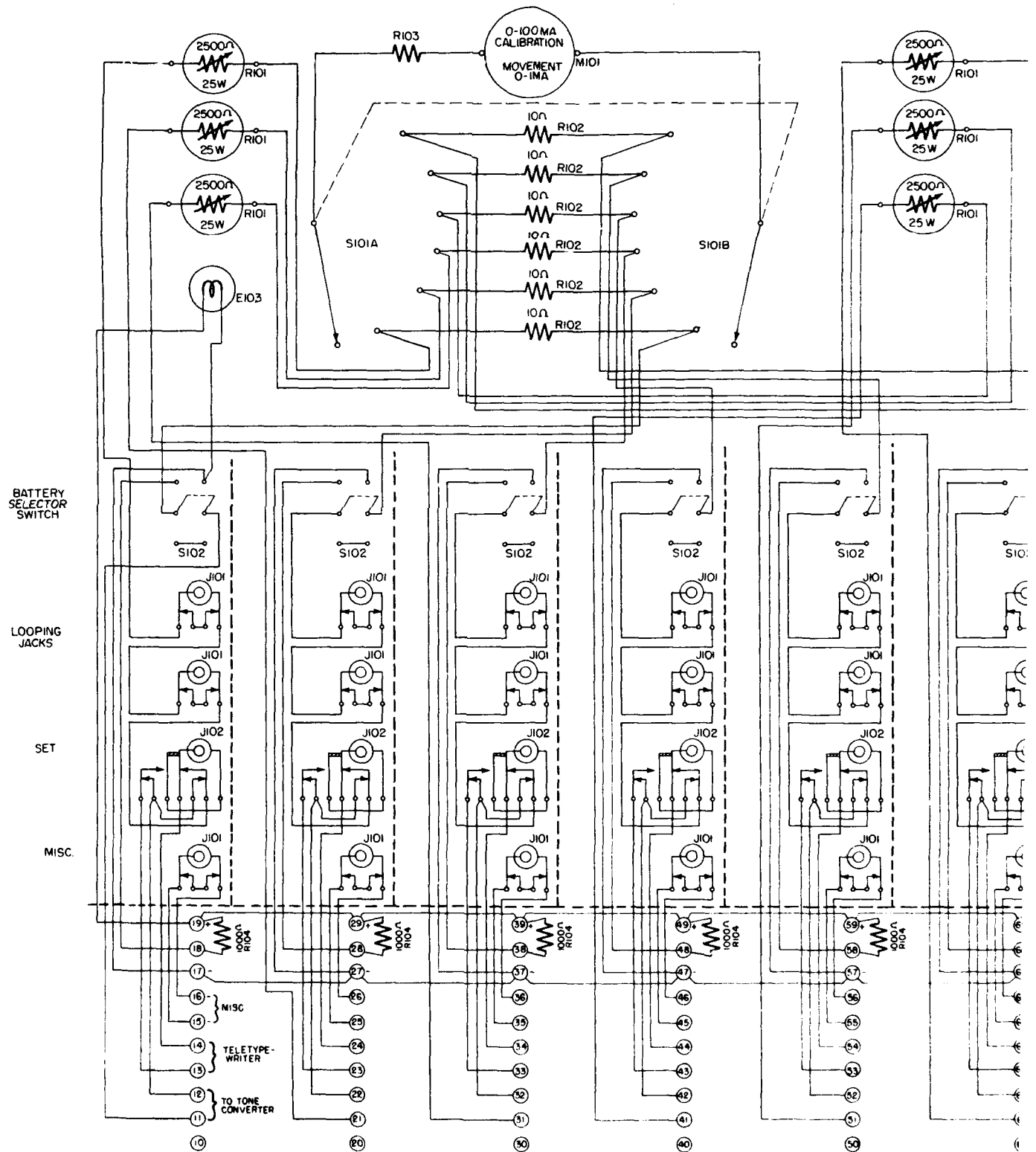
converters and tone modulation equipments, as previously described. Teletype Panel TT-23/SG is illustrated in figure 13-9.

The teletype panel contains 6 channels, each comprising a looping series circuit of two looping jacks, one set jack, a rheostat for adjusting line current, and a toggle switch for selecting either a local or external source of line current. The panel includes a meter and rotary selector switch for measuring the line current in any channel. There are six miscellaneous jacks to which may be connected any teletype equipment not regularly assigned to a channel. There is a connection block mounted inside the cabinet to which all teletype equipment, radio adapters, and local current connections are terminated.

A schematic diagram of Teletype Panel TT-23/SG is illustrated in figure 13-10, A. A single channel is illustrated in figure 13-10, B. All radio adapters, such as frequency shift keyers, converters, and tone modulated terminal equipment should be connected to the 1 and 2 (series) lugs. All teletypewriters that are to be in a looping circuit (top two rows of jacks) should be connected to the 3 and 4 (series) lugs. Other miscellaneous teletype equipment may be connected to the 5 and 6 (series) lugs. The bottom row of jacks are used for interconnecting this equipment. The local source of line current, 115 volts d-c, should be connected across the 7 and 9 (series) lugs.

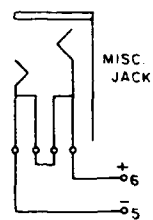
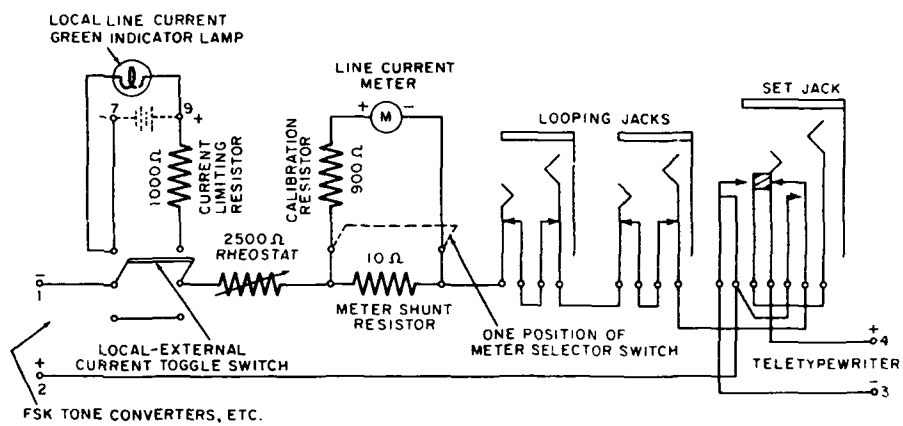
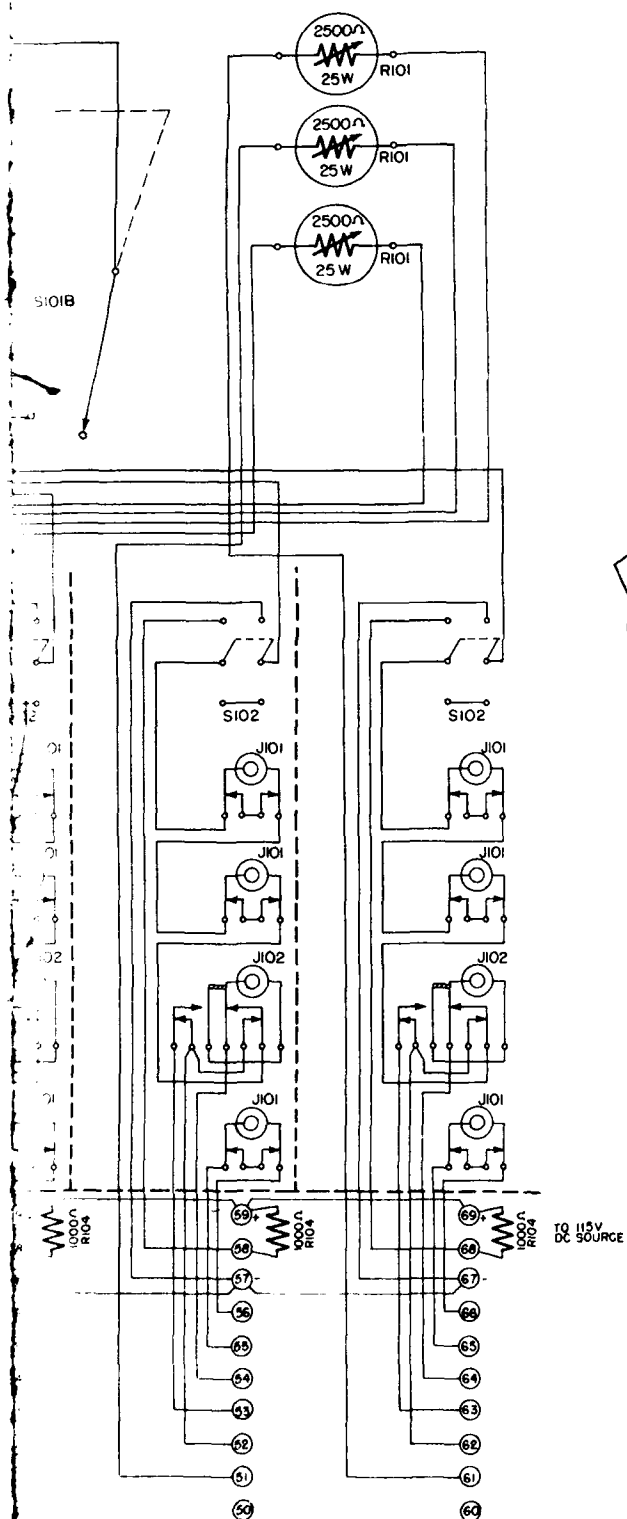
To operate the teletype panel:

1. Turn all line current rheostats counterclockwise to increase circuit resistance to maximum value.
2. Turn on the local line current supply at the distribution panel (not shown in the figure). The green indicator light on the teletype panel will come on.
3. If the desired teletype equipment is wired in the same looping channel as the radio adapter to be used, no patch cords will be required.

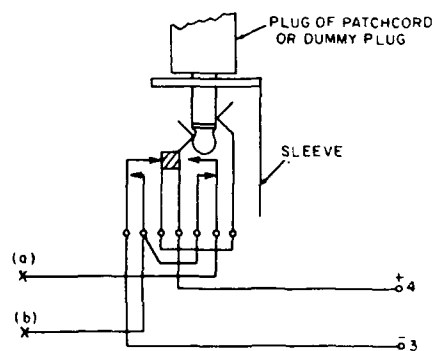


A WIRING DIAGRAM

Figure 13-10.—Schematic diagram of Teletype I



B SINGLE CHANNEL SCHEMATIC



C SWITCHING ACTION OF SET JACK

4. If the radio adapter supplies its own line current, operate the battery selector switch to the EXTERNAL CURRENT position. If the line current is not supplied externally, operate the switch to LOCAL CURRENT position.

5. Turn the meter selector switch to the desired channel and adjust the corresponding rheostat to give a line current indication of 60 ma.

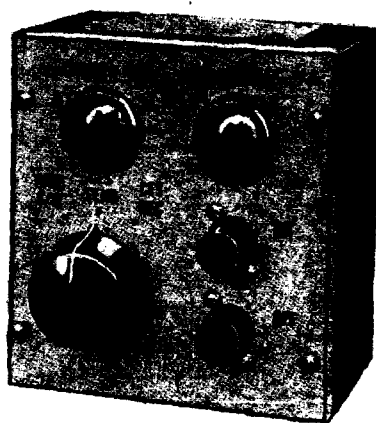
6. If the desired teletypewriter (for example in channel 1) is not wired in the same looping channel as the radio adapter to be used (for example, channel 3), insert one end of a molded patch cord (supplied with panel) in the set jack in channel 1, and the other end in either one of the two looping jacks in channel 3 may be made inoperative by inserting a dummy plug (supplied with panel) in the set jack of channel 3, or it may be patched to the looping jacks of another channel (for example, channel 4), by inserting one end of a second patch cord in the set jack of channel 3 and the other end in a looping jack of channel 4.

In any switching operation between the various plugs and jacks of the teletype panel, remember to never pull the patch plug from the machine (set) jack before first removing the other end of the cord plug from the loop jack. Pulling the plug from the set jack first would open circuit the channel and cause all teletype messages in the channel (whether local or remote) to be interrupted. The channel is close circuited as long as the plug is inserted in the set jack. Removing the plug from the set jack first, with the other end of the patch cord inserted in either looping jack, would open circuit the channel because the tip-sleeve connections between the set jack and plug would be interrupted.

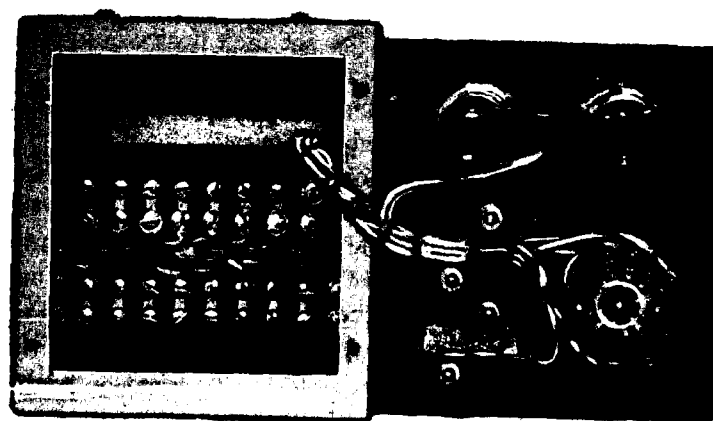
The proper procedure is to take the plug out of the looping jack first, or to insert it last. This action maintains closed-circuit operation of all channels in the panel at all times. The switching action of the set jack is illustrated in figure 13-10, C.

Transmitter Teletype Control Unit C-1004A/SG

Another equipment used with teletype installations aboard ship is a control unit, for example, Navy Model C-1004A/SG (fig. 13-11). This unit permits control of a teletypewriter radio circuit from a remote position.



A EXTERNAL VIEW



B INTERNAL VIEW

Figure 13-11.—Transmitter Teletypewriter Control Unit C-1004A/SG.

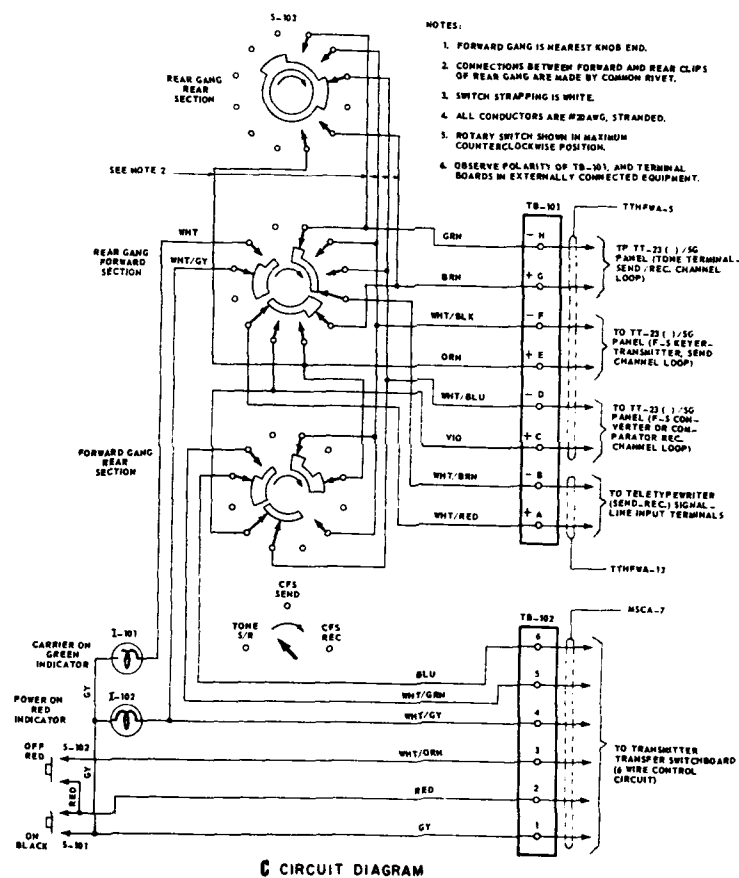


Figure 13-11.—Continued.

It provides a transmitter power ON-OFF switch, a power-on indicator lamp, a carrier-on indicator lamp, and a three-position rotary selector switch. The rotary selector switch, S103, provides the following functions:

1. Connects a send-receive teletypewriter to (a) a frequency shift keyer circuit (CFS send), (b) a frequency-shift converter or comparator circuit (CFS receive) or, (c) a tone terminal on a send receive basis (tone S/R).

2. Shorts the other two unused sets of terminals when the send-receive teletypewriter is connected to the set of terminals associated with a particular switch position; that is, when the switch is in the TONE S/R position, the frequency-shift keyer terminals, E and F (CFS send) and the frequency-shift converter terminals, C and D (CFS receive) are shorted (close circuited).

3. Turns on the transmitter carrier by closing a circuit in the radio transmitter (terminals 5 and 6 are shorted in the CFS SEND position only).

4. Energizes the carrier-on indicator lamp in the CFS SEND position only.

When S103 (fig. 13-11, C) is in the TONE S/R position, the carrier-on indicator lamp and the transmitter carrier are off; the teletypewriter is connected to the tone terminal loop (terminals G and H) while the unused terminals, frequency-shift keyer terminals E and F and frequency-shift converter terminals C and D, are shorted.

When S103 is in the CFS RECEIVE position, the carrier-on indicator light and the transmitter carrier are off; the teletypewriter is connected to the frequency-shift converter circuit while the unused terminals, tone terminals G and H and frequency-shift keyer terminals E and F, are shorted.

FACSIMILE EQUIPMENT

Facsimile provides a means of reproducing still pictures over a communications system. The principle of operation is described briefly in chapter 1. Common operating adjustments on various components of facsimile transmitting and receiving terminal equipments are described in the following portion of this course.

Facsimile Transceiver TT-41B/TXC-1B

Facsimile Transceiver TT-41B/TXC-1B is an electro-mechanical optical facsimile set of the revolving-drum type for the transmission and reception of page copy. It is used for transmission of maps, photographs, sketches,

and printed or handwritten text over regular voice communications channels, either wire or radio, between two or more stations. Colored copy may be transmitted, but all reproduction is in black, white, and intermediate shades of gray. Received copy is recorded either directly on chemically treated paper, or photographically in either negative or positive form. The equipment will transmit or receive a page of copy 12 by 18 inches in 20 minutes at regular speed or in 40 minutes with half-speed operation. A block diagram of the over-all equipment is illustrated in figure 13-12.

The complete electrical circuit of the transceiver and power unit may be subdivided into the following eight principal components: (1) fork oscillator unit, (2) photo cell bridge modulator, (3) signal amplifier circuit, (4) phasing circuit, (5) motor circuit, (6) B+ regulator circuit, (7) rectifier power supply, and (8) exciter lamp supply.

The fork oscillator unit (AV1, V2, and V3) generates a steady 1800-cycle audio signal for use in several other circuits. This unit acts as the signal source at 1800 cycles.

The bridge modulator circuit, built around a 5652 photo tube, V24, is used only on transmission. It amplitude modulates the 1800-cycle signal in accordance with the variations in light intensity of the small portion of the transmitted copy being scanned at any instant.

The signal amplifier circuit (V10, V11, V12, V13, and V14) amplifies the 1800-cycle a/m signal. On transmission the circuit is fed by the photo tube bridge modulator; the output goes to the line terminal and thence via auxiliary equipment to the radio transmitter. On reception the circuit is fed by the signal one the line from a radio receiver; the output drives either the stylus for direct recording or the recorder lamp for photo recording. The signal amplifiers are also used in the talk-back circuit.

The phasing circuit, V15 and V16, is used for phasing



of the facsimile receiver before each transmission. A series of phasing pulses from the transmitter actuates a clutch mechanism, which positions the receiver drum so that the clamp bars of both drums (receiver and transmitter) pass the scanning mechanisms at the same time. The clamp bars hold the copy to the drum (fig. 13-13).

The motor circuit (V4, V5, and V6, fig. 13-12) amplifies the 1800-cycle signal from the fork oscillator unit and drives the synchronous motor at constant speed. A multivibrator, V26, is used to provide half-speed operation of the synchronous motor.

The B+ regulator circuit (V7, V8, V9, and V25) provides a closely regulated voltage of 250 volts from the rectifier power supply of 450 volts. Regulated B+ voltage is used on critical transceiver circuits.

The rectifier power supply (V22 in the power unit) provides an unregulated 450-volt B+ output. The power unit also provides 6.3 volts a-c for filament operation and 115 volts a-c for starting the synchronous motor (not shown in the figure).

The exciter lamp supply (V17, V18, V19, V20, V21, and V23 in the power unit) amplifies and regulates the

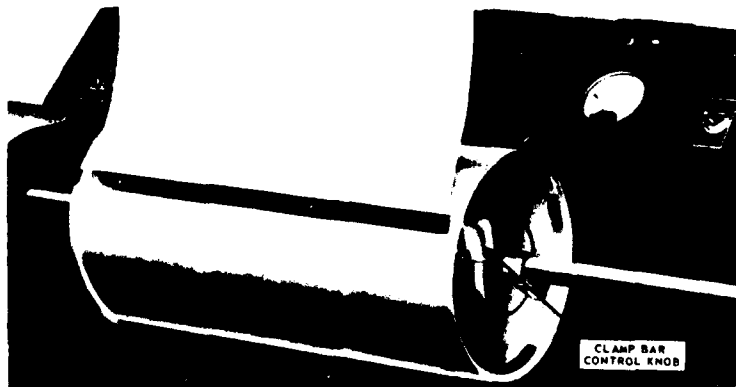


Figure 13-13.—Placing copy on drum.

1800-cycle signal from the fork oscillator unit to provide a steady supply for the transceiver exciter lamp, which illuminates the transmitted copy with a constant brilliancy.

All electrical operating controls of the facsimile transceiver, except the motor speed-control switch are located on the sloping front panel of the transceiver (fig. 13-14). The motor speed-control switch is located on the left end of the base of the transceiver. Two mechanical controls, the drum engaging lever and the clamp bar, are located on the drum. Input and output connections are located on the right-hand end of the transceiver. The power unit has no operating controls.

The power ON-OFF switch is located on the right-hand side of the control panel. It makes and breaks one side of the 115-volt, 60-cycle a-c line circuit feeding the primary of the main power transformer located in the rectifier power unit. In the OFF position power is removed from all parts of the facsimile set. In the ON position plate and filament voltages are applied to all tubes, and power is available for starting and operating the synchronous motor.

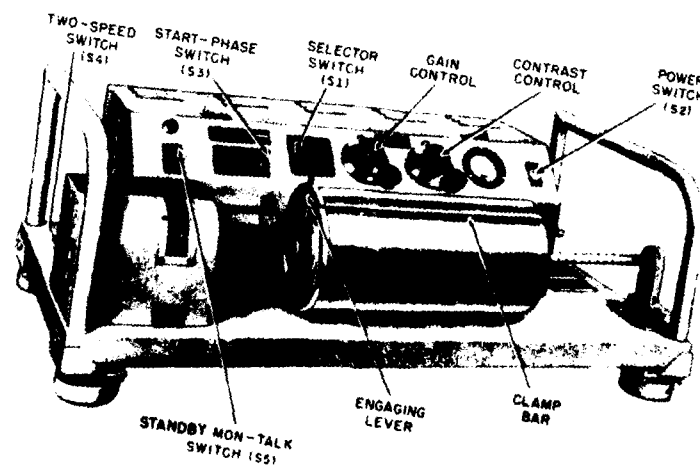


Figure 13-14.—Facsimile transceiver controls.

The selector switch located to the left of center on the front panel is the principal control for determining the function of the transceiver. It has five positions, which are labeled (from top to bottom) TRANSMIT, SET RANGE, STANDBY, RECORD PHOTO, and RECORD DIRECT.

In the TRANSMIT position the facsimile transmitting circuit is established, and impulses representing elements of the facsimile copy are sent out over the facsimile circuit. This is the normal operating position when the transceiver is transmitting copy. In this position the switch also closes the radio transmitter relay circuit associated with the carbon mike jack.

In the SET RANGE position the transmitting circuit is established as in the TRANSMIT position, except that impulses are not sent out over the line. This position is used when the operator is engaged in setting the contact range for transmitting a specific piece of copy.

In the STANDBY position the electron tubes are kept ready for operation of the transceiver. This is the normal setting during periods when copy is not being transmitted or received.

In the RECORD PHOTO position the receiving circuit is established to permit use of the recorder lamp for recording the received copy on photographic paper. This switch position is used to set the gain and to phase the receiving transceiver before recording either "photo" or "direct." A raised stud on the selector switch nameplate enables the operator to set the switch at record PHOTO by "feel" in the dark room.

In the RECORD DIRECT position the receiving circuit is established to permit use of the stylus instead of the recording lamp. The stylus causes recording of received copy on electrosensitive recording paper. Moving the selector switch to the RECORD DIRECT position mechanically moves the stylus into contact with the paper.

The start-phase switch is a three-position, nonlocking lever type switch, which is spring loaded to return to neutral when released from either the START or PHASE positions. The switch is located on the front panel be-

tween the selector switch and spare fuse for the motor. The transmitting and receiving operators throw the start-phase switch to the START position momentarily to apply power to the start motor and to bring the synchronous motor above the normal operating speed. When the switch is released, the synchronous motor slows down to its normal operating speed and continues to operate at that speed. The receiving operator throws the start-phase switch to the PHASE position to energize the phasing circuit of the receiving transceiver while the transmitting operator is sending phasing pulses. When the relatively short-phasing operation is completed, the machines remain synchronized.

The motor speed control switch is a three-pole, double-throw toggle switch located on the left end of the base of the transceiver to the rear of the motor cover (fig. 13-14). It is used in the 60-rpm position for normal operation or in the 30-rpm position to provide half-speed operation when transmitting over long radio circuits under adverse receiving conditions.

The standby non-talk switch is a three-position (two locking, one nonlocking) key switch located at the left on the front panel. The three positions, from the top to the bottom, are labeled STANDBY, MON, TALK. The talk-back circuit is operated only when the selector switch is on STANDBY.

In the STANDBY position, with a speaker plugged into the speaker jack, the speaker will be connected in the circuit and the operator can monitor the communication channel. If the standby mon-talk switch is in the STANDBY position, and the selector switch is also in the STANDBY position, the synchronous motor will not operate. This position is used to receive voice communications when it is not necessary to have the motor running.

In the MON position, with a speaker plugged into the speaker jack, the speaker is also connected and the operator can monitor the communication channel. In this position, however, the motor receives power and can be started and run at synchronous speed. This is the normal

position for receiving voice communications, when phasing transmitting and receiving equipments, preparatory to sending and receiving facsimile copy. Some 1800-cycle interference will be noticed in the talk-back circuit.

In the TALK position, with a speaker plugged into the speaker jack, the speaker becomes the microphone of a voice intercom system. The switch must be held in the TALK position; if pressure is released, it will snap back to the MON position. The TALK position is used when talking to the facsimile operator on the other end of the circuit.

It should be noted that the talk-back circuit only operates when the selector switch is at STANDBY. Voice communications cannot be carried on over this circuit when the selector switch is at TRANSMIT, SET RANGE, RECORD PHOTO, or RECORD DIRECT.

It should also be noted that the talk-back circuit will not function over a radio circuit that uses auxiliary radio equipment unless the auxiliary equipment is bypassed for voice communications.

The contrast control is a calibrated potentiometer located to the left of the db meter on the front panel of the transceiver; it adjusts the contrast range (difference between minimum and maximum signal strength) of the transmitted signal by adjusting the magnitudes of the currents in the photo-tube bridge circuit. This control is operated only by the transmitting operator. The dial on this control is numbered from 1 to 100, with the applicable ranges for use when transmitting either positive or negative indicated on the dial.

The contrast control may be used to balance the bridge in the photo-cell bridge modulator (V24, fig. 13-12) either on maximum light (white) or on minimum light (black). In either case when the bridge is balanced, the output signal has a minimum amplitude. Thus, if the contrast control is adjusted so that the bridge is balanced when the light is a maximum, the output signal will have minimum amplitude on white and maximum amplitude on black. This type of transmission is called positive trans-

mission. When the bridge is balanced on minimum light, the output signal will have minimum amplitude on black and maximum amplitude on white. This type of transmission is called negative transmission.

The gain control, located between the contrast control and the selector switch, is a dual potentiometer, which serves to control the level of the signal handled by the transceiver both in transmitting and receiving. It does not change the contrast range.

The front panel db meter, which serves as a guide in setting gain and contrast controls, is calibrated in db with reference to a zero-power level of 6 milliwatts in 600 ohms.

To turn the transceiver on, throw the power on-off switch to ON and turn the selector switch to SET RANGE. Normally a 5-minute warmup period should be allowed before making adjustments or actually transmitting.

To place copy on the drum, raise rear edge of clamp bar (fig. 13-13) by turning the clamp-bar control knob to its clockwise position. Place the lower edge of the copy (face up) under the rear edge of the clamp bar. Turn the knob to its counterclockwise position, thus closing the clamp on the leading edge of the copy and opening the other clamp. Revolve the drum forward, wrapping the copy around the drum. Insert the loose edge of the copy under the clamp; pull the copy tight around the drum with a wiping motion of the hand, and close the clamp by turning the clamp-bar control knob back to its center position. Examine the copy after it is placed on the drum to make sure there are no bulges.

The following adjustments should be made for transmitting positive for direct recording:

1. Turn selector switch to SET RANGE.
2. As a starting point, set the gain control at 65 and the contrast control near zero.
3. Turn the drum so that the whitest portion of the copy is illuminated by the spot of light. Carefully turn the contrast control to a higher setting until the meter reads the required minimum. Check the meter reading

and move the drum slightly backward and forward while examining a different white portion of the copy to be sure that the whitest spot is used. For radio operation the required minimum will depend on the type of auxiliary equipment being used with the radio transmitter. Modulator, Radio MD-168/UX will accept any contrast signals from 10 db to 20 db, but the wire-line minimum ($\frac{1}{16}$ inch below the -10 calibration mark on the db meter) is recommended.

4. Move the drum so that the blackest portion of the copy is illuminated by the spot of light. Be sure that the blackest portion actually is used by again rotating the drum slightly backward and forward while checking the meter.

5. Adjust the gain control so that the meter reads +2 db.

6. Shift back to the whitest portion of the copy and readjust the contrast control for a minimum reading of -10 db on the meter.

7. Repeat steps 4, 5, and 6 until the final adjustments of the gain and contrast controls give meter readings, differing by at least 12 db between the blackest and whitest portions of the copy.

Adjustments for transmitting negative are not given here in the interest of brevity but may be obtained by referring to the appropriate technical manual.

A summary of operation and coordination is given in table 25.

TABLE 25
SUMMARY OF OPERATION AND COORDINATION

Transmitting	Receiving
Joint Operations Determine the type circuit to be used, wire or radio. Determine the type transmission and reception required, either direct (single or duplicate copies) or photographic (positive or negative).	

TABLE 25—Continued
SUMMARY OF OPERATION AND COORDINATION

Transmitting	Receiving	
Prepare copy. Turn Power ON/OFF switch to ON.	Turn power ON/OFF switch to ON.	
Turn selector switch to SET RANGE.		
Allow warm-up period.	Allow warm-up period.	
Disengage drum by means of drum engaging lever and push drum to far right end of lead screw.	Disengage drum by means of drum engaging lever and push drum to far right end of lead screw. Turn selector switch to STANDBY.	
	Direct Recording	Photographic Recording
		Turn off all lights except safelight.
Place copy on drum.	Place recording paper on drum.	Place film or photographic paper on drum.
	Turn selector switch to RECORD PHOTO.	Turn selector switch to RECORD PHOTO.
Set GAIN and CONTRAST so that db meter readings differ by the required contrast between blackest and whitest portions of copy.		
If using wire line transmission set STANDBY-MON-TALK switch momentarily at TAL). Advise receiving operator of forthcoming min and max signals.		

TABLE 25—Continued
SUMMARY OF OPERATION AND COORDINATION

Transmitting	Receiving	
Turn selector switch to TRANSMIT and transmit max signals for 15 seconds. Then alternately send min and max signals for about 5 seconds each.	Adjust GAIN control.	Adjust GAIN control.
Move drum so that light shines on phasing drum.		
Turn selector switch to SET RANGE (STANDBY-MON-TALK) switch at MON) and press START-PHASE switch toward START to start motor.	Press START-PHASE switch toward START to start motor.	Press START-PHASE switch toward START to start motor.
Turn selector switch to TRANSMIT and send about 25 phasing pulses.	Hold START-PHASE switch at PHASE until drum is phased.	Hold START-PHASE switch at PHASE until drum is phased.
Pull drum engaging lever forward to engage half nuts with lead screw.	When copy signals start, pull drum engaging lever forward to engage half nuts with lead screw and turn selector switch to RECORD DIRECT.	When copy signals start, move drum approx. $\frac{1}{4}$ " to left so that recorder lamp shines on extreme left hand edge of photographic paper on film. Pull drum engaging lever forward to engage half nuts with lead screw. Turn off safelight.

TABLE 25—Continued
SUMMARY OF OPERATION AND COORDINATION

Transmitting	Receiving	
When copy has been completely scanned, turn selector switch to STANDBY.	When copy has been completely scanned turn selector switch to STANDBY.	When copy has been completely scanned turn selector switch to STANDBY.
If no more copy is to be transmitted, also turn STANDBY-MON-TALK switch to STANDBY to stop motor.	If no more copy is to be recorded also turn STANDBY-MON-TALK switch to STANDBY to stop motor.	If no more copy is to be recorded also turn STANDBY-MON-TALK switch to stop motor.
Remove transmitted copy.	Remove recording paper. Make hectograph copies if recorded on Timefax A.	Remove photographic paper or film. Turn on safelight. Develop photographic paper or film.
When closing down, throw power switch to OFF.	When closing down throw power switch to OFF.	When closing down throw power switch to OFF.

The transmission of facsimile signals by amplitude modulation on the radio channel ordinarily results in a change in the loudness or levelness of the received signals with fading. If fading occurs, streaks or level changes will appear in the record picture. Therefore it is desirable to transmit a type of signal over radio

circuits whose amplitude when demodulated at the receiving station will be independent of changes in the volume or level of the radio signal. This action may be accomplished by a frequency shift of the signal in which different picture values are represented by different frequencies. Because the facsimile transceiver generates an amplitude-modulated signal in transmitting and the recorder is designed to operate on an amplitude-modulated signal, picture signal conversion equipment is necessary between the facsimile transmitter and the radio transmitter, and between the radio receiver and the facsimile recorder.

The components of two radio facsimile transmission systems (introduced in chapter 1) will be described in the following portion of this training course. The first system employs carrier frequency-shift (CFS) keying and includes two auxiliary units between the facsimile transmitter and the radio transmitter. These units include Keyer Adapter KY-44A/FX and Frequency-Shift Keyer KY-75/SRT.

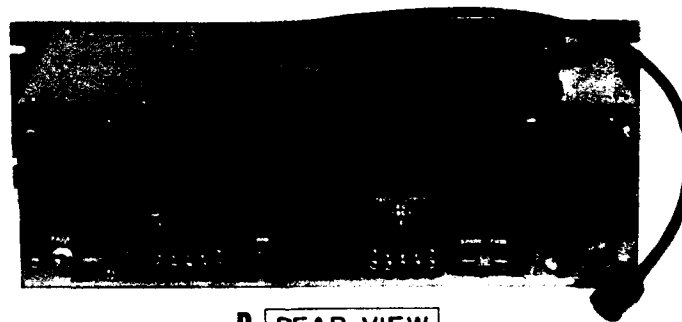
Keyer Adapter KY-44A/FX

Keyer Adapter KY-44A/FX (fig. 13-15) is used to provide d-c keying signals for frequency-shift exciter units in radio transmitters. The input is an amplitude-modulated, audio-frequency, facsimile signal that may be similar to the output from Facsimile Transceiver TT-41B/TXC-1B when transmitting. The input signal level has a range of -20 to +6 dbm. The output signal is a d-c voltage of varying amplitude. The unit can amplify and detect a-m input signals to produce output levels between 0 and 20 volts d-c. The carrier frequency range is from 1500 cycles to 7000 cycles. There are three essential circuits: the input, the signal amplifier, and the demodulator circuits.

The power ON-OFF switch turns the set completely on or off. A preliminary warmup period of a few minutes should be allowed before using the set.



A FRONT VIEW



B REAR VIEW

Figure 13-15.—Keyer Adapter KY-44A/FX.

The test-level control is used for alignment of the unit. This control should be in the OFF position for normal operation.

The input-filter IN-OUT switch should be in the IN position only when receiving frequencies in the range of 900 to 2500 cycles and when signals are noisy. The switch should be in the OUT position for all other input frequencies.

The output selector switch determines the type of output from the unit. In the AMPLIFIER position the unit becomes a linear amplifier. In the DETECTOR position the unit becomes a detector with the carrier still unfiltered from the detected envelope. The output level meter reads average d-c values. The KEYER position converts the unit into a detector with the carrier removed to provide d-c keying signals.

The input level control adjusts the level of the signal input to the amplifier to give the desired output level. The level of the incoming signal is read on the input level meter.

When the input switch is in the FACS position, an incoming facsimile signal is permitted to pass through the circuits of the unit to the output terminals. When the input switch is in the TTY position, a teletype signal is permitted to bypass the unit.

As a preliminary setting, turn the input level control to its extreme counterclockwise position. Turn the test oscillator level control counterclockwise to the OFF position. Throw the input filter switch to the OUT position. Turn the output selector switch to the desired type of function for the unit. Throw the input switch to the FACS position.

To operate the set, throw the power switch to the ON position. Allow a warmup period, as previously mentioned. Turn the input level control clockwise to obtain the desired output level as indicated on output meter.

Frequency-Shift Keyer KY-75/SRT

As a part of a radio facsimile terminal transmitting equipment the primary purpose of Frequency-Shift Keyer KY-75/SRT (fig. 13-16) is to replace the conventional exciter of a c-w transmitter with a source of r-f excitation that can be shifted a small amount upward and downward to produce r-f facsimile signals corresponding to the d-c facsimile signals connected to the input of the keyer.

The output of the keyer can be applied to any existing c-w transmitter capable of operating from a 2 to 20-volt excitation source, for passage through class C amplifier or multiplier stages. The keyer is used principally for comparatively long-distance communications in the high-frequency range. The frequency range of the keyer output signal is from 1 to 6.7 megacycles. Rated power output is 6 watts into a 75 ohm resistive load.

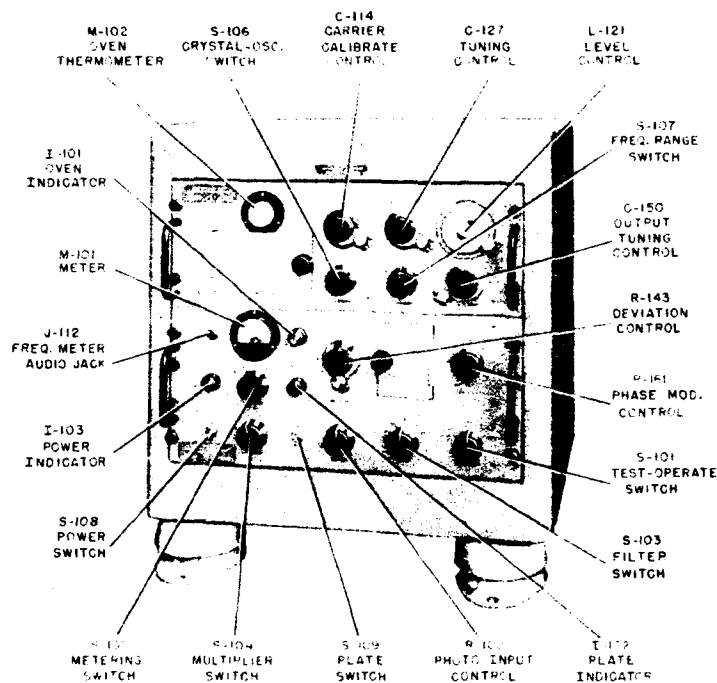
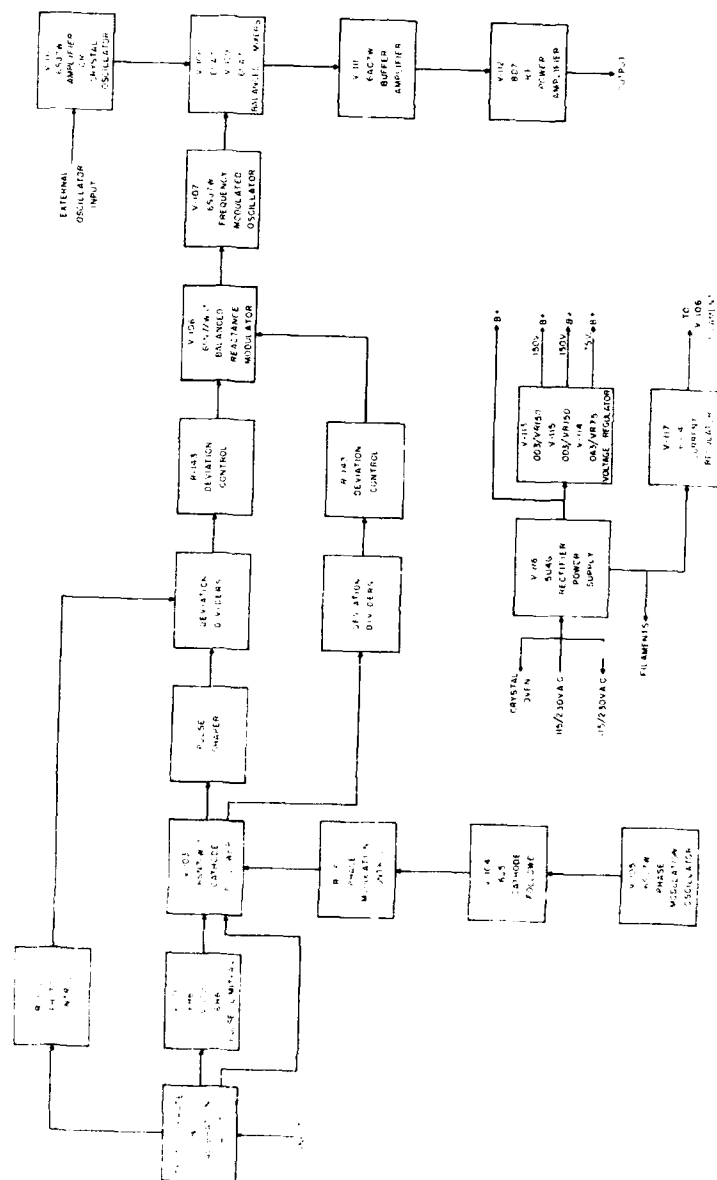


Figure 13-16.—Frequency-Shift Keyer KY-75/SRT (front panel component identification).

The frequency range is covered by a three-position bank switch with calibrated frequency ranges of 1 to 1.8 megacycles, 1.8 to 3.5 megacycles, and 3.5 to 6.7 megacycles. A four-position switch is provided for selection of one of three crystals; the fourth position is provided so that an external oscillator can be used. The frequency shift capabilities of the keyer for photo transmission provide a range of zero to 2000 cycles so that the transmitter frequency may be adjusted to any value from zero to 1000 cycles higher than the assigned frequency to 1000 cycles lower than the assigned frequency.

A block diagram of the frequency-shift keyer is illustrated in figure 13-17. There are three functional sub-



divisions. These include (1) the r-f circuits, (2) the modulator circuits, and (3) the power supply. The r-f circuits comprise the crystal oscillator, V-110; the low-frequency oscillator, V-107; the balanced reactance modulator, V-106, the buffer amplifier, V-111, the final power amplifier, V-112; and the output circuits. The modulation circuits comprise the test-operate and calibration circuit; the photo-input control, R-102; pulse limiters, V-101 and V-102; phase-modulation oscillator V-105; phase modulation control R-161; cathode followers V-104 and V-103; pulse shaper; deviation dividers; and deviation control R-143.

The power supply includes a full-wave rectifier stage, V-116; three voltage regulator stages V-113, V-114, and V-115; and an a-c filament current regulator stage, V-117.

The test-operate calibrate switch is a five-position switch used to select the circuit arrangement required for frequency-shift or photo operation and the arrangement required to perform the alignment adjustments for carrier, mark, and space signals.

The operating adjustments for photo transmission are as follows:

1. Turn the power switch on. The white-jewel power lamp will light. The amber-jewel oven lamp will also light, thereby indicating that the crystal oven heater is on. This lamp will go on and off with changes in the crystal oven temperature. When the lamp is illuminated, heat is being applied and the lamp will remain on until the oven temperature rises to 70° C, at which time it will go off. When the lamp is off, no heat is being applied to the oven. The lamp will remain off until the oven temperature falls slightly below 70° C, at which time it will come on again.

2. After the oven lamp has turned off (the oven is at the correct operating temperature), set the plate switch at ON. The red-jeweled plate lamp will light. The illumination given off by the foregoing three lamps may

be adjusted by rotation of the serrated rim of the lamp assembly.

Note that when the keyer is not in use, the a-c power supply should remain connected and the power switch turned on to maintain the correct operating temperature of the oven. The plate switch should be set at OFF.

3. Set the test operate switch at PHOTO. In this position the limiting (V-101 and V-102) and wave-shaping circuits are not used.

4. Set the crystal-oscillator switch at the position corresponding to the socket position of the crystal providing the desired channel frequency.

5. Set the frequency range switch to the desired output frequency of the keyer. This frequency is the sum of the crystal frequency and the 200-kc frequency from V-107.

6. Set the input filter switch at PHOTO.

7. Set the multiplier switch at the position corresponding to the multiplication factor employed in the transmitter. For example, if the multiplication factor is 8, the switch should be set at "X8."

8. Set the phase-modulation control at OFF (extreme counterclockwise position).

9. Set the metering switch at GRID.

10. Unlock the tuning control. Set the tuning control at a setting corresponding to the keyer output frequency and carefully adjust it about this setting for a maximum meter reading. A normal reading is about 1.5 ma (actual meter reading 0.5 ma). Lock the tuning control.

It will be noticed that three current peaks are observed on the panel meter. These peaks correspond to the resonant peaks for the lower sideband, the r-f carrier, and the upper sideband, respectively. The tuning control is normally set at the position that corresponds to the upper sideband resonant peak.

11. Set the metering switch at PLATE.

12. Release the lock on the output tuning control. Adjust the output tuning control for minimum plate current, as indicated on the meter.

13. Release the lock on the output level control. Set the output level control for the maximum grid drive required to drive the first amplifier or multiplier stage of the transmitter, as indicated by a maximum reading on the grid meter of the associated transmitter.

Care should be taken in this adjustment because if the tuning range is located near the lower markings on the tuning dial it is possible that a dip may also be obtained in the plate current near the higher markings of the dial to the second harmonic of the keyer frequency.

14. Repeat steps 12 and 13, adjusting the output tuning control and the output level control simultaneously. As the output coupling is increased and the plate tuning maintained at resonance, the output power should increase, as indicated by a rising-plate current reading and an increase in grid drive, as noted on the grid meter of the associated transmitter. Rated power output is obtained when a reading of 85 ma (actual reading of the meter 0.425 ma) is indicated on the panel meter. Lock the output tuning and output level controls in position.

15. Set the deviation control at the desired deviation. This control functions to vary the amount of frequency deviation. The control dial has a multiplication factor of 100 for FSK operation and 200 for photo operation.

During high-frequency transmission when the r-f carrier frequency is multiplied by some factor in the transmitter, the amount of deviation of frequency shift is multiplied simultaneously by the same factor. Therefore it becomes necessary to reduce the amount of deviation in the frequency-shift keyer by a factor equal to the frequency multiplication factor of the transmitter. This action is accomplished by a multiplier switch that provides a means of dividing the frequency deviation by a factor of 1, 2, 3, 4, 6, 8, 9, or 12, thereby keeping the deviation of the frequency of the amount of frequency

multiplication employed in the transmitter. For example, if the frequency of the transmitter output is to be deviated 425 cycles when the transmitter frequency multiplication is 1; when it is 2, the frequency shift at the keyer output will be $\frac{425}{2} = 212.5$ cycles; when the transmitter multiplication is 4, the frequency shift of the keyer output will be $\frac{425}{4} = 106.25$ cycles.

In normal operation the deviation control is adjusted to obtain the desired deviation, as read directly on the calibrated dial of the control. After the multiplication factor employed in the transmitter is determined the multiplier switch is set at a position corresponding to this factor. In this manner the amount of deviation is determined and held constant despite any ensuing multiplication in the transmitter.

16. Set the metering switch at photo.

17. Adjust the photo input control, *R102*, for 5 volts, as indicated on the panel meter. The 5 volts can be obtained by locking the photo scanner in a maximum signal position. If the photo scanner is not available, any battery source providing 5 volts or more can be used.

18. To shut the keyer off, set the plate switch at OFF and the power switch at OFF.

The common operating adjustments of the auxiliary components of the FS method of radio facsimile transmission have been described in the preceding section.

A second method of radio facsimile transmission (introduced in chapter 1) is called the audio frequency-shift (AFS) method. This method may be used with UHF radiophone transmitters with only one additional piece of equipment between the facsimile transmitter and the radio transmitter. A typical equipment for this application is Modulator, Radio MD-168/UX.

MODULATOR RADIO MD-168/UX

Modulator, Radio MD-169/UX (fig. 13-18) is designed to convert amplitude modulated facsimile signals from a

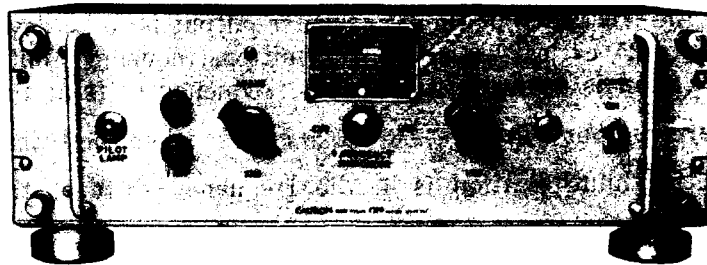


Figure 13-18.—Modulator, Radio MD-168/UX.

facsimile transmitter (for example, Facsimile Transceiver TT-41B/TXC-1B acting as a transmitter) to audio frequency-shift facsimile signals of 1500 to 2300 cycles suitable for modulating a radiophone transmitter.

A block diagram of the modulator is illustrated in figure 13-19. Basically, the unit consists of a preamplifier; a keyer (detector); a variable-frequency, phase-shift oscillator; a frequency indicator; and a power supply (not shown). The amplifier increases the re-

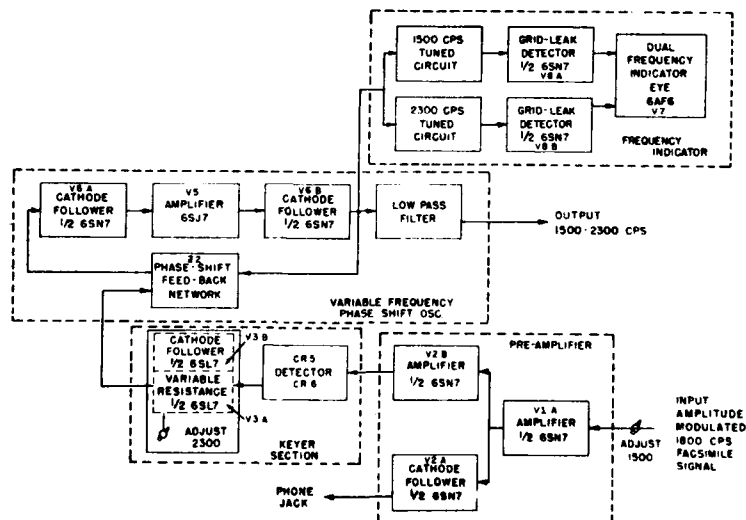


Figure 13-19.—Block diagram of Modulator, Radio MD-168/UX.

ceived facsimile signal to the proper level for operating the phase-shift oscillator and a pair of plug-in earphones. The input signal to the modulator may be monitored by using the phone jack. The frequency limits of the output signal may be monitored by means of a dual-type, tuning-eye indicator.

The input signal to the modulator has a frequency of 1800 cycles and an amplitude that varies in accordance with the light and dark segments of the picture being scanned at the facsimile transmitter.

The output signal from the modulator is an audio signal in which 1500 cycles represent the maximum signal input and 2300 cycles represent the minimum signal input to the modulator from the facsimile transmitter. Amplitudes between maximum and minimum signals are changed to corresponding frequencies between 1500 and 2300 cycles. The output from the modulator is connected to the audio modulator section of a radio a/m transmitter. Because the audio frequency-shift signal from the modulator is of constant amplitude the emitted radio frequency from the radio a-m transmitter is modulated at a constant percentage of modulation. The audio frequency-shift signal is sometimes referred to as sub-carrier-frequency modulation (SCFM).

The variable-frequency, phase-shift oscillator is caused to change its frequency in accordance with the variations in the magnitude of the d-c output voltage from the detector. The phase shift network is so connected that changes in the resistance of the variable resistance tube (caused by the varying magnitude of the d-c voltage applied to its grid) cause a change in the time constant of one branch of the network. This action introduces a change in phase shift through the network, which in turn changes the frequency of the oscillator.

The operating controls and indicators are located on the front panel (fig. 13-18). The pilot lamp operates when the set is turned on. Both sides of the powerline are fused.

The adjust 2300 control is a potentiometer used to adjust the output frequency of the unit to 2300 cycles when the amplitude of the input facsimile signal is a minimum.

The adjust 1500 control is a potentiometer used to adjust the output frequency of the unit to 1500 cycles when the amplitude of the input facsimile signal is a maximum.

The 2300-1500 frequency indicator is used to indicate the proper frequency limits of the output audio frequency-shift signal. The left half of the indicator closes when the output signal has a frequency of 2300 cycles and the right half closes when the output signal has a frequency of 1500 cycles.

The gain of the amplifier is such that when the adjust 1500 control is set at the proper position, the audible level at the earphones will be a comfortable level.

When the power ON-OFF switch is in the OFF position, power is removed from the entire unit.

When operating the unit, throw the power switch on and allow a 5-minute warmup period.

Turn the adjust 1500 control to the extreme clockwise position. When an incoming signal is being received, the 2300-1500 tuning eye indicator will flicker; monitoring with the headphones will indicate when maximum and minimum levels are being received.

When the input signal to the modulator is maximum, adjust the "adjust 1500" control until the 1500 side of the frequency indicator closes.

When the input signal to the modulator is minimum, adjust the "adjust 2300" control until the 2300 side of the frequency indicator closes.

Because the adjust 2300 and adjust 1500 controls are interdependent, repeat the preceding two adjustments.

Facsimile Receiving Equipment

To receive radio facsimile signals of either radio carrier frequency-shift transmission or audio frequency-shift transmission, conventional superheterodyne receivers (for example, Navy Model RBB or RRC) may

be used. With either system, the signal output of the radio receiver is an audio frequency-shift signal in which 1500 cycles represent the maximum signal and 2300 cycles represent the minimum signal output from the facsimile transmitter at the sending terminal.

In order to convert the audio frequency-shifted signal output of the radio receiver into an amplitude-modulated signal suitable for operation of a facsimile recorder, an additional unit must be interposed between the receiver and the recorder. This unit may be Frequency Shift Converter CV-172A/U. The facsimile recorder may be similar to Facsimile Recorder RD-92A/UX. The frequency-shift converter is described first, and the subject of radio facsimile receiving equipment is concluded with a discussion of the common operating adjustments of Facsimile Recorder RD-92A/UX.

FREQUENCY SHIFT RECEPTION.—Frequency-shift reception (fig. 13-20, A) requires that a local oscillator frequency be introduced ahead of the second detector of the radio receiver in order to produce an audio beat note with the incoming frequency-shift radio signal. In general, the use of the receiver BFO does not give satisfactory results because for most receivers the converter and beat frequency oscillators do not have adequate stability. Usually one or the other will drift enough during transmission to cause the received copy to be useless toward the end of the transmission.

Frequency-shift reception with radio receivers that have crystal controlled converters and beat frequency oscillators is satisfactory because of the increased stability of the oscillators. The proper crystal frequency must be selected so that the converter oscillator places the FS signals in the center of the i-f pass band. The BFO crystal frequency is selected so that the audio output from the radio receiver is 1500 cycles for one r-f signal limit and 2300 cycles for the other r-f signal limit. A different crystal must be used in the converter oscillator for each operating frequency, but the BFO crystal is

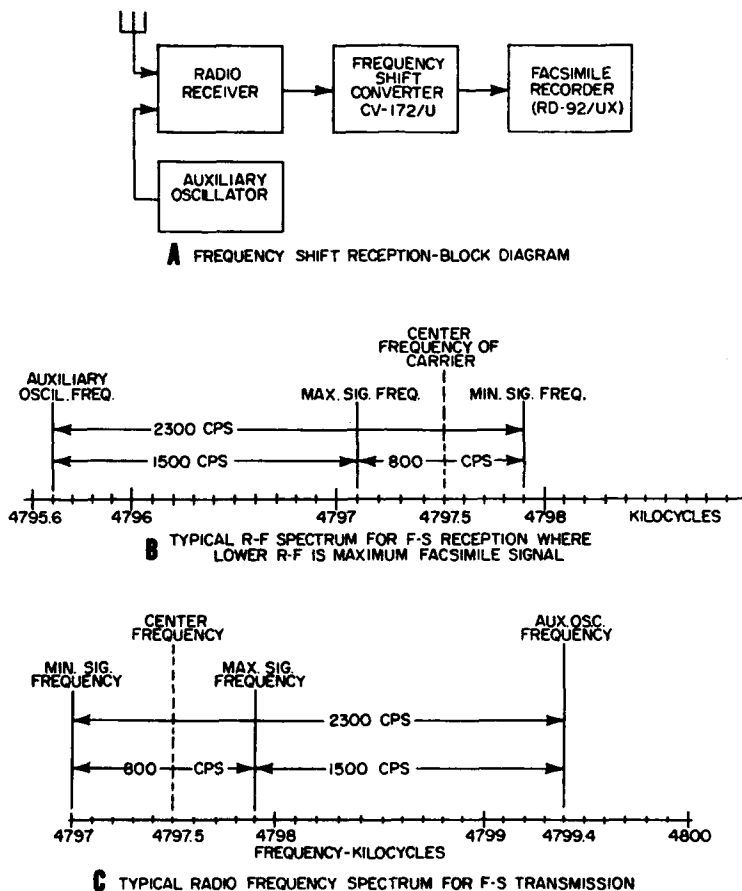


Figure 13-20.—Radio facsimile FS reception.

not changed. Usually a trimmer capacitor is provided in the converter oscillator circuit to permit a small frequency adjustment to be made.

For receivers that do not have crystal controlled oscillators, the use of a stable oscillator such as Navy Frequency Meter LM is recommended. The signal from the frequency meter auxiliary oscillator is fed to the radio receiver by placing a wire from the oscillator antenna

binding post near the antenna terminal of the radio receiver. Positive or negative copy may be received, depending upon which side of the carrier frequency-shift signal the oscillator is set.

If the transmitting station uses the lower radio frequency limit for transmitting the maximum signal from the facsimile transmitter (fig. 13-20, B), the auxiliary oscillator should be set 1500 cycles below this frequency to reproduce the maximum signal at the output of the frequency-shift converter.

If the transmitting station uses the higher radio frequency limit for transmitting the maximum signal from the facsimile transmitter (fig. 13-20, C), the auxiliary oscillator should be set 1500 cycles above this frequency to reproduce the maximum signal at the output of the frequency-shift converter.

If the radio receiver is equipped with a "S" meter, tune for maximum indication on the meter when the auxiliary oscillator is off and frequency-shift signals are being received.

The received copy defect may be blamed on poor radio transmission conditions; whereas, the defect may frequently be corrected by simply tuning the receiver properly. For optimum results care should be taken to tune the receiver so that the FS signals are centered in the pass band of the i-f amplifier in the radio receiver.

The same tuning procedures should be used for tuning a high stability radio receiver, as with a receiver employing an auxiliary oscillator. Turn off the BFO before making the tuning adjustments. After the proper tuning adjustments are made, as previously described, turn on the BFO and vary its control for the proper audio frequency output from the radio receiver. Do not change the receiver tuning to vary the audio frequency.

Frequency-Shift Converter CV-172A/U

Frequency-Shift Converter CV-172A/U (fig. 13-21) is used to convert 1500 to 2300-cycle facsimile signals re-

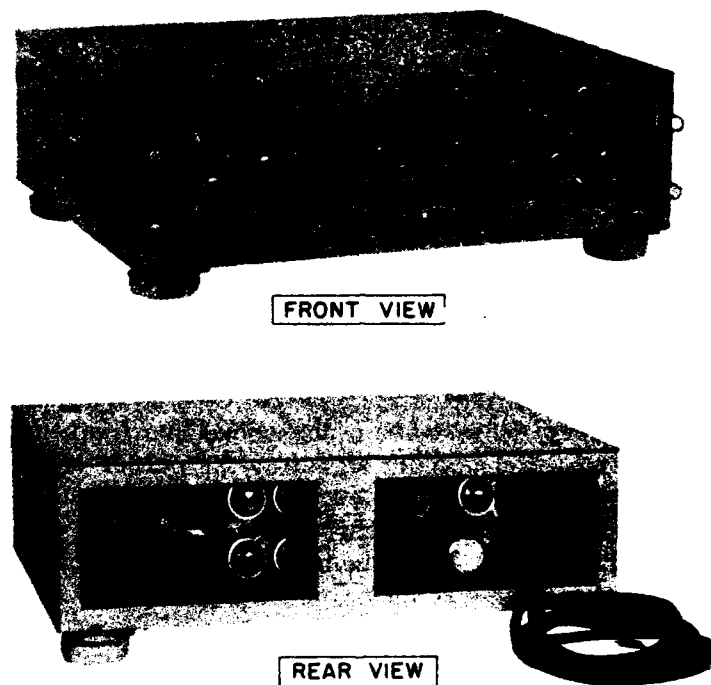


Figure 13-21.—Frequency-Shift Converter CV-172A/U.

ceived from a radio circuit to a-m signals suitable for operating a facsimile recorder (for example, Facsimile Recorder RD-92A/UX). The unit contains provision for audible monitoring of the incoming signal and for visual checking of the frequency limits.

Another method that may provide for even more reliable tuning is to turn off the auxiliary oscillator and tune slowly through the frequency-shift signals. As the signals are approached from one side a thumping sound will be heard. Continuing to rotate the tuning dial slowly in the same direction will cause this sound to disappear almost completely and then to reappear again before it disappears on the other side of the signal. The

proper tuning position corresponds to the quiet zone between the two thumping sounds.

Satisfactory frequency-shift reception may be obtained with high stability radio receivers without the need for an auxiliary oscillator provided the receivers are properly tuned. If the converter and BFO have been sufficiently stabilized, the BFO can be used as the heterodyne oscillator to provide the audio frequency output.

The ET 3 who is familiar with tuning v-w radio signals has observed that a-f or tone output from the radio receiver changes as either the main tuning dial or the BFO control is moved. Thus it is possible to have the right sense of signals (no inversion) and still not be tuned properly for optimum results. Improper tuning results in an inferior signal-to-noise ratio and may cause broadening of lines or multiple images somewhat similar to those caused by multipath transmission of the radio signals.

The facsimile signal obtained from the radio receiver is fed through an amplifier and filter to a limiter and then through a frequency discriminator (fig. 13-22). The output of the amplifier is controlled by an input level control potentiometer to adjust the signal level to the limiter. A loudspeaker with a separate volume control connects to the output of the line amplifier. This output also feeds two tuned circuits resonated at 1500 and 2300

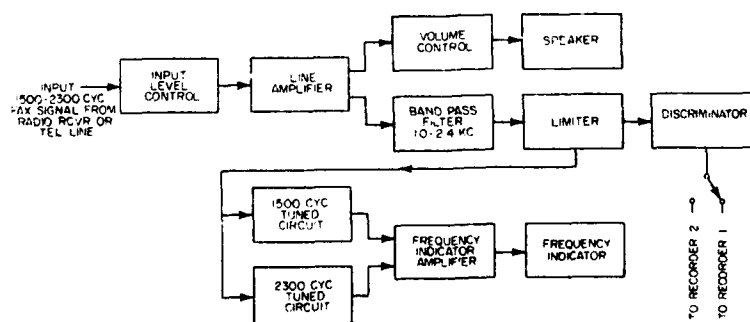


Figure 13-22.—Block diagram of Frequency-Shift Converter CV-172A/U.

cycles respectively to operate a tuning eye frequency indicator.

The input signal from the radio receiver is an audio frequency-shift signal in which 1500 cycles represent black and 2300 cycles represent white for the RD-92A/UX recorder. The discriminator is a low-pass filter having a cutoff frequency of 1500 cycles. The output from the filter at 2300 cycles can be adjusted to be from 10 to 20 db lower than the output at 1500 cycles. Thus, the input signal to the converter is changed from an a-f signal of substantially constant amplitude to an output signal of varying amplitude in which the maximum amplitude (corresponding to 1500 cycles) is 10 to 100 times the minimum amplitude (corresponding to 2300 cycles).

To operate the frequency-shift converter, turn the input level control clockwise (fig. 13-21). This action applies power to the unit. Allow a few minutes warmup time.

Adjust the input level and volume controls fully clockwise until a signal is received.

When a signal is received, adjust the input level control until the speaker does not distort. (Distortion exists when there are overtones.) This adjustment provides sufficient level to operate the limiter.

Adjust the volume control for a convenient speaker level.

When a 1500-cycle signal is being received, the "1500" tuning eye will close and the output will be the maximum signal level for the facsimile recorder. Also, when a 2300-cycle signal is being received, the "2300" tuning eye will close. The difference in output levels will depend upon the trimmer control (not shown), which provides a variable-resistance bypass around the discriminator circuit.

When the radio receiving equipment is properly adjusted, the tuning eye indicators will show that 1500- and 2300-cycle signals are being fed to the input of the frequency-shift converter. When a copy that has mostly

Facsimile Recorder RD-92A/UX

RECORD BUTTON

PAPER LOAD CONTROL

POWER CABLE

POWER FUSE INDICATOR

BY FUSE

SELECTOR SWITCH

PULSE SWITCH

CIRCUIT BREAKER

POWER ON SWITCH

RECORD FUSE INDICATOR

PAPER LOAD CONTROL

RECORD BUTTON

745

dividual fuses and tube heaters instantly indicate a blown fuse or burned out tube heater filament.

Facsimile Recorder RD-92A/UX performs its functions of recording pictures, drawings, or messages by rotating a drum at a constant speed, while feeding a stylus needle along the drum, one scanning line for each revolution until the complete drum has been covered. This function is performed by means of three motors and suitable gears and mechanical linkages contained within the recorder subassembly. The power, signal, and phasing currents for proper operation of the recording mechanism are obtained from the outputs of the electronic subassemblies.

The amplifier-detector unit (fig. 13-24) receives the input facsimile signal. This signal, consisting of phasing pulses and facsimile intelligence between the frequency limits of 900 and 2700 cycles, is amplified by a class A amplifier and demodulated through the action of a full-wave rectifier and low-pass filter to form a varying d-c facsimile signal.

The varying d-c facsimile signal output of the amplifier-detector unit is coupled to the amplifier modulator

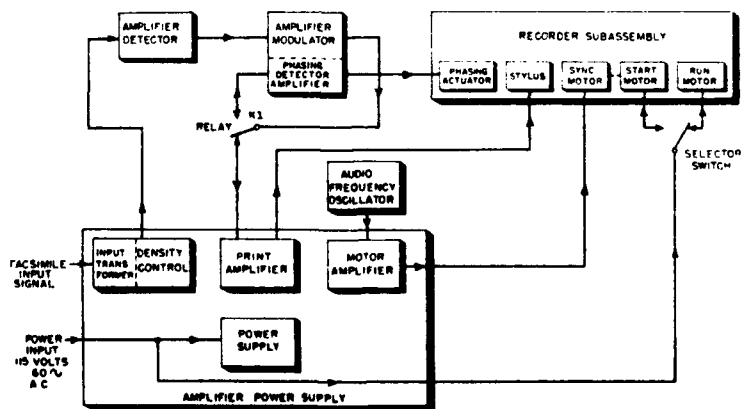


Figure 13-24.—Simplified block diagram of Facsimile Recorder RD-92A/UX.

subassembly where it combines with a signal from a 15-kc oscillator in a modulator stage. The 15-kc output of the modulator varies with the amplitude of the d-c facsimile signal. The resulting modulated signal connects through the normally closed contact of relay K1 to the print driver and amplifier in the amplifier-power supply assembly.

The signal from the amplifier modulator unit is amplified by the print driver and amplifier to sufficient intensity, so that, when connected to the stylus needle in the recording mechanism assembly, it will record on the recording paper points representing varying shades of dark elements of the transmitted copy.

For phasing pulses, relay K1 is operated to transfer the signal from the amplifier modulator to the phasing detector and amplifier, located in the amplifier-modulator subassembly. The phasing pulses, which are transmitted at the beginning of each copy, are amplified to operate the phasing actuator in the recorder subassembly.

The phasing actuator, on receiving the phasing pulses, releases the stop bar on the synchronous-drive mechanism in the proper position to frame the recorder drum with the drum of the facsimile transmitter.

The a-f oscillator generates an 1800-cycle signal, which is amplified by the buffer amplifier (not shown) and motor amplifier in the amplifier-power supply assembly and then coupled to the recording mechanism assembly to operate the synchronous motor. The 1800-cycle signal also connects to the test signal position on the density control (fig. 13-24), where it is available for connection to the input of the signal amplifier for testing the various circuits with the circuit test switch.

The synchronous motor, rotating at a speed of 1800 rpm, is geared down to the required recorder drum speed of 60 rpm. A start motor, mechanically coupled to the synchronous motor, serves to bring the synchronous motor up to a speed higher than synchronous speed after which it coasts down to the synchronous speed when the

synchronous motor runs on 1800-cycle power. The synchronous motor regulates the speed of the recorder drum. The run motor drives the drum through reduction gears.

When the record button (fig. 13-23) is depressed and the selector switch is in the RUN position, the stylus needle records on recording paper fastened to the drum. The stylus is held in a carriage assembly that is moved across the drum to the right when engaged with a lead-screw shaft geared to the drum. When the carriage assembly reaches the right end of the recorder paper, it operates an automatic release mechanism, which disengages the carriage mechanism from the lead screw and lifts the stylus from the paper. A return spring, located in the left side gear box, then pulls the carriage back to the left side of the drum so that it will be ready for the next copy.

OPERATING ADJUSTMENTS.—To operate Facsimile Recorder RD-92A/UX (fig. 13-23) proceed as follows:

1. Turn the selector switch to the STANDBY position. Note that the pilot light lights up, indicating that power is being applied to the recorder. Wait about 1 minute for the tubes to warm up. The recorder may be left at STANDBY while waiting for a transmission so that the set is ready for immediate operation.
2. Turn the selector switch to the START position. Wait about 5 seconds for the start motor to bring the synchronous motor above synchronous speed.
3. Turn the selector switch to the SYNC position. Wait until the synchronous motor coasts down the locks in synchronous speed. This is distinguished by a distinctive high-pitch tone.
4. If the motor does not lock in but falls below the synchronous speed, switch back to the START position and repeat steps 2 and 3. If the motor does not come down to synchronous speed, turn to STANDBY and allow the motor to stop. Omit step 2 and switch directly to the SYNC position.

5. Turn the selector switch to the RUN position. It is necessary for the drum to rotate into the proper position for loading the paper.

To load paper on the drum, proceed as follows:

1. With the selector switch in the RUN position, push the paper load control to the left and hold there until the drum stops rotating. Then lift the projecting lever.

2. Open the hinged cover over the drum.

3. When the paper load lever is lifted, the paper clamp fingers on the drum will open. The paper load lever remains in the UP position. Drop a fresh sheet of recording paper into the space between the paper guide and the drum so that it rests up against the clamp fingers.

4. Flip down the paper load lever. This action causes the fingers to close quickly and grab the paper. This action also releases the drum, which quickly picks up speed to the synchronous speed of 60 rpm.

5. Close the hinged cover.

The adjust density control affects the gain of the signal amplifier so that the proper d-c voltage is obtained to key the print oscillator signal. In correct setting of the density control may result in faulty recording. Proceed as follows:

1. Set the density control when facsimile signals are being received. When steady signals of maximum signal level are received, preferably on phasing signal, start near zero and advance the control to the lowest point that gives maximum reading on the meter on the front panel. This reading is normally about 100.

2. In some types of copy it is desirable to advance the dial setting of the density control slightly beyond the point that gives a maximum meter reading. Try this procedure if the copy is too light.

3. Leave the density control at the setting that gives the best recording.

The phasing operation is performed with the recorder drum stationary. Phasing pulses may be identified by

a downward dip of the meter pointer occurring once a second. To phase the recorder proceed as follows:

1. Switch to the SYNC position and wait for the drum to stop.
2. Turn the phase button to LOCAL.
3. When phasing pulses are received, depress the phase button and hold depressed for five pulses. While phasing, two clinks per second are usually heard; one when the phasing actuator trips, and another when the stop bar passes the drum drive coupler.
4. Turn the selector switch to the RUN position. The drum will rotate in the properly phased position.
5. Press record button when the copy starts. This is indicated by a change in meter pulses. Usually the meter reading drops down to about zero and flicks upward instead of downward. The stylus now feeds across the drum to print the copy, and releases automatically at the end of travel.

If it is desired to take less than a complete copy, release the stylus by (1) turning the selector switch from the RUN to SYNC position, or (2) operating the paper load lever. The stylus returns automatically to the left-hand end of the drum when it is released.

A summary of operation of the Facsimile Recorder RD-92A/UX is printed on the front panel of the unit as follows:

1. Switch to STANDBY. Wait 1 minute for tube warm up.
2. When ready to receive copy, switch to START.
3. After 5 seconds, switch to SYNC.
4. When motor coasts into SYNC (constant speed) switch to RUN.
5. Push and hold paper load lever to the left to stop drum and then lift to open paper clamp.
6. Load paper and push paper load lever down.
7. Switch to SYNC and wait for drum to stop.
8. On phasing signal (indicated by meter pulsing downward once per drum rev) adjust density control for highest meter reading.

9. Turn phase button to LOCAL; press and hold for 5 meter pulses.

10. Switch to RUN.

11. When copy starts (indicated by change in meter pulses), press record button.

12. At termination of copy, operate paper load lever as in steps 5 and 6 to remove copy, and then reload.

QUIZ

1. What is the usual extent of the frequency shift in frequency-shift keying?
2. How does phase modulation combat the effect of selective fading?
3. What effect does space signals have on the frequency of the output of the radio receiver with BFO in figure 13-1?
4. How is the bias of the tone modulator in figure 13-1 affected by a mark signal from the keyer?
5. What is the minimum spacing of receiving antennas used in space diversity systems?
6. What is the function of the comparator in a diversity reception system?
7. What portion of Frequency-shift Converter CV-89A/URA-8A maintains an optimum axis, or bias for keying nonsymmetrical signals?
8. What is the purpose of the cable filter assembly in the frequency-shift converter?
9. If in figure 13-5 the second converter delivers a 3-volt positive pulse with respect to ground, and, simultaneously, the first converter delivers a 2-volt positive pulse with respect to ground, which converter delivers the output voltage?
10. When frequency-shift signals are being received, the BFO of the receiver should be adjusted to produce a beat note of what average center frequency for (a) narrow-shift operation and (b) wide-shift operation?
11. In the CV-89A/URA-8A Frequency-Shift Converter, what control selects the fast- or slow-keying speed filters?
12. What are the four necessary initial adjustments when the converter-comparator group is put into operation for the first time?
13. In Tone Converter AN/SGC-1A, what frequency represents (a) mark and (b) space?

14. What prevents the tone converter from shifting directly from transmit to receive and vice versa?
15. In what position must the control switch of Tone Converter AN/SGC-1A be placed so that when a station has completed sending its message it is ready for reception of any return message after a 3-second time delay?
16. In a tone-modulated system, why is the first character transmitted usually lost?
17. What is the purpose of the meter and rotary selector switch in Teletype Panel TT-23/SG?
18. Why must the patch plug NEVER be pulled from the machine (set) jack before first removing the other end of the cord plug from the loop jack?
19. What is the purpose of the Transmitter-Teletype Control Unit C-1004A/SG?
20. What is the purpose of the phasing pulses used with Facsimile Transceiver TT-41B/TXC-1B?
21. What type of paper is used in recording when the selector switch is in (a) the record photo position and (b) the record direct position?
22. Under what circumstances is half-speed (30 rpm) operation employed?
23. When the bridge of Facsimile Transceiver TT-41B/TXC-1B is balanced on minimum light, what will be the relative amplitude of the output signal on (a) black and (b) white?
24. In facsimile, why is it desirable to employ a frequency-shifted signal in which different picture values are represented by different frequencies?
25. What is the purpose of Keyer Adapter KY-44A/FX used between FAX equipment and a radio transmitter?
26. What is the purpose of Frequency-Shift Keyer KY-75/SRT when used with facsimile equipment?
27. If the frequency of the transmitter output is to be deviated 425 cycles when the transmitter frequency multiplication is 1, what should the frequency shift at the keyer output be if the transmitter frequency multiplication is 4?
28. What is the function of Modulator MD-168/UX?
29. What types of radio receivers are used to receive facsimile signals of the carrier frequency shift or audio frequency shift variety?

30. What unit of equipment is needed to convert the audio frequency-shifted signal output of the radio receiver into an amplitude-modulated signal suitable for operating a facsimile recorder?
31. Why is it generally necessary to use an auxiliary oscillator with the radio receiver in frequency-shift reception (see fig. 13-20, A)?
32. For optimum results in the reception of FS signals, where must the FS signals be located with respect to the pass band of the receiver i-f amplifier?
33. What is the function of Frequency-Shift Converter CV-172A/U?
34. What is the purpose of the start motor in the Facsimile Recorder RD-92A/UX?

CHAPTER

14

COMMON OPERATING ADJUSTMENTS: RADAR AND SONAR EQUIPMENT

INTRODUCTION

Necessity for Familiarity with External Adjustments

The ET 3 must be familiar with the external adjustments on radar and sonar sets. The four basic types of radars aboard ship are (1) surface search, (2) air search, (3) low-angle search and height finding, and (4) fire control. The ET 3 works on the first three types; the fire control technician takes care of the fourth.

Every radar has a host of controls and switches used in operating the set. Unfortunately for the ET 3 the controls on different makes of radars are placed in different positions on the operating panels. He must learn what and where the controls are, and know what they will do. Radars also must be operated under changing conditions. The ET 3 must analyze a given situation and be able to adjust the controls so as to obtain the maximum information from the set, regardless of operating conditions. Controls that are constantly being used while operating the gear include the gain control, the range crank, manual and automatic antenna controls, and anti-jamming controls for operation of identification (IFF) equipment.

The ET 3 should know what range scale to use for a given situation and when the scale should be shifted. He should know when to set the gain control at high, low,

or medium; how fast the antenna should rotate; and whether the antenna should be stopped to check a target, and how long. He should know how to read the range scale, whether to use the range step and associated dials when provided, and when to use estimated ranges.

If the radar set is equipped with two or more types of cathode-ray indicators, he should know which should be used, and under what conditions one is preferable to another.

The importance of radar cannot be overemphasized. It is used to detect aircraft, and to protect ships and shore installations from surprise attack. It is also used to direct and fire guns, to support land operations (shore bombardment etc), and as a navigational aid. In all of these applications the radar set must be in good working condition. Here, as with communications equipment, the ET 3 must be prepared to assist the radar operator (when the occasion arises) in making the necessary adjustments for optimum performance.

The principal means of detecting submerged submarines is by sonar, and if the equipment is not working properly, the sub may get away or get in a fatal blow. Thus, it is important to have the sonar gear in good shape at all times. Here, as with communications equipment and radar equipment, the ET 3 must, when occasion demands, assist the sonar operator in making the necessary adjustment for optimum performance.

The sonar operating station is called sonar control. In this station are several units of sonar equipment, which the ET 3 must be prepared to operate. First there is the remote control console popularly known as the stack. The stack is made up of several units, one of which is the receiver. As described in another chapter of this training course, this unit is similar to a superheterodyne radio receiver. The ET 3 must be able to tune the receiver and use its other controls intelligently if he is to determine its performance capability. In order to maintain sonar gear in good working order, the ET 3 must

know how to make many other adjustments by using external controls.

Some of the common operating adjustments are described in a general way as introductory material; later they are spelled out in detail for a typical equipment. The arrangement is similar to the plan followed for radio transmitters, radio receivers, radars, and teletype equipments.

Quantities Commonly Controlled

Quantities commonly controlled in a radar equipment may be grouped under three headings. The first group includes those controls that are adjusted and set before starting to operate the radar. This group includes (1) the on-off switch, including voltage and current regulating controls; (2) the calibration controls, and (3) the tuning controls. The second group of controls includes the voltage controls for the cathode-ray oscilloscope. They are (1) the focus control, (2) the intensity control, (3) the vertical and horizontal centering controls, (4) the position control for the PPI, (5) the astigmatism control, and (6) the range and bearing markers for the PPI. The third group of controls are those that are constantly being used while operating the radar. This group includes (1) the gain control, (2) the manual and automatic antenna controls, (3) the range crank, and (4) the antijamming controls for operation of identification equipment.

Quantities commonly controlled in sonar equipments vary with the type of equipment and number of components. For one type of scanning sonar, the controls may be grouped as (1) operator's controls at the control-indicator console and (2) controls for remote indication on the azimuth-range indicator.

The first group includes (1) the main power on-off switch, (2) the stabilization switch, (3) the power level control, (4) the video sum-difference switch, (5) the local audio volume control, (6) the manual ODN (own ship's

Doppler nullifier) control, (7) the stabilization switch, (8) the keying selector switch, (9) the cursor hold button, (10) the pulse length switch, (11) the training control, (12) the master gain control, (13) the cursor range control, and (14) the hand key.

Sonar controls on the azimuth range indicator for remote indications include the (1) video signal level control, (2) cathode-ray tube intensity control, (3) cathode-ray tube focus control, and (4) loudspeaker volume control.

RADAR SET AN/SPS-4

Radar Set AN/SPS-4 has been selected as a typical shipboard surface search radar to present the common operating adjustments. As in the previous examples of specific equipments, a general description is given of the major components followed by a detailed discussion of some of the common operating controls and procedures.

General Description

The AN/SPS-4 radar is a medium power (180- to 285-kw peak power output) surface search radar having a tunable magnetron, which may be operated at any frequency between 5450 and 5825 megacycles. The antenna permits the operator to observe targets on and near the surface of the water. Input power may be 440, 220, or 115 volts, 60-cycles, single phase.

Targets are presented on the screens of a Range Indicator, CRP-55AGT (A-scope presentation) and a Navy Model VJ-1 Radar Repeater (which is supplied) as well as on other repeaters, which may be connected. Both 1-speed and 36-speed OSC (own ship's course) information is required.

The AN/SPS-4 equipment is similar to the $X_{\text{b},1}$ -band (6275-6575 mc) Navy Model SG-6b Radar Equipment, except for changes in the antenna, the transmitter, and

the receiver to permit operation on the lower frequencies and at a higher power output.

A pictorial diagram of the AN/SPS-4 Radar Set is illustrated in figure 14-1. The various components are drawn to scale and connected by flow lines to indicate the basic operation of the system.

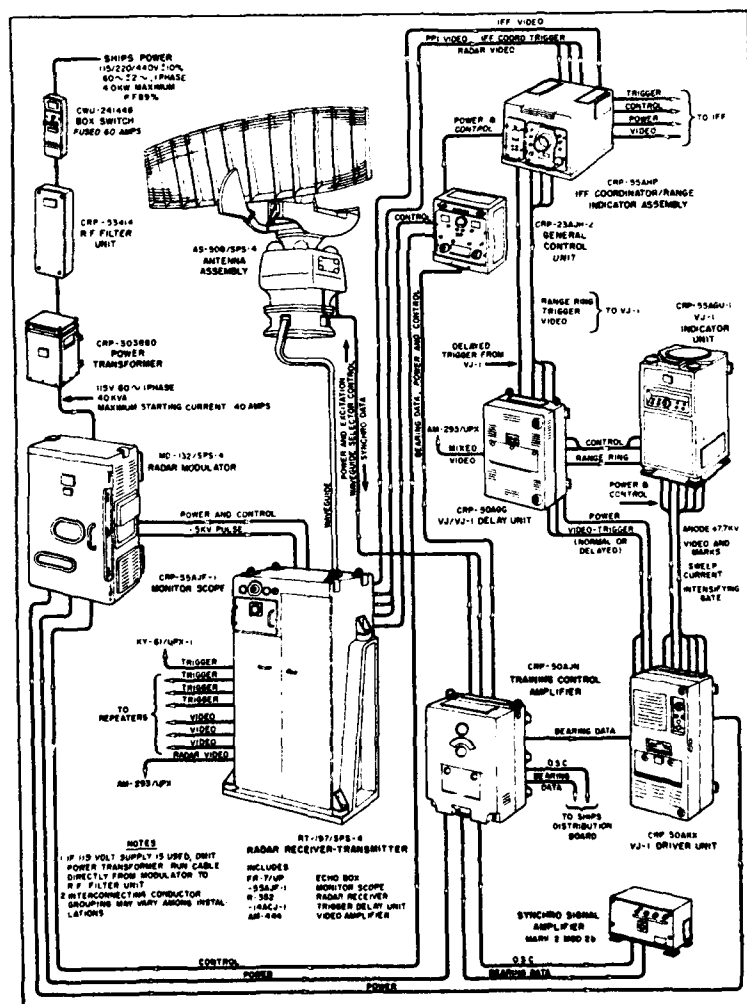


Figure 14-1.—Radar Set AN/SPS-4 with Model VJ-1 Repeater showing relationship of units.

When the power input is 440 or 220 volts, the power transformer is used, as shown. When the input is 115 volts, the transformer is not required, and the input cable is extended directly from the r-f filter unit to the modulator.

Pulses are formed by one of two pulse lines contained in the modulator, either of which may be selected by a motor-driven switch. The selected line is charged at high voltage through a choke and blocking diode and is discharged by a thyatron to produce 5-kv negative pulses across the primary of a pulse transformer. The thyatron is triggered from the tugger chassis by a rep-rate oscillator whose repetition rate is variable (by means of a motor-driven variable capacitor) between 625 and 650 pulses per second.

The pulse transformer (located in the receiver transmitter) steps the modulator pulses up to 22 kv. They are applied to the cathode of the magnetron to produce r-f power which, in turn, is fed to the antenna through the waveguide system. Low-voltage samples of these pulses are taken from a sync winding of the pulse transformer for use in timing other circuits of the system. These triggers are delayed (by a delay line) to compensate for the waveguide transit time and other system delays of the particular installation. They are then fed to the IFF coordinator and thence to the range indicator and the VJ-1 indicator unit as well as to any repeaters in use.

The r-f energy is conducted through type RG-49/U waveguide to the antenna assembly where it passes to the surface search reflector. The pattern of the surface search reflector is approximately 2° in the horizontal plane and 15° in the vertical plane.

As the antenna rotates (5 or 15 rpm under automatic drive in a clockwise direction only, or slowly in either direction in servo or manual control), the beam sweeps over the surrounding area.

Energy reflected from targets is picked up by the antenna and returns through the waveguide to a duplexing

cavity (TR tube) and ATR tubes in the radar receiver transmitter. This cavity acts as an electronic switch, isolating the receiver when the transmitter is on and connecting the receiver to the waveguide when the transmitter is off. The echo is amplified and detected in the receiver (a superheterodyne) and is fed to the video amplifier as a rectified video signal. Here it is further amplified in two channels (range scope and PPI). The PPI channel has five output positions for the VJ-1 indicator unit and for any repeaters that may be used.

Triggers (sync pulses) are derived from the pulse transformer and delayed, as previously mentioned. They are then fed to the IFF coordinator and subsequently distributed to the IFF equipment (if used), to the range scope, and through four separate channels to the various repeaters in use.

Because the trigger starts the range scope and PPI presentations at the same time that the main pulse leaves the antenna, the distance along the range scope and repeater PPI sweep traces at which an echo signal appears is directly proportional to the antenna-to-target distance. Fixed range marks are provided for estimating range. A variable range mark is also provided for accurate range determination. In the range indicator this feature takes the form of a step in the trace that may be aligned with the target so that the accurate range may be read directly from the position of the adjusting mechanism by a mechanical counter. In the PPI indicator this mark forms a ring, which also may be aligned with a target and the range similarly may be read from a counter.

With the antenna in automatic rotation, the direction of the sweep trace when a target appears on the VJ-1 indicator (or any repeaters in use) indicates the target bearing. With the antenna in manual control, bearing is shown directly on an illuminated scale at the operating position. Either true or relative bearing indication may be selected in either case by means of a switch.

The antenna reflector assembly is rotated by a d-c motor. In automatic operation, at 5 or 15 rpm, the motor is continuously supplied with d-c power. In manual operation the motor is supplied power by a servo amplifier under the control of a type 3CT synchro to which a handcrank is attached. A type 6G synchro, geared to the antenna reflector assembly to revolve at the same speed, furnishes antenna bearing data directly to the radar distribution switchboard and to the VJ-1 indicator when the system is in relative bearing operation. In true bearing operation, however, the information is first fed to the Synchro Signal Amplifier Mark 2 Mod 2B, where it is modified by OSC information to provide correct true-bearing data.

Although both 1-speed and 36-speed OSC information is required to operate the Synchro Signal Amplifier Mark 2 Mod 2B, the rest of the AN/SPS-4 system utilizes 1-speed information only.

Through cam-operated microswitches located in the antenna, the sweep of the VJ-1 and any PPI repeaters in use may, if desired, be momentarily intensified at the instant the antenna is pointing dead ahead. This action permits a direct reading of relative bearing when the system is in true-bearing operation. In relative-bearing operation, of course, the flash will always occur at 0° .

The effective range of the equipment varies primarily with the location, size, and character of the target; the antenna height; the pulse width; and the existing weather conditions. The 1.3-microsecond pulse will give considerably longer ranges than the 0.37-microsecond pulse, but with somewhat poorer definition. Under average conditions the equipment is capable of locating fair-size targets slightly beyond the optical horizon, as seen from the antenna.

An echo box, directly calibrated in frequency, is located in the receiver-transmitter cabinet. This arrangement permits the magnetron to be accurately tuned to any frequency in the 5450- to 5852-mc band and the receiver tuning to be adjusted accordingly. In addition, the echo

box provides a means for checking over-all system performance in the absence of targets. It can be tuned either manually or electrically by a drive motor. The use of the echo box is described in chapter 8 of this training course.

Antenna Assembly

The Antenna Assembly AS-508/SPS-4 is composed of two major parts: the pedestal and the reflector assembly. The pedestal contains a d-c motor, gearing, 6G synchro, and various other components, such as a safety switch, SHM (ships head marker) microswitches, terminal strips, and heaters.

The reflector assembly supports a slatted parabolic surface search reflector and waveguide nozzle.

Box Switch

The box switch contains a double-pole knife switch and two 60-ampere line fuses. It is bulkhead mounted.

R-F Filter

The R-F Filter Unit CRP-53414 contains two identical low-pass pi-network filters (one for each power lead), which provide a minimum attenuation of 60 db to all frequencies between 150 kc and 150 mc.

Power Transformer

The Power Transformer CRP-303880 is a 5-kva, 60-cycle, single-phase unit, which can be connected to reduce a 440-volt or 220-volt input to 115 volts. With a 115-volt primary supply, this transformer is not used.

Radar Modulator

The Radar Modulator MD-132/SPS-4 distributes fused 115-volt power to the rest of the AN/SPS-4 system and furnishes the high-voltage negative pulses for keying the transmitter. In addition to fuses, relays, and an autotransformer, the unit contains a trigger chassis, a thyatron modulator (keyer) and low- and high-voltage

power supplies. Also included are a remotely controlled, high-voltage, pulse-width switch and a motor-driven capacitor to vary the pulse repetition rate. A blower furnishes ventilation. Two time meters record the tube-filament hours and the radiation "on" time respectively.

Radar Receiver Transmitter

The enclosure of the Radar Transmitter RT-197/SPS-4 houses six major assemblies. These are the transmitter, receiver, video amplifier, trigger delay unit, monitor scope, and echo box. In addition, the cabinet contains a meter, which reads relative magnetron current, and a waveguide assembly, which passes through the top of the cabinet for connection to the antenna waveguide run. The case contains two ventilating blowers, as well as fuses for the blowers, the transmitter, and the receiver.

The transmitter includes a high-voltage pulse transformer with a trigger winding, a magnetron filament transformer, an undercurrent relay, a clipping diode, and a magnetron oscillator feeding into the waveguide assembly.

The radar receiver is a superheterodyne using a low-noise, balanced-mixer circuit, which employs two type 1N23B crystals. It is equipped with special antijam (AJ) circuits, automatic frequency control (AFC), sensitivity time control (STC), fast time constant (FTC), and instantaneous automatic volume control (IAVC) circuits. It also includes a crystal checking circuit and a meter on its front panel.

The AJ circuits include a high video pass (HVP) filter and the FTC circuit. Enemy jamming often hides the signals from the operator in a sea of grass and clutter. The effect of some types of jamming is to overload the r-f or video stages and hence block the receiver. The HVP and FTC filters tend to pass the high frequencies (leading edges of the echoes) and to reduce the lower frequencies. As the filters pass only the sharp spikes corresponding to the leading edge of an echo, they pre-

vent saturation of later video stages by jamming signals, closely spaced targets or large blocks of returns.

The AFC circuit automatically holds the receiver local oscillator 30 mc higher than the transmitter magnetron frequency, thereby keeping the receiver signal at the i-f input centered on 30 mc.

The STC circuit reduces the gain of the second and fourth i-f stages for several microseconds during and immediately following the transmitter pulse in order to prevent large returns (from nearby targets from saturating the receiver).

IAVC circuits reduce the gain of the receiver whenever strong signals are received. These circuits are useful in reducing interference both from clouds and from jamming (under certain conditions of continuous wave jamming). When used, they allow the first portion of a solid block of signals to pass unattenuated through the receiver, but gradually attenuate the rest of the block. Thus small signals occurring during block signals can be seen; whereas, without IAVC the i-f channel would be driven to saturation, and small signals would be masked by large, long-duration signals occurring at the same time. Many of the circuits are analyzed in detail in the training course ET 2, volume 2, NavPers 10191.

Video Amplifier AM-444/SPS-4 contains one channel for the range scope (A-presentation) and another for the VJ-1 repeater (PPI presentation) and any other indicator that may be used. The repeater channel is equipped with five output positions. Calibrating range marks or IFF signals may be introduced into the repeater channel. An unsynchronized 450-kc multivibrator, triggered by antenna microswitches, provides a ship's heading marker for the repeaters.

The trigger delay unit contains four tapped trigger delay lines in series, various dividing resistor networks, and switches for terminating unused outputs. The unit permits delaying sufficiently the sync pulses used for all

indicators and for IFF operation to compensate for video delays inherent in the system.

Echo Box FR-7/UP is a directly calibrated manually tuned unit equipped with a variable attenuator together with a 1N23B crystal and an output meter. The input may be connected to a probe in a slotted section of the waveguide for SWR (standing wave ratio) measurements. Normally, it is connected to a directional coupler for the following uses: magnetron frequency reading and tuning, over-all system performance checks, power output indications, spectrum analysis, TR-tube recovery time checks, and general troubleshooting (see chapter 8 of this training course).

Monitor Scope CRP-55AJF-1, employing a 3-inch cathode-ray tube, combines the functions of a standard oscilloscope and of a synchroscope. It includes an internal trigger generator, video amplifier, and power supplies. Its location in the receiver-transmitter cabinet makes it convenient for tuning the equipment. It may also be removed and used as a portable test instrument for checking waveshapes and for general troubleshooting.

The waveguide assembly mounted in the receiver-transmitter cabinet includes two directional couplers (one feeding the echo box and the other the receiver AFC input); a duplexing cavity (TR tube); two ATR tubes; and three flange couplings, which connect to the magnetron output, the receiver input, and (at the top of the cabinet) to the external waveguide r-f fittings.

IFF Coordinator-Range Indicator

IFF Coordinator-Range Indicator Assembly CRP-55AHP (fig. 14-2) houses the IFF coordinator and the range indicator in a shock-mounted cabinet. The cabinet also contains a trigger-switching relay, a ventilating blower, and terminal strips for cable interconnections and tie points.

IFF Coordinator CRP-23AGG receives radar sync pulses from the receiver-transmitter, and uses a flip-flop

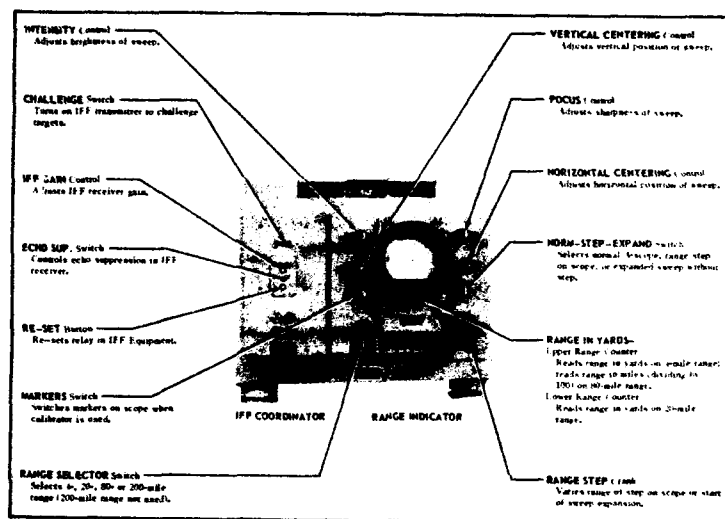


Figure 14-2.—IFF coordinator-range indicator assembly.

multivibrator circuit in conjunction with a regenerative variable-delay amplifier to furnish triggers for an IFF transmitter and a range scope trigger to the range indicator. It also provides PPI sweep triggers to the VJ-1 and other repeaters that may be used.

Panel controls provide for IFF challenge, echo suppression, IFF relay reset, and IFF receiver gain adjustment. Chassis controls permit variation in IFF trigger compensatory delay and adjustment of the multivibrator circuit bias voltage for proper synchronization.

Range indicator CRP-65AGJ employs a 5-inch range scope and includes sweep and video circuits, power supplies, and a phantatron delay circuit for accurate ranging. In addition to conventional scope controls, a panel switch selects manual A-scope presentation, a sweep with a step that appears at the position corresponding to the setting of a range counter, and a sweep that is expanded from the point of the range counter setting.

When IFF is in use, two alternately triggered sweeps appear. Radar targets are presented on the upper sweep

and corresponding IFF response signals on the lower. The normal range-step, or expanded sweep may be started by a delayed trigger from the VJ-1 repeater to obtain an expanded view of an area remote from the antenna.

General Control Unit

General Control Unit CRP-23AJH-2 is illustrated in figure 14-3. It contains all the normal controls for operating and controlling the radar system, except those for the range indicator scope, IFF equipment, and the VJ-1 indicator. At this unit the system can be turned on, antenna rotation controlled, plus width and receiver bandwidth determined, repetition rate varied, echo box operated, receiver gain varied, and antijam circuits selected. Also, a trigger switch is provided for delaying the range scope presentation.

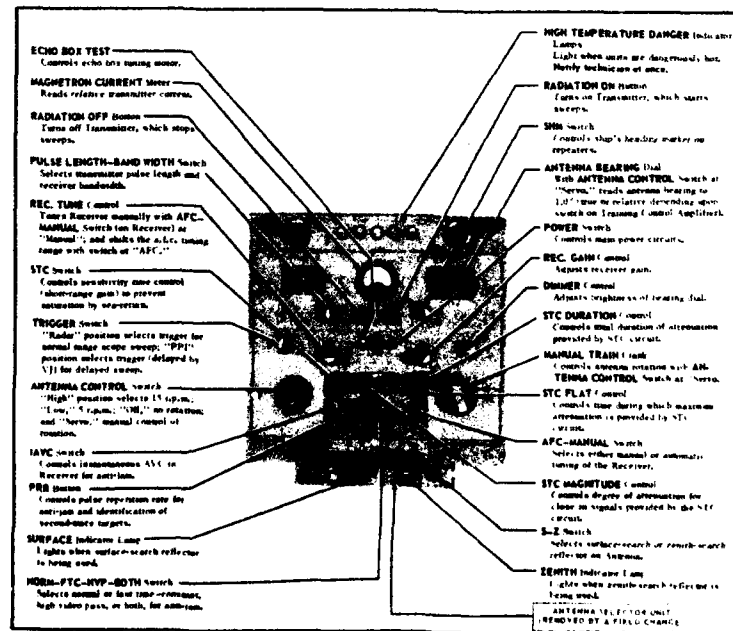


Figure 14-3.—General control unit.

The general control unit includes a meter indicating relative magnetron current, a dimmer for the manual-train antenna bearing dial, a manual-train crank, and five high-temperature warning lamps for other units of the system. Two 115-volt, 60-cycle, power outlets are provided for convenience in servicing.

Training Control Amplifier

Training Control Amplifier CRP-50AJN (fig. 14-4, A) serves as a synchro distribution center for the equipment and supplies d-c power to the antenna drive motor. The unit interconnects the antenna assembly, general control unit, Synchro Signal Amplifier Mark 2 Mod 2B, modulator, VJ-1 repeater, and the ship's radar distribution board (see chapter 9 of this training course).

The unit includes a true-relative switch on the panel, fuses for the synchro-excitation bus output and the convenience outlet, and a servo amplifier. A time meter on the panel records tube hours so that tubes may be replaced regularly, as experience dictates. Also included are synchro power factor correction capacitors.

The servo amplifier is used conventionally for manual control of antenna rotation, or is switched by means of three relays to operate as a rectifier circuit for automatic rotation at 5 or 15 rpm. A 60-second time-delay relay protects the tubes by allowing them to heat up before plate voltage is applied. Four screwdriver chassis controls are provided for maintenance adjustments, but no operating controls are required.

Synchro Signal Amplifier

Synchro Signal Amplifier Mark 2 Mod 2B (fig. 14-4, B) modifies antenna bearing data by adding OSC information when the training control amplifier is switched to true so that all synchro data to the VJ-1 indicator and any other repeaters are true bearing. The synchro signal amplifier is energized from the 115-volt, 60-cycle

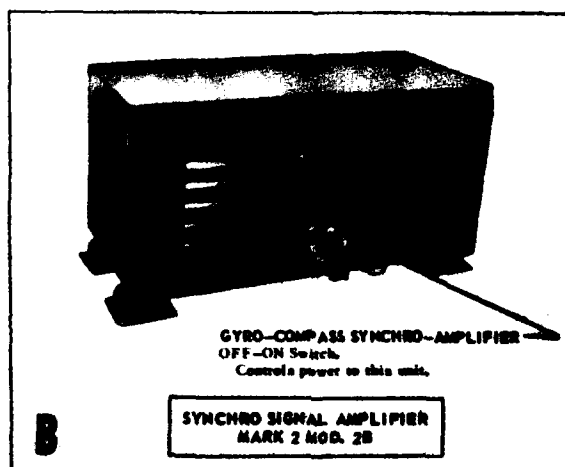
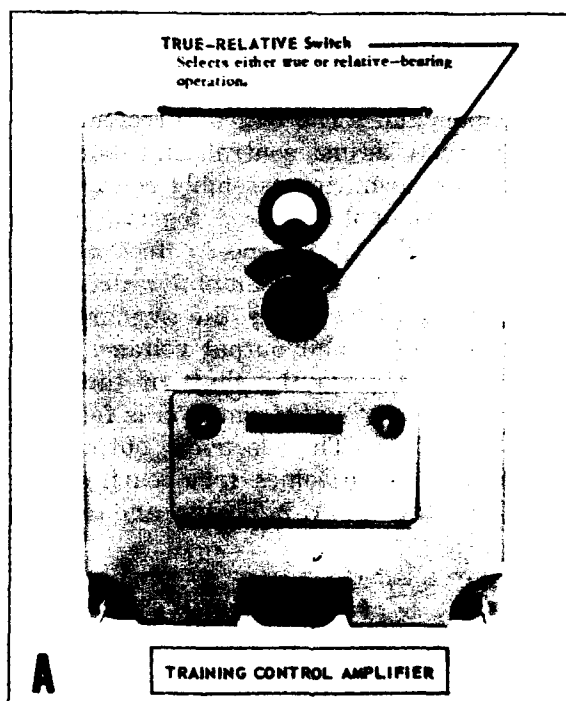


Figure 14-4.—Training control amplifier and synchro signal amplifier.

synchro bus. The unit consists of two main parts: the amplifier and the mechanical assembly.

The amplifier consists of six electron tubes and accessory components. There are three adjustments: a gain control, relay adjust control, and damping control.

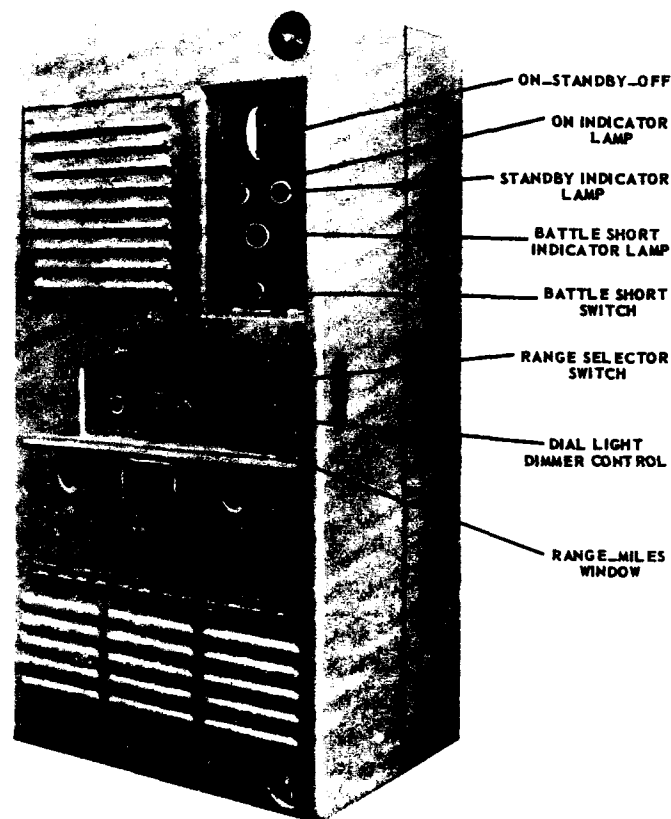
The synchro-transmitter assembly contains three synchros and a servo motor geared together. Two of the synchros (1 speed and 36 speed) feed the servo amplifier. The output of the amplifier drives the servo motor, which, in turn, drives the synchro rotors in a feedback loop to zero their output voltages. This action introduces OSC data via the shaft of the DG synchro. Antenna relative bearing information is fed to the stator of the DG synchro. The electrical output of the DG rotor windings then becomes true-bearing information that is fed to the VJ-1 indicator and any other repeaters.

Radar Repeater

Radar Repeater Navy Model VJ-1 (fig. 14-5) comprises three units: Driver Unit CRP-50AKX (fig. 14-5, A), Delay Unit CRP-55AGG (fig. 14-5, B), and Indicator Unit CRP-55AGU-1 (fig. 14-5, C). It provides two types of PPI operation: undelayed (normal) and delayed.

In undelayed operation, radar trigger pulses are amplified and used in a normal manner to generate fixed range marks, PPI sweep voltages, and PPI unblanking gates. Also, a movable range ring is obtained by a variable delayed trigger generated in the delay unit and controlled at the indicator by a range crank with an associated range counter from which accurate ranges may be read.

In delayed operation, the variable delayed trigger is used to initiate the PPI sweep to permit an expanded presentation of targets as far away as 200 miles. In this case, the movable range ring is obtained from the phantastron ranging circuits of the range indicator. The

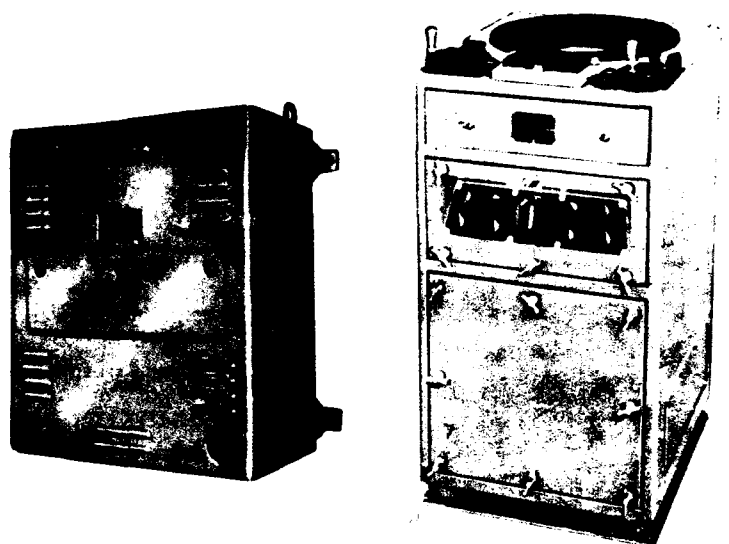


A DRIVER UNIT CRP-50AKX (VJ-1)

Figure 14-5.—Radar Repeater VJ-1.

phantastron is a special type of multivibrator that produces a square wave of variable width. This output is superimposed on the range scope to obtain accurate range information.

Provision is made for transmitting range and bearing information to remote stations and for alerting such stations by an alarm.



B DELAY UNIT CRP-50AGG (VJ-1)

C INDICATOR UNIT CRP-55AGU-1 (VJ-1)

Figure 14-5.—Continued.

Driver Unit CRP-50AKX (fig. 14-5, A) contains power supply and electronic equipment needed for repeater operation, and for the PPI tube itself. It also contains a portion of the video amplifier.

The function of the driver unit is to (1) amplify the video and trigger inputs; (2) generate sweep voltages, PPI unblanking gates, and range-mark signals; (3) furnish servo amplification; and (4) supply plate and filament voltages for the indicator unit and its associated circuits in the driver unit.

Delay Unit CRP-50AGG (fig. 14-5, B) receives triggers from the IFF coordinator-range indicator and delivers both undelayed and delayed triggers (the delay of which is controlled by the range crank at the VJ-1 indicator) to the other repeaters as needed. The delay unit also supplies and accepts special triggers required by the use of the VJ-1 as an integral part of the AN/

SPS-4 radar system. The delayed trigger is used as a movable range-ring signal for target ranging. When desired, this signal may be used instead as a delayed trigger for delayed sweep operation of the PPI. The delay unit also contains a repetition-rate converter (count-down circuit), which ensures that no trigger from the master radar will be applied to any other circuit in the VJ-1 unit until it has completed its cycle of operation. Circuit operation is controlled at the indicator unit.

Indicator Unit CRP-55AGU-1 (VJ-1 repeater) receives electrical information from the other units and reproduces on its 12-inch PPI screen the target information originating at the AN/SPS-4 radar (see fig. 14-5, C). All VJ-1 operating controls except the on-standby-off switch are located on the VJ-1 repeater console. These include the usual PPI repeater controls as well as controls for system selection and delayed sweep operation. Transmission synchros are included for transmitting range and bearing information of selected targets to remote stations.

Operation

Once the radar has been turned on (as will be described) the ET 3 can perform all the normal operating functions at the VJ-1 indicator the IFF coordinator range indicator cabinet, and the general control unit.

To start the equipment, make sure that the box switch (fig. 14-1) is turned on. Then turn the general control unit controls (fig. 14-3) as follows:

1. Antenna control switch to OFF.
2. Trigger switch to RADAR.
3. Norm-FTC-HVP both switch to NORM.
4. Pulse length-band width switch to WSP (wide band, short pulse).
5. STC switch to OFF.
6. IAVC switch to OFF.
7. SHM switch to OFF.

8. Receiver gain control to fully counterclockwise.
9. AFC manual switch to AFC.
10. Power switch to ON.

Now turn the following IFF coordinator-range indicator controls to the specified positions:

1. Challenge switch to OFF.
2. Norm-step-expand switch to NORM.
3. Intensity control fully counterclockwise.

At the training control amplifier (fig. 14-4, A), turn the true-relative switch to TRUE.

After waiting for at least 5 minutes for the time-delay relay to operate, press the "radiation on" button at the general control unit (fig. 14-3).

Turn the following driver unit controls (fig. 14-5, A) to the specified positions:

1. On-standby-off switch to ON.
2. Battle short switch to OFF.
3. Range selector switch to REMOTE.

Turn the following VJ-1 indicator unit controls (fig. 14-5, C) to the specified positions:

1. Delayed-undelayed switch to UNDELAYED.
2. Video gain control fully counterclockwise.
3. Intensity control fully counterclockwise.

Now observe the magnetron current meter on the front panel of the general control unit (fig. 14-3). If the meter reads outside the green zone, shut down the equipment to prevent possible damage.

To stop the equipment, first determine that the intensity control at the IFF coordinator-range indicator cabinet is turned fully counterclockwise.

At the general control unit (1) press the "radiation off" button, (2) turn the antenna control switch to OFF, (3) throw the power switch to OFF, and (4) at the VJ-1 driver unit, turn the on-standby-off switch to OFF.

Operating Adjustments

With the equipment turned on as previously described, advance the receiver gain control at the general control unit (fig. 14-3) until the "grass" appearing on the range

scope reaches nearly $\frac{1}{4}$ the amplitude of the signals. Signals should also appear on the range scope, depending on the setting of the range selector switch and the targets available.

To rotate the antenna automatically, set the antenna control switch on the general control unit either to low for a speed of 5 rpm, or to high for a speed of 15 rpm. With automatic rotation, there is no indication for antenna bearing except on the VJ-1 indicator and on any other repeaters.

To rotate the antenna manually, set the antenna control switch to SERVO and turn the manual train crank as desired. With manual rotation only, the antenna bearing may be read from the antenna bearing dial. The bearing will be either true or relative, depending on the setting of the true-relative switch on the training control amplifier (fig. 14-4).

Assuming that the equipment controls have been adjusted at the VJ-1 repeater, as previously described in starting, make the following adjustments:

1. Set the range-miles switch to the desired range (2, 4, 10, 20, or 80 miles). The 200-mile range is not used on the AN/SPS-4 radar.
2. Turn the intensity control clockwise until a trace appears on the PPI.
3. Adjust the focus control for the sharpest trace.
4. Turn the intensity control counterclockwise until the trace is barely visible.
5. Turn the range marks switch to ON.
6. Advance the video gain control for the best contrast of targets on the PPI.

For complete operating instructions of the VJ-1 repeater, see *Technical Manual*, NavShips 900,829(A).

With the radar equipment started as previously described, make the following adjustments at the IFF coordinator-range indicator (fig. 14-2).

1. Set the range selector switch on the range indicator to the desired range (4, 20, or 80 miles).

2. Turn the intensity control clockwise until a trace appears on the range scope. If none is visible, adjust the vertical- and horizontal-centering controls until a trace appears.

3. Adjust the focus control for the sharpest trace.

4. Turn the intensity control until the trace is barely visible.

In manual tuning, at the general control unit (fig. 14-3) adjust the receiver tune control until targets appear on the range scope. If targets appear intermittently with the antenna stationary, adjust the receiver tune control for stable operation. Set the control in the middle of the stable range.

If targets do not appear, snap the AFC manual switch on the receiver (fig. 14-6) to MANUAL. Then adjust the receiver tune control on the general control unit (fig. 14-3) for maximum signals. Check the setting of this control frequently while using manual tuning because the AFC circuit is disconnected, and drifting may occur.

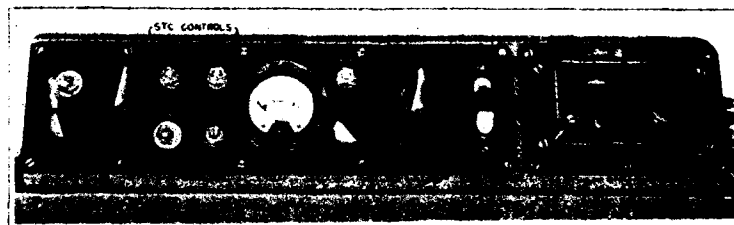


Figure 14-6.—Radar receiver control panel.

In the absence of targets or at the discretion of the ET 3, the receiver can be tuned with the aid of the echo box. The echo box is tuned remotely by the echo box test button on the general control unit. This switch controls the echo box motor, which tunes the echo box over the entire frequency covered by this equipment.

To tune the receiver by using the echo box, press the echo box test button on the general control unit. Throw

the AFC manual switch to MANUAL. While observing the PPI screen, and with the receiver gain control set at or near maximum, adjust the receiver tune control for maximum artificial echo signal.

With the antenna stopped (antenna control switch at OFF), the signal will appear as a solid line extending from the center of the screen out to about 2 miles. With the antenna rotating in a clockwise direction (antenna control switch at LOW), the signal will appear as two elliptical shaped lobes extending from the center of the screen out to about 2 miles. This picture is the result of tuning the echo box back and forth through resonance.

Release the echo box test button and return the AFC manual switch to AFC.

Approximate range is estimated by the use of the number on the range-scope window. The trigger switch on the general control unit (fig. 14-3) must be on RADAR and the delayed-undelayed switch on the VJ-1 indicator (fig. 14-5) must be on UNDELAYED.

More accurate range is read from the illuminated range counters on the range indicator, after the range step is set on the left-hand edge of the target on the range scope. For maximum precision the pulse-bandwidth switch on the general control unit is set on WSP to obtain wide bandwidth and short pulse length. For maximum ranges the switch should be set on NLP or WLP to obtain long pulse length and either narrow or wide bandwidth.

SONAR SET AN/SQS-10

The subject of common operating adjustments of electronic equipment is concluded with a discussion of Sonar Set AN/SQS-10. Until recently this equipment was a representative scanning sonar, the basic principles of which were previously described in chapter 10 of this training course. Although it is being superseded by

other sonars, it contains many typical operating adjustments, and, for this reason forms the basis for this discussion. The ET 3 is urged to carefully read again the analysis of the block diagram of a scanning sonar (fig. 10-34) in order to better understand the common operating adjustments and how they affect the operation of the various components of the sonar set.

Sonar Set AN/SQS-10 (fig. 14-7) is a scanning sonar designed primarily for use aboard naval vessels. It is, in effect, a combination of two types of ultrasonic echo-ranging and listening equipments operating simultaneously; one provides a continuous display of acoustic reception in all directions, and the other provides an audio response from any desired single direction.

Detection by echo ranging is accomplished by transmitting a pulse of sound energy in all directions and then scanning in azimuth for all echoes, which are made to appear as bright spots on a cathode-ray tube screen at the correct bearing and at a distance from the screen center that is proportional to the range.

More detailed investigation of a particular signal is obtained by training the audio system to the bearing indicated, the resulting audio output assisting in identification as well as providing the signal for accurate range determination.

The reception of signals from noise sources, which is possible without transmission, produces a continuous radial pattern on the cathode-ray tube screen at the proper bearing, and the audio character of the noise may be ascertained by training the audio system along that line of bearing.

Transmission

A block diagram of Sonar Set AN/SQS-10 is shown in figure 14-8. The pulse type sonar transmitter operates at a fixed frequency of 20 kilocycles. The control-indicator produces a keying pulse of the proper length and correlated with the various display functions that

Each portion of the transducer consists essentially of cylindrically arranged elements for converting this electrical energy to sound energy and delivering it to the surrounding water. The difference between the two portions of the transducer lies in the direction in which they transmit the sound energy; the search portion transmitting in a horizontal direction, and the MCC portion transmitting downward at an angle of approximately 30 degrees.

In both portions of the transducer the elements are arranged to form 48 vertical staves, which are connected in parallel during transmission. This arrangement provides a sound wave having equal amplitude at all bearings and traveling outward from the source at a velocity of approximately 4800 feet per second.

Reception

When the sound wave strikes an object with adequate reflective characteristics, a small part of the total energy is returned to the source as a sound wave with essentially a plane front whose direction indicates the bearing of the echo-producing object. The time interval between the sound transmission and the arrival of any echo is a measure of the range to that object. The transducer converts the received acoustic energy to electrical energy, and the 48 staves of the transducer produce voltages whose magnitude and phase relationships are determined by the intensity and direction of the plane sound wave. In the same manner, ultrasonic components of acoustic energy from a noise source will be converted into electrical signals.

Each of the 48 signals from the transducer is fed by way of the transfer switch to the AF-RF amplifier and amplified by one of 48 preamplifier circuits. From the preamplifiers, the signals are delivered to two scanning switches in parallel (located in the receiver scanning switch assembly), each scanning switch combining the voltages in a manner to produce a sharp beam pattern in a direction corresponding to the instantaneous posi-

tion of each scanning switch (see figure 10-29, chapter 10, Introduction to Sonar).

The audio scanning switch produces a single-beam pattern with its center directed at the switch.

The video scanning switch produces a split-beam pattern with two lobes, one on each side of the instantaneous switch position.

The video switch rotates continuously, thereby sampling all echo or noise signals and producing short signal pulses as its beam pattern sweeps through the acoustic signal bearing. These pulses are then fed into the receiver video channels.

The audio scanning switch is positioned to any desired bearing by a servo system in response to the training control order from the operator at the control indicator, delivering all voltages from echo and noise sources along that bearing. These signals are then fed to the audio channel of the receiver.

Presentation

The receiver portion of the receiver scanning switch assembly performs a dual function: the amplification and conversion of video signals to a form and value suitable for proper video presentation on the cathode-ray screen in the control indicator, and the amplification and conversion of audio signals to a level and frequency for audio presentation.

The video portion of the receiver utilizes a left and right channel for left and right lobe signals from the video scanning switch. The output signals from these two channels are combined and rectified to produce a brightening voltage for the visual presentation. Two modes of signal combination are available. In the sum mode the signals from the left and right channels are combined in a manner that results in a broad effective beam pattern. In the difference mode the signals are combined in a manner that results in an extremely sharp pattern.

The audio channel of the receiver employs a simple superheterodyne circuit, utilizing a beat frequency oscillator to provide an audible signal. The frequency of the BFO may be varied by a manually controlled Doppler nullifier circuit to eliminate the effect of own ship's speed on echo tone.

Integration of the video channel with other effects to be displayed on the cathode-ray screens is performed in the control indicator, which contains all of the necessary operational controls. The correlation of the transmission pulse, beam deflections of the cathode-ray tube, and screen brightening by the received signals is performed automatically by circuits in this unit.

The manner in which the video information is presented is dependent upon the operating mode of the equipment. The three modes of operation available are (1) echo ranging at either of four range scales (500, 1000, 3000, and 6000 yd), (2) listening without transmitting and producing echoes, and (3) echo ranging with a range-gated sweep.

In echo ranging the automatic sequence of events in the visual presentation begins with the collapse of sweep potentials of the cathode-ray tube indicator prior to the beginning of a new sweep cycle. During this interval there is produced on the tube screen a straight line, or cursor, originating at the center and having an angular position corresponding to the bearing along which the acoustic beam pattern of the audio scanning switch is trained. The length of this line can be adjusted by the operator and the approximate range, corresponding to its length, read from a calibrated dial.

Following the presentation of the cursor line, the cathode-ray screen is blanked for a brief interval, after which transmission occurs. The transmission pulse may be 6, 30, or 80 milliseconds in duration, as selected by the operator. At the instant of transmission, the electron beam begins with a slowly expanding spiral sweep that is synchronized with the rotation of the video

scanning switch. Thus, the angle through which the electron beam has spiraled during the interval between the start of transmission and any instant in the ensuing cycle corresponds to the center of the acoustical beam pattern produced by the switch.

Expansion of the sweep is linear with respect to time. Therefore the reception of an echo signal will cause brightening of the cathode-ray screen at a spot that corresponds to the range and bearing of the echo producing object. Because the system is continually alert in all directions, the persistence of the screen results in a map of all echo-producing objects. Independently of transmission and echoes, the signals from continuous noise sources will cause brightening of the screen each time the sweep passes the related bearing and will thus produce an illuminated narrow sector whose center is the bearing of the noise source. Both video and audio presentations are duplicated at remote points by one or two azimuth-range indicators in conjunction with loudspeakers.

In the listen mode of operation, the scope picture consists of a continuously oscillating spiral sweep without blanking. This sweep occupies approximately the outer third of the screen. A continuously displayed twin-dotted cursor is superimposed on this sweep, the center of the cursor corresponding to the bearing along which the audio scanning switch is trained. Signals from an underwater noise source appear as a narrow radial line on the screen. By training the cursor so that it straddles this line, the bearing of the noise source can be determined.

When the cursor is centered on a noise source, the exact bearing of the source is indicated by an illuminated dial located just below the cathode-ray tube. Rotation of the training control knob rotates the cursor in the same direction, one revolution of the knob causing 20 degrees rotation of the cursor. If a large change in bearing is required, the knob may be depressed and turned to the right or to the left through a small angle that will cause the cursor to slew right or left at a speed of approxi-

mately 8 rpm. In echo ranging, the cursor is a solid radial line, which appears momentarily before each transmission and which is trainable by the same means as the listening dotted cursor. In echo ranging, the operator may interrupt the video display and produce the solid radial cursor by depressing the cursor hold button and then, by means of the training control knob, position the cursor precisely with respect to an echo "blip."

In the range gated sweep position, the transmission pulse is initiated by the OKA-1 recorder. The bearing cursor remains on the screen during the receiving interval. The deflection circuits are held at sweep start for the interval between flyback and a point 300 yd in advance of the recorder range cursor setting (300 yd in advance of the expected echo). At this point the indicator sweep commences and is allowed to expand at approximately a 400-yard range rate to the off-tube limit (rim of the screen) where it awaits the next flyback. The sweep rate is such that the echo should appear at approximately half the maximum sweep radius.

During all the remaining time of the keying cycle the radial bearing cursor is visible, thus providing the operator with more time to adjust the cursor to precisely the indicated target bearing. The rapid sweep also provides a radial expansion of the echo picture, thereby providing useful information concerning the target.

Angular positions indicated by the cathode-ray tube and the associated bearing dial are normally in terms of true bearing. A single-dotted cursor, indicating the position of the stern on the ship appears in both listening and echo-ranging operations, thus providing the operator with an indication of ships heading, and hence relative bearing. If the gyro system fails, the indication is automatically transferred to relative bearing, and a pilot lamp labeled GYRO OFF is illuminated, thus indicating that true bearing indication does not exist.

Operation

A single master gain control simplifies the operation of the equipment and this, along with various semi-permanent adjustments, provides the operator with control of the visual and aural channels. The choice of producing and maintaining the electronic cursor by interrupting the video display is also under the control of the operator. He may take this action to facilitate training the cursor and the audio switch to some desired bearing when large changes are necessary.

The operation of the training system is complex and should be studied with the aid of the associated *Technical Manual*, NavShips 91544(B). The training system is closely associated with related equipment in the sonar installation. Related equipment may include depression system equipment, a stabilization computer, and an attack director.

Connections are made to the various available synchro orders from and to these equipments so that the visual indication on the cathode-ray tube is oriented with respect to true bearing, and the echo (audio signal) position is stabilized in the direction of the electronic cursor. Also, the training mechanism of the control indicator is arranged to accept increments of generated relative bearing, as originated by the attack director. The training control knob serves merely to correct the bearing if the generated bearing will not accurately track the target, and to provide for slewing or large change in bearing.

The result of the combination described is that once contact is established with the target, the echo will remain fixed on the cathode-ray tube screen regardless of maneuver of the ship, or pitch and roll unless there be actual change in the true bearing of ship and target, as measured in the horizontal plane of the ocean. Such changes are slow, and if bearing information to the attack director has been valid, the bearing change information generated by the director should compensate in a manner such that the electronic cursor will remain centered on the target echo blip despite movement of the latter. If

the solution of the director is perfect, no manual training is required of the sonar operator.

ENERGIZING EQUIPMENT.—To energize the equipment, throw the power switch on the control indicator top panel (fig. 14-9, A) to the ON position. The bearing and range dials on the control panel will then be illuminated, and the power indicating lamp in the receiver scanning switch assembly (fig. 14-7) will be lighted. After approximately 12 seconds, the power indicating lamps in the AF-RF amplifier, signal data converter, and the sonar transmitter will light, indicating that these units are energized. During the warm-up period the selector switch should be in the LISTEN position. In approximately 30 seconds aural response will be obtained, in approximately 60 seconds a significant video presentation will be obtained, and in 270 seconds echo-ranging operations may begin.

The azimuth-range indicator will be energized and one of its indicating lamps lighted approximately 12 seconds after the power switch in the control indicator is thrown to the ON position, provided the local power switch in the azimuth range indicator is at the ON position. This switch, which is located on the azimuth-range indicator chassis immediately behind the hinged front panel, allows the power to this unit to be independently turned off when not in use.

PRELIMINARY ADJUSTMENTS.—Optimum use of the visual indicator requires that the cathode-ray tube intensity adjustment be made to suit the level of illumination of the control indicator compartment. Turn the master gain control (fig. 14-9, A) to zero, lower the control indicator front panel and adjust the intensity control (fig. 14-9, B) until the circular sweep trace is just below the threshold of visibility. Depress the bearing cursor hold push button and adjust the cursor intensity to the desired level of brilliance.

With the front panel still lowered, make certain that the gyro on-off switch immediately below the cathode-ray tube cursor intensity control is in the ON position. Re-

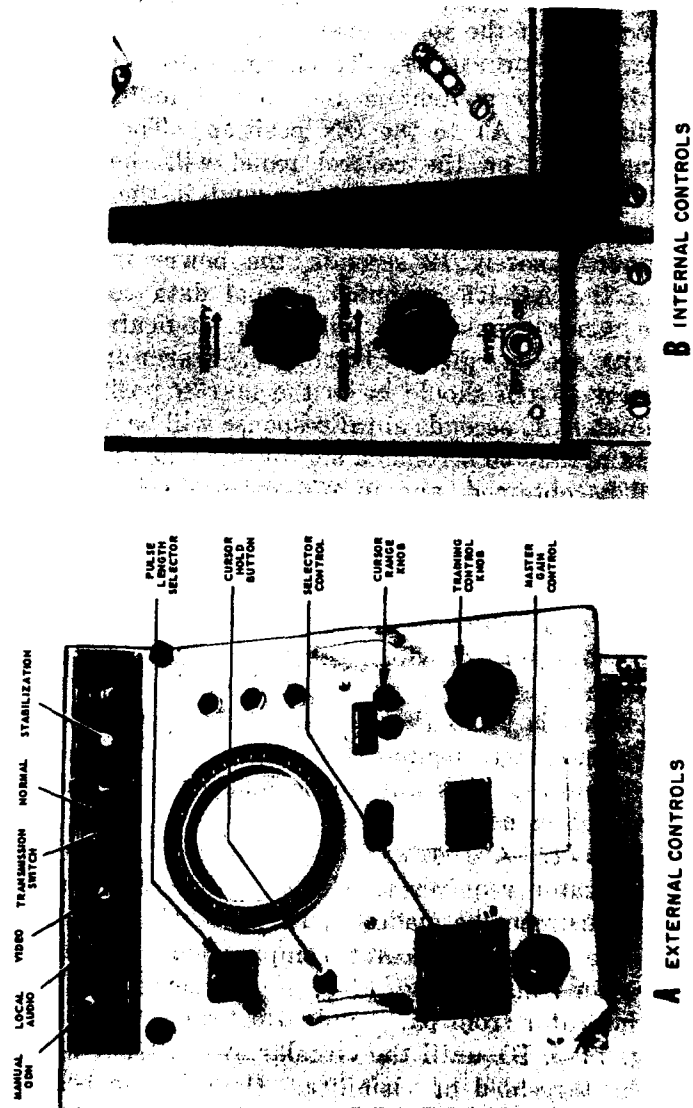


Figure 14-9.—Operator's controls, control indicator.

store the front panel to the normally closed position and note that the "gyro off" pilot lamp is not lighted. Observe that the approximate heading of own ship, as indicated by the stern cursor, is in agreement with own ship's course, as reported from the bridge.

OPERATION IN SEARCH.—To operate the sonar set in search (echo ranging) the controls are arranged as follows:

1. Set the stabilization switch in the OFF position.
2. Set the MCC reduced power—normal (transmission switch in the NORMAL position).
3. Set the video switch in the SUM position.
4. Set the manual ODN control to own ship's speed, as reported from the bridge.
5. Set the pulse length selector in the MED (medium) position.
6. If the sonar signal indicates an assured range of 2500 yards or less, set the selector at 3000 yd; if the assured range exceeds 2500 yd, set the selector at 6000 yd.
7. Set the master gain control to the point where water noise causes faint and random, brightening of the cathode-ray tube.
8. Set the local audio control to the desired level, or, if so instructed, plug in the headphones, which will disconnect the loudspeaker.

The search procedure is indicated as follows:

1. If an echo blip occurs at the same range and bearing for several transmissions, a contact should be investigated. Train the radial cursor to the suspected echo, determine the range and bearing, and from the response of the audio channel determine whether any Doppler effect is present. If the Doppler is uncertain, try several transmissions with the pulse length selector in the long position. If the contact appears to be a target, report the range and bearing.
2. In the process of exploring a suspected target, skillful use of the master gain control is required. Avoid excessive gain setting to obtain the maximum amount of information from the cathode-ray tube.

3. The hand key of the control indicator located on the right-hand side of the front panel (not shown in the figure) is useful in search operations because depression of the key will recycle the sweep of the equipment and cause a new transmission pulse. By this device, targets detected at relatively close range may be investigated with optimum rapidity by depressing the hand key immediately after reappearance of the suspected target echo. This feature is particularly important in the event that the 600-yd sweep rate is being employed because at this sweep, rate transmission occurs only once every 7.5 seconds.

4. In search operation, occasional use of the listen mode may be helpful, particularly if a noise source is suspected while echo ranging. Any noise sources in the water should be investigated immediately with the audio channel by training the cursor to the indicated bearing.

After contact is established and the operator is instructed to proceed with tracking the target, the arrangement of the controls should be adjusted at once, and the procedure varied accordingly.

TARGET TRACKING.—The arrangement of the controls for target tracking is as follows:

1. Set the video switch in the DIFF (difference brightening) position.
2. Set the pulse length switch in the SHORT position.
3. Correct the manual ODN control to the latest advice concerning ship's speed.
4. Keep the stabilization switch in the OFF position and the transmission switch in the NORMAL position.

The procedure for target tracking is as follows:

1. Set the selector switch at the fastest sweep rate which will permit the echo signal to remain on the screen and manipulate the master gain control for optimum resolution of the echo. Be careful to avoid an excessive gain setting that will cause defocusing. Immediately after the echo appears on the screen, depress the cursor hold button and at once adjust the training control so

that the cursor precisely bisects the echo blip. Report bearings continuously and determine the target range with the bearing cursor until such time as a range recorder may assume control of the keying of the equipment. If target Doppler is not evident, try an occasional transmission on medium pulse.

2. Accurate determination of range must be made by means of a range recorder, which is controlling the keying of the equipment. When controlled by a recorder, the operator may elect to gate the sweep of the indicator to the recorder's prediction of target range. Operating in this mode echo ranging with a range-gated sweep, it will be unnecessary to depress the cursor hold button because the display circuits automatically provide for adequate display time of the bearing cursor to assure precise bearing determination.

3. If contact is lost as the range diminishes, throw the transmission switch to MCC. If contact is not regained, try medium pulse and then sum brightening. If contact is regained, revert to difference brightening and a short pulse.

4. In regaining contact after an attack, the target will, in general, be obscured by own ship's wake. If the predicted range of the target is not over 1000 yards, use of the MCC mode of operations can be very useful in this phase. When the target is not found in the wake immediately, shift to normal transmission and carry out standard search plan procedures.

QUIZ

1. What are the four basic types of radars used aboard U. S. Naval vessels?
2. Name four controls that are constantly being used while operating a typical air search radar?
3. What are three controls that are adjusted and set before starting to operate the radar?
4. What are the six controls for the cathode-ray oscilloscope used with a typical air search radar?
5. In figure 14-1, what is the function of the two pulse lines in the modulator?
6. What is the function of the pulse transformer (located in the receiver transmitter)?
7. What is the function of the low-voltage samples of the magnetron pulses taken from the trigger winding of the pulse transformer?
8. What are the two principal functions of the radar modulator?
9. What are the six major assemblies housed in the radar receiver-transmitter enclosures?
10. What are the five principal components included in the transmitter?
11. What circuit in the radar receiver maintains the local oscillator frequency 30 mc higher than the transmitter magnetron frequency in order to keep the receiver signal at the i-f input centered on 30 mc?
12. What circuit in the radar receiver reduces the gain of the second and fourth i-f stages for several microseconds, during and immediately following the transmitter pulse in order to prevent large returns from nearby targets from saturating the receiver?
13. What circuits in the radar receiver reduce the gain of the receiver whenever strong signals are received in order to reduce interference both from clouds and from jamming?
14. What unit is used to determine magnetron frequency, overall radar system performance, power output, spectrum analysis, T-R tube recovery time, and other checks in the general troubleshooting of radar circuits?
15. What four adjustments are provided by the IFF coordinator panel controls?

16. The general control unit contains all the normal controls for operating and controlling the radar system except those for which three units?
17. What is the function of the training control amplifier?
18. What is the function of the synchro signal amplifier?
19. The radar repeater (VJ-1) comprises what three units?
20. Which unit amplifies the video and trigger inputs, generates the sweep voltages and the PPI unblanking gates and rangemark signals, furnishes servo amplification, and supplies plate and filament voltages for the indicator unit and its associated circuits in the unit in question?
21. Once the radar has been turned on, the ET 3 can perform all the normal operating functions at any one of which three units?
22. What is the first check to make in turning on the radar?
23. (a) At which unit are the first 10 steps taken in turning on the radar?
 (b) At which unit are the following three starting steps taken: challenge switch to OFF, norm-step-expand switch to NORM, and intensity control fully counterclockwise?
 (c) In the process of starting the radar, what time interval should be allowed for the time-delay relay to operate before pressing the "radiation on" button?
 (d) What is the starting procedure at the VJ-1 driver-unit controls?
 (e) What is the starting procedure at the VJ-1 indicator-unit controls?
 (f) Where and in what way is excessive magnetron current indicated?
 (g) What should be done if the magnetron current is excessive?
 (h) What procedures are followed first at the general control unit and later at the VJ-1 driver unit to shut down the equipment?
24. During normal operation how is the correct amount of receiver gain (fig. 14-3) ascertained?
25. What is the procedure for placing the radar antenna in manual operation?
26. At the VJ-1 repeater, assuming that the equipment controls have been adjusted properly for starting the radar:
 (a) What is the first important control adjustment to make.
 (b) What control adjustment is made to make a trace appear on the PPI?
 (c) What control adjustment is made to sharpen the trace?

27. What two types of response are provided by the AN/SQS-10 sonar?
28. (a) How is the reception of signals from noise sources indicated on the AN/SQS-10 sonar?
(b) How is the audio character of the noise ascertained?
29. In which component of the sonar system (fig. 14-8) is a signal pulse originated and amplified?
30. What is the principal difference between the search portion and the MCC portion of the AN/SQS-10 sonar transducer?
31. How are the 48 transducer staves connected during transmission?
32. What is the function of the transducer during reception?
33. What is the function of the preamplifiers (fig. 14-8)?
34. What is the function of the video scanning switch?
35. What is the function of the audio scanning switch?
36. (a) The output signals from the left and right channels of the video portion of the receiver may be combined in what two modes?
(b) How do these modes affect the beam pattern?
37. (a) What switch is operated to energize the sonar set?
(b) Which lights will be illuminated immediately following this action?
(c) Which lights will be illuminated approximately 12 seconds later?
38. During the warmup periods with the selector switch in the LISTEN position, approximately how long will it take to obtain
(a) an aural response and (b) a significant video presentation?
39. For operation in search, at what point is the master gain control set?
40. What action occurs as a result of depressing the hand key located on the right-hand side of the front panel of the control indicator?

APPENDIX I
ANSWERS TO QUIZZES

CHAPTER 1

PREPARING TO BE AN ET 3

1. That of maintaining electronic equipment in top working order.
2. Because occasionally there are changes in the quals, and it is necessary to be sure that he has the latest quals.
3. His mental processes will be blocked when he tries to understand circuit operation.
4. *Electronics Maintenance Book (EMB)*
5. Chapters 6 (Inspections, Records, Reports, and Tests) and Chapter 67 (Electronics).
6. Electronic Equipment History Card (NavShips 536).
7. Resistance Test Record (NavShips 531).
8. Record of Field Changes (NavShips 537).
9. (1) Repair Record (NavShips 529), (2) Alteration Record (NavShips 530), and (3) Record of Field Changes (NavShips 537).
10. Electronics Performance and Operational Report (NavShips 3878).
11. Electronics Failure Report (DD787).
12. (a) Tone modulated and (b) carrier frequency-shift.
13. By a distance greater than one wavelength.
14. (1) Scanning, (2) transmitting, and (3) recording.
15. By driving both receiving and transmitting drums with synchronous motors operating at exactly the same speed.
16. Because in SSB all of the power goes into the single sideband that carries the useful voice intelligence.
17. Relative bearing with respect to the station being received.
18. Distance and bearing.
19. Station-identification information.

20. To trigger the distance-measuring system aboard a ship or station.
21. So that the observer can determine on which branch of the hyperbola he is located.
22. (1) Transit time of the pulse between the master station and the slave station, (2) delay of one-half the pulse-repetition period at the slave station, and (3) coding delay added at the slave station.
23. Target height, slant range, bearing, and beacon information.
24. To permit the displacement of the entire picture so that any target within a 250-mile range may be brought to the center (or any other region) of the display.
25. It cancels the effects of own ship's motion.
26. The counters show (in miles) how far the picture has been shifted from its centered position by the use of the off-center and the DRA.
27. It supplies a synchro signal indication of the angular displacement of the ship's deck with respect to the horizontal as the ship pitches and rolls.
28. It provides a continuous display of acoustic reception in all directions and an audio response from any desired single direction.
29. A pair of special transmitter-receiver units.
30. It receives the interrogating signal and replies automatically to the interrogating signal by transmitting an identifying signal.
31. The frequency of transmissions, type of modulation, and receiver bandwidth.
32. To measure the frequency, strength, and type of modulation of a transmission.
33. Special filters.

CHAPTER 2

ELECTRONICS SAFETY PRECAUTIONS

1. Immediately.
2. *United States Navy Safety Precautions, OpNav 34P1 and Chapter 67 of the Bureau of Ships Manual, NavShips 250,000.*
3. These items should be removed.

4. By danger signs.
5. The terminals should be short circuited.
6. The docking officer.
7. (1) Interlock switches, (2) bleeder resistors, (3) current-limiting resistors, (4) insulated controls, and (5) powerline safety devices.
8. To bleed off the dangerous charges on filter capacitors.
9. Because it sometimes burns out and thus becomes useless as a protective device.
10. Green.
11. An ohmmeter.
12. The individual who opened and tagged the circuit.
13. 30 me and below.
14. *United States Navy Safety Precautions*, OpNav 34P1.
15. Fatal internal burns.
16. (1) Goggles should be worn, (2) gloves should be worn, and (3) no part of the body should be exposed to possible glass splinters.
17. Assimilation, breathing radon, and radiation.
18. In covered metal containers or buckets containing water.
19. About four times.
20. The tag for each party shall be placed on the supply switch and each party shall remove only its own tag upon completion of the work.

CHAPTER 3

COMPONENT AND EQUIPMENT NOMENCLATURE AND DESIGNATIONS

1. Identification.
2. Stock numbers, circuit symbol number, and reference numbers.
3. They are used to obtain the correct stock number for the replacement of a repair part in a specific electronic equipment and to identify parts in the repair parts boxes with a good stock number.
4. 11.

5. A cognizance symbol, a class designator, a group designator, and a stem number.
6. The equipment is used on water surface craft, it is radar equipment, and it is used for detecting and/or range and bearing.
7. T.
8. R-7/APS-2.
9. To indicate the basic purpose of the equipment.
10. The third terminal board in the tenth unit of an equipment.
11. (1) Common primary power circuits, (2) ground terminals, (3) common servo and synchro circuits, (4) video circuits, (5) trigger circuits, and (6) audio circuits.
12. Primary power.
13. The terminal to which that end of the wire is connected, the terminal board to which the other end of the wire is connected, and the particular terminal to which the other end is connected.
14. (a) Black, (b) red, (c) green, and (d) blue.

CHAPTER 4

THE USE OF HAND TOOLS IN ELECTRONICS

1. The method by which he selects, handles, and cares for hand tools.
2. When space will not permit the use of a standard-size screwdriver.
3. To prevent the screw slot from becoming burred and the screwdriver blade from becoming damaged.
4. Because this is the weakest position and the jaws may be spread.
5. The slugging wrench.
6. To match the 60° angle of a standard twist drill.
7. Because the punch may be broken.
8. Brass, tool steel, and cast iron.
9. Because the blade may become hot and expand.
10. A large, coarse, double-cut file.
11. It aids in clearing the teeth.
12. They are used for bending and shaping wire.

13. The jaws may be twisted or loosened sufficiently to make them essentially useless.
14. To provide a starting hole for the drill to prevent it from wandering around and to enable the drill to start cutting without excessive pressure.
15. High-speed drill.
16. To decrease the heating in the transformer and to concentrate it in the point where it is needed.
17. Because the soldering gun will overload the transformer and create the danger of a burnout.
18. To ensure long-lasting, low-resistance contacts by preventing oxidation or loosening of the mechanical contact.
19. To ensure freedom from rusting of the threads so that it will not be difficult to remove.
20. Fuse pullers.

CHAPTER 5

ELECTRONIC INSTALLATIONS

1. Two.
2. The current-carrying capacity and the voltage-drop limitations.
3. The 2R-ER indicates the second radar remote indicator, and the 3 indicates cable No. 3 of the radar remote indicator.
4. To prevent the passage of liquids and gases at the point of cable entrance.
5. Radio interference generated by electromechanical devices, such as motors, generators, relays, etc.
6. Shot effect, thermal noise, and microphonic noise.
7. By the use of a filter or filter network at the noise source.
8. Low-pass filter.
9. The antenna lead, a-c power lead, and audio output lead.
10. (1) The range depends on the height of the antenna, and (2) a great deal of energy is lost when the length of the waveguide is increased.
11. Polyethylene, teflon, and synthetic rubber.
12. Synthetic rubber (neoprene).

13. To reduce coupling and interference.
14. (1) Do not change the physical dimensions, (2) a damaged insulating jacket may allow water into the cable, (3) avoid putting a strain on a cable, and (4) avoid exposing the cable to abrasion.
15. Ship's service distribution system, emergency distribution system, casualty power distribution system.
16. Splices, kinks, sharp bends, deformed spots, and broken strands.
17. So that a minimum of energy will be picked up from the local transmitter.
18. Because vertical conductors, such as masts, rigging, and cables in the vicinity of UHF antennas, will cause unwanted directivity.
19. It prevents the metallic support mast from acting as a radiating portion of the antenna, and it establishes the ground level at the base of the antenna.
20. To enable a receiver in any radio space to be connected to any receiving antenna, regardless of its topside location.
21. To avoid high-voltage, standing-wave ratios.
22. To carry r-f energy from the transmitter to the wire antenna with minimum loss, minimum interference, and maximum safety.
23. To permit the simultaneous operation of a number of transmitters and/or receivers into a single antenna, thus reducing the number of antennas needed.
24. To enable the operator to establish the correct impedance match indicated by a zero reading on the tuning indicator.
25. The dielectric constant and the power factor.
26. Air with moisture is breathed into the coaxial lines as if no protex plug were there.

CHAPTER 6

MAINTENANCE PROCEDURES

1. Operational.
2. Technical.
3. (1) Transmitter, (2) receiver, (3) amplifier, and (4) indicator.
4. Dust on insulators and other high-voltage components forms a convenient path for arc-overs; also, dust mixed with lubricant forms an excellent abrasive.

5. It is formed from the first letters of the words Performance, Operational, Maintenance Standards, Electronic Equipment.
6. (1) It is a nuisance to reach and lubricate, (2) it is hazardous to lubricate at sea, (3) a great deal of strain is put on the moving parts, and (4) salt air and salt water attacks the lubricant.
7. (a) To permit grease to enter.
(b) To keep dirt out of the bearings.
8. (a) Deterioration of the insulation.
(b) (1) Churning, (2) increased temperature, (3) deterioration of the grease, and (4) ultimate destruction of the bearing.
9. To allow the abrasive to pass under the brush.
10. Because these materials contain carbon, which will become embedded in the commutator slots and short circuit the armature coils.
11. (a) To remove foreign material (dust, dirt, etc) from the air that passes through them.
(b) Because they get clogged and prevent air from moving through to cool the equipment.
12. Because some antennas are short circuited with respect to direct current.
13. Moisture and impurities such as salt spray, soot, or dust.
14. Failure of the electron tube.
15. No.
16. The polarities are opposite; that is, in the reverse type (1N23CR) the tip is the anode and in the ordinary type (1N23C) the tip is the cathode.
17. To avoid damage by exposure to a strong r-f field.
18. (1) Faulty TR operation, (2) incorrect tuning, and (3) distorted modulator pulses.
19. To ensure that they are handled properly.
20. To prevent oscillation, feedback, and other circuit disturbances.
21. To avoid damaging the contact surfaces.
22. The magnitude of the input to the receiver in microvolts required to develop a standard output of 6 mw.
23. Checking the calibration of the range step on the range indicator and the echo box ringing time.
24. Weekly.

25. A leaky oil-filled capacitor.
26. Because a layer of dust interferes with heat radiation.
27. Fuse pullers.
28. Repairs that do not affect calibration.
29. Diligent study.
30. To measure accurately certain circuit values or to indicate certain circuit conditions.
31. The corrective maintenance and the theory of operation sections.
32. (a) The tuning meter and the output meter.
(b) The pilot light and the dial light.
33. 1000 volts.
34. An attempt to localize the trouble to a particular unit or circuit.

CHAPTER 7

PRACTICAL APPLICATIONS OF TEST EQUIPMENT

1. Multimeters.
2. In decibels (db) or decibels with a reference level of one milliwatt (dbm).
3. A dummy antenna and a thermocouple ammeter.
4. WWV in Washington, D. C. and WWVH in Hawaii, both operated by the National Bureau of Standards.
5. Noise-field intensity meter.
6. Receiver sensitivity.
7. 5000 ohms.
8. 0.04 μ f.
9. 30 mh.
10. By means of (1) a r-f probe, (2) a directional coupler, and (3) a test antenna.
11. A thermistor.
12. By varying the d-c supply to the bridge.
13. 100 divisions.
14. To absorb r-f energy from waveguide.
15. To reflect nearly all the r-f power away from the thermistor without disturbing the setting of the attenuator.

16. 0.002.
17. 10,000 w.
18. To compensate for ambient temperature changes that would normally affect the calibration of the power-measuring bridge.
19. 47.5 dbm.
20. 10 w.
21. Variation, substitutions, and bridge.
22. 30 ohms.
23. Approximately the same.
24. Same.
25. Equal.
26. A loading device that changes in resistance as the power dissipated in it changes.
27. Thermistor and barretter.
28. By means of a probe antenna.
29. Because more energy is extracted from the guide, leaving less to be absorbed by the power thermistor.
30. By adjusting C102 until the beat note (difference frequency) between the heterodyne oscillator and the selected crystal oscillator is zero.
31. To ground the r-f coupling control, R106, to prevent interference from external r-f signals.
32. The 500-cycle output of the audio oscillator is fed to the suppressor grid of the heterodyne oscillator where its amplitude modulates the r-f carrier.
33. It is the ratio of measured noise to calculated noise.
34. They are equal.
35. 0.1 mw.

CHAPTER 8

USE OF THE OSCILLOSCOPE, SYNCHROSCOPE, AND ECHO BOX

1. To reduce the input signal to avoid overloading the vertical deflection amplifier.
2. The signal applied to the vertical plates, the line voltage, and the signal applied to the external sync terminal.

3. The intensity control.
4. A voltage divider.
5. 0.5 mm per volt.
6. To avoid pickup of stray signals.
7. The calibration of its deflection sensitivity.
8. (1) High input impedance, (2) ability to measure equally well voltages of a wide frequency range, and (3) its ability to indicate magnitude regardless of waveform.
9. A pattern created on an oscilloscope screen when sinewave voltages (usually of differing frequencies) are applied simultaneously to both the horizontal and vertical deflecting plates.
10. 2000 cycles.
11. A circle.
12. The wave envelope pattern and the trapezoidal pattern.
13. 50%.
14. Measuring pulse widths, determining pulse repetition rates, and calibrating the sweep.
15. To permit the linear time base, the markers, and the intensification gate to start functioning properly before the signal reaches the vertical plates of the CRT.
16. The receiver.
17. Its indication reflects the combined relative effectiveness of the transmitter as a transmitter of energy and the receiver as a receiver of energy.
18. By means of a pickup dipole, or, more generally, a directional coupler.
19. One or both are less than they should be.
20. Four.
21. Because radars have a tendency to drift in frequency.
22. The transmitters output is frequency modulated during the pulse.
23. The transmitter tube is double moding.
24. 1 μ s.
25. The radar receiver.
26. The transmitter tube or transmitter tuning adjustments.
27. To protect the echo box meter.
28. Maximum ringtime and proper crystal current.

29. Change in the loading as the antenna is rotated; the cause may be a bad rotating joint or a reflecting surface near the antenna.
30. Bad spectrum or the fact that the local oscillator is tuned to a frequency on the wrong side of the transmitter frequency.
31. One mile or less.
32. Bad TR tube.
33. The peak (pulse) power of the radar transmitter to the power of the minimum discernible signal.

CHAPTER 9

SWITCHES, SWITCHBOARDS, AND SWITCHING SYSTEMS

1. The switch has four poles and it is double throw.
2. The switch contains two forms A (make) and 1 form B (break).
3. One circuit is opened before the next circuit is closed.
4. One circuit remains closed until an instant after the next circuit is closed; then it is opened.
5. To maintain constant crystal temperatures.
6. The rotary tooth is made wider than the distance between adjacent clips.
7. To avoid spurious resonance effects.
8. S11.
9. Start-stop indicator, keying, 12-volt, d-c microphone, carrier-control, and carrier-indicator circuits.
10. To prevent two or more transmitters from feeding a single radiophone station at the same time.
11. To allow for an increase in the number of transmitters and receivers at some future time or for some other switching function.
12. The power transformer, rectifiers and filters at the transmitter via connecting circuit through switch S3D.
13. To enable the operator to listen to the output of the receiver when the transmitter is off and to listen to speech sidetone when the transmitter is being used.
14. To provide a means of selectively connecting the individual transmitter employed in a radio facility to the various antenna systems available.

15. (a) Transmitter switching (b) antenna switching.
16. The receivers operate at reduced efficiency.
17. (1) Guard against interference at frequencies falling outside the channel being used and (2) prevent receivers connected to alternate rows of jacks from interacting with each other when their tuning and trimming adjustments are made.
18. The bottom jack painted red.
19. (1) The number of signal sources and (2) the number of repeaters to be served.
20. Seven inputs and ten remote repeaters.
21. Zero.
22. Signals from the alternate gyrocompass is provided and indicator lights inform the operator which gyro output is appearing.
23. Gyro or the electrical zero reference voltage.
24. Ten.
25. The parallel circuits and switch (S504) section.

CHAPTER 10

INTRODUCTION TO SONAR

1. A combination of the first letters of the words "Sound Navigation And Ranging."
2. Detecting echoes (reflected energy).
3. Very much slower.
4. Only one.
5. All directions.
6. Listening, sounding, echo ranging, and communicating.
7. Ultrasonic.
8. (a) 1100 fps, (b) 4800 fps, (c) 16,500 fps.
9. Transmitters, transducer, receiver, and group of indicators.
10. A clock.
11. The true echo is an echo mark that is repeated over and over again.
12. Searchlight.
13. Split transducers divided into right and left sections.

14. It is rotated 90° so that right-left indications become down and up.
15. (1) Own ship's track, (2) the path of own ship's sound beam, and (3) the appropriate firing range for a throwing attack.
16. As bright spots on a dark background.
17. Doppler effect.
18. Temperature, pressure, and salinity.
19. Bathythermograph.
20. Crystal and magnetostrictive.
21. Many times the power output of a crystal.
22. High sensitivity and adjustable bandwidth.
23. 12.5 seconds.
24. 7.5 minutes.
25. 80 times as long.
26. At the center.
27. The distance from the center of the screen to the bright spot that is identified as the target.
28. Nondirectional.
29. It gives, in effect, a rotating and highly directional listening pattern.
30. Spiral scan.
31. They are the same.
32. To enable the operator to listen to the signals coming from a particular direction at the same time that he is observing the pattern of echoes coming in from all directions.
33. To enable the operator to listen to the target echo and to obtain target range and bearing information.
34. The depth-determining transducer can be tilted so that it can send its searchlight beam down into the water at any desired angle.
35. An attack director.
36. It emits a pulse of ultrasonic energy into the water and measures the time required for the pulse to travel to the bottom and return. This time interval is proportional to the depth of water beneath the hull.
37. Single sideband suppressed carrier transmission.

CHAPTER 11

INTRODUCTION TO RADIAC

1. The intensity of ionizing radiations at the location of the sensitive element of the detector at the time the reading is being made.
2. The total dosage of ionizing radiations accumulated by the instrument during the time of exposure to the ionizing radiations.
3. Uranium, thorium, actinium, neptunium.
4. Fast-moving helium ions.
5. Fast-moving electrons.
6. They have a much higher frequency and a much shorter wavelength.
7. Because they have opposite charges.
8. Ionizing effect.
9. Photomultiplier tubes.
10. Intensity (or dose rate) and dosage (total amount of radiation absorbed).
11. 3.7×10^7 .
12. The rad.
13. 12.5%.
14. A thickness of the shielding material that will absorb or shield out one-half of the incident radiation.
15. Two.
16. Because of its relatively large size and because of its two positive charges.
17. Secondary ionization effects.
18. Photoelectric effect, Compton effect, and pair production.
19. Elastic.
20. The total number of ion pairs resulting from the initial pair.
21. Because at the higher voltages the negative ions have sufficient energy to dislodge other electrons, and these electrons contribute to the current flowing through the current indicator.
22. The gold leaf.

23. To place an original charge on the central wire; and, after the charge has been partially dissipated by ionizing radiation gamma rays, to indicate the dosage in terms of the remaining charge.
24. Region B.
25. Alpha particles.
26. To discriminate against the small pulses produced by beta particles.
27. Beta and gamma radiations together or gamma radiations alone.
28. A sensitive phosphor detector.
29. (1) Intensity of the incident radiations, (2) the time of exposure, (3) the sensitivity of the film, and (4) the way the film is developed.
30. To extend the range of radiation measurements that can be made.
31. 25 mr/hr.
32. It permits compensation for the fog level (the normal density of the unexposed film) of the batch of film from which it was selected.
33. They permit the density readings to be interpreted by means of a graph in terms of the amount of radiation exposure.
34. To avoid prolonged exposure to the radiations.

CHAPTER 12

COMMON OPERATING ADJUSTMENTS: RADIO TRANSMITTERS AND RECEIVERS

1. By varying the mutual inductance in an autotransformer coupling circuit.
2. By adjusting the coupling mutual inductance between the antenna feed line and the transmitter.
3. The inductance.
4. To break out the technical manual (instruction book) for that particular equipment and study it carefully.
5. The booster.
6. To match the output of the radio frequency amplifier to the input of the antenna coupler.

7. (1) The band switch, (2) the tune IPA control, and (3) the tune PA control.
8. The high-level radio modulator.
9. It is an impedance-matching device.
10. To provide the 10-, 100-, and 1000-cycle frequency steps.
11. 0.3 mc to 2 mc.
12. To match the impedance of the r-f transmission line (50 ohms) to the antenna input impedance over the entire frequency range.
13. The low-voltage power supply (LVPS).
14. (1) By depressing the stop push button on the LVPS or (2) by throwing the emergency switch to the OFF position.
15. When it is desired to have the transmitting set operate at the 500-watt level.
16. The cabinet heater switch and the main power switch.
17. Throughout transmitter bay to energize (a) all filament supplies, (b) the blower in the RFA, (c) the main power indicator, (d) the +250-volt regulated and the -12 volt power supplies in the LLRM, and (e) through interlocks to the LVPS time delay.
18. The 100-watt level.
19. (a) AN/SRR-11 (14 to 600 kc), (b) AN/SRR-12 (0.25 to 8 mc), and (c) AN/SRR-13 (2 to 32 mc).
20. The AN/SRR-11 receiver A1, A2, and F1.
The AN/SRR-12 receiver A1, A2, A3, and F1.
The AN/SRR-13 receiver A1, A2, A3, and F1.
21. The incoming signals are heterodyned in a BFO mixer stage with signals from a BFO to produce a difference frequency in the audio range.
22. (a) FSK, A1 broad, or A1 sharp and (b) A2 broad.
23. The crystal-controlled calibrator circuit.
24. It provides a tuning adjustment for the antenna preamplifier to compensate for variations in the antenna impedance.
25. To clip equally on positive and negative portions of the audio cycle.
26. To provide attenuation for the output meter circuit.
27. Either A3 sharp or A3 broad.

CHAPTER 13

COMMON OPERATING ADJUSTMENTS: TELETYPE AND FACSIMILE

1. 425 cycles below the assigned frequency and 425 cycles above the assigned frequency.
2. It spreads the energy of the signal over a wider frequency band, thereby providing a means of achieving a certain amount of frequency diversity.
3. A low audio tone is produced.
4. It is decreased so that the audio tone is amplified.
5. One wavelength.
6. It selects and uses the better of two signals to ultimately control an automatic teletype printer.
7. The axis restorer.
8. It removes extraneous noise and other signals that might cause errors in keying.
9. The second converter.
10. (a) 1000 cycles and (b) 2550 cycles.
11. Speed.
12. The intensity, focus, vertical position, and horizontal position.
13. (a) 700 cycles and (b) 500 cycles.
14. The interlocking functions.
15. Auto.
16. Because of the time delay incurred in the operation of the control circuits of the local and distant terminals.
17. To measure the line current in any channel.
18. Because this would open circuit the channel and cause all teletype messages in the channel to be interrupted.
19. It permits control of a teletypewriter radio circuit from a remote position.
20. To actuate a clutch mechanism, which positions the receiver drum so that the clamp bars of both drums (receiver and transmitter) pass the scanning mechanism at the same time.
21. (a) Photographic paper and (b) electrosensitive paper.

22. When transmitting over long radio circuits under adverse receiving conditions.
23. (a) Minimum amplitude and (b) maximum amplitude.
24. To avoid streaks or level changes that will appear in the recorded picture because of level changes in the received signal.
25. It provides d-c keying signals for frequency-shift exciter unit in radio transmitters.
26. It replaces the conventional exciter of a c-w transmitter with a source of r-f excitation that can be shifted a small amount upward or downward to produce facsimile signals corresponding to the d-c facsimile signals connected to the input of the keyer.
27. 106.25.
28. It converts amplitude-modulated facsimile signals from a facsimile transmitter to audio frequency-shift facsimile signals of 1500 to 2300 cycles, suitable for modulating a radiophone transmitter.
29. Conventional superheterodyne receivers.
30. A frequency-shift converter.
31. Because in most receivers the converter and beat frequency oscillators do not have adequate stability.
32. They should be centered in the pass band.
33. It converts 1500- to 2300-cycle facsimile signals received from a radio circuit to a-m signals suitable for operating a facsimile recorder.
34. It brings the synchronous motor up to a speed higher than synchronous speed, after which it coasts down to its synchronous speed of 1800 cps.

CHAPTER 14

COMMON OPERATING ADJUSTMENTS: RADAR AND SONAR EQUIPMENT

1. (1) Surface search, (2) air search, (3) low-angle search and height finding, and (4) fire control.
2. (1) Gain control, (2) range crank, (3) manual and automatic antenna controls, and (4) antijamming controls for IFF equipment.

3. (1) The ON-OFF switch, (2) the calibration controls, and (3) the tuning controls.
4. (1) Focus, (2) intensity, (3) vertical and horizontal centering, (4) position for PPI, (5) astigmatism, and (6) range and bearing markers for the PPI.
5. To form one of two pulses either of which may be selected.
6. To step up the 5-kv negative pulses across its primary to 22 kc across the secondary for application to the magnetron cathode.
7. To time other circuits of the system.
8. To distribute the fuse, 115-volt power to the rest of the AN/SPS-4 system and to furnish the high-voltage negative pulses for keying the transmitter.
9. (1) Transmitter, (2) receiver, (3) video amplifier, (4) trigger delay unit, (5) monitor scope, and (6) echo box.
10. (1) High voltage pulse transformer with a trigger winding, (2) magnetron filament transformer, (3) under current relay, (4) clipping diode, and (5) magnetron oscillator.
11. The automatic frequency control (AFC) circuit.
12. The sensitivity time control (STC) circuit.
13. The instantaneous automatic volume control (IAVC) circuits.
14. The echo box.
15. (1) IFF challenge, (2) echo suppression, (3) IFF relay reset, and (4) IFF receiver gain adjustment.
16. (1) The range indicator scope, (2) the IFF equipment, and (3) the VJ-1 indicator.
17. To serve as a synchro distribution center for the equipment and supply d-c power to the antenna drive motor.
18. To modify antenna bearing data by adding OSC information when the training control amplifier is switched to TRUE, so that all synchro data to the VJ-1 indicator and any other repeaters are true bearing.
19. (1) Drive unit, (2) delay unit, and (3) indicator unit.
20. Driver unit.
21. (1) The VJ-1 indicator, (2) the IFF coordinator/range indicator cabinet, and (3) the general control unit.
22. Make sure that the box switch is turned on.

23. (a) The general control unit.
(b) At the IFF coordinator/range indicator.
(c) Five minutes.
(d) On-standby-off switch to ON, battle short switch to OFF, and range selector switch to REMOTE.
(e) Delayed-undelayed switch to undelayed, video gain control fully counterclockwise, and intensity control fully counterclockwise.
(f) The magnetron current meter on the front panel of the general control unit reads outside the green zone.
(g) The equipment must be shut down.
(h) At the general control unit (1) press the "radiation off" button, (2) turn the antenna control switch to OFF, (3) throw the power switch to OFF, and (4) at the VJ-1 driver unit, turn the on-standby-off switch to OFF.
24. The receiver gain control is adjusted until the amount of grass appearing on the range scope reaches nearly $\frac{1}{4}$ the amplitude of the signals.
25. Set the antenna control switch to SERVO and turn the manual train crank.
26. (a) Set the range-miles switch to the desired range.
(b) The intensity control is turned clockwise.
(c) The focus control is turned in the proper direction.
27. (1) A continuous display of acoustic reception in all directions and (2) an audio response from any desired single direction.
28. (a) By the display of a continuous radial pattern on the cathode-ray tube screen at the proper bearing.
(b) By training the audio system along that line of bearing.
29. The receiver scanning switch assembly.
30. The search portion transmits in a horizontal direction; the MCC portion transmits downward at an angle of approximately 30 degrees.
31. In parallel.
32. To convert the received acoustic energy to electrical energy.
33. To amplify each of the 48 signals on reception from the transducer before they are delivered to the scanning switches.
34. It rotates continuously, thereby sampling all echo or noise signals and producing short signal pulses as its beam pattern sweeps through the acoustic signal bearing.
35. It is positioned by the operator to any desired bearing and delivers all voltages from echo and noise sources along that bearing.

- 36. (a) Sum and difference.
 - (b) The sum mode results in a broad effective beam pattern; the difference mode results in an extremely sharp pattern.
- 37. (a) The power switch on the control indicator top panel.
 - (b) The bearing and range dial lights and the power indicating lamp in the receiver scanning switch assembly.
 - (c) The power indicating lamps in the AF-RF amplifier, the signal data converter, and the sonar transmitter.
- 38. (a) 30 seconds and (b) 60 seconds.
- 39. At the point where water noise causes faint and random brightening of the cathode-ray tube.
- 40. Depressing the hand key will recycle the sweep of the equipment and cause a new transmission pulse.

APPENDIX II
QUALIFICATIONS FOR ADVANCEMENT
IN RATING

ELECTRONICS TECHNICIANS (ET)

Quals Current Through Change 11

General Service Rating

Scope

Electronics technicians maintain, repair, calibrate, tune, and adjust all electronic material—except airborne and weapon control equipment—used for communication—except interior communication systems and teletypewriter machines—detection and tracking, recognition and identification, aids to navigation, and electronic countermeasures.

Emergency Service Ratings

ELECTRONICS TECHNICIANS N (Communications)----- ETN

Maintain, repair, calibrate, tune, and adjust communication equipment, radio aids to navigation, and radio countermeasures equipment including: Radio equipment; facsimile equipment; teletype terminal equipment and similar types of terminal equipment; data transmission systems; radio direction finding equipment; loran receiving equipment and radio beacons.

ELECTRONICS TECHNICIANS R (Radar)----- ETR

Maintain, repair, calibrate, tune, and adjust electronic sea, land, and air detection and tracking equipment; electronic recognition and identification equipment and radar countermeasures equipment including: Search radar equipment, radiac equipment, IFF systems, and racons.

ELECTRONICS TECHNICIANS S (Sonar)----- ETS

Maintain, repair, calibrate, tune, and adjust electronic underwater detection and tracking equipment and sonar countermeasures equipment.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see *Manual of Navy Enlisted Classifications*, NavPers 15105 (Revised), codes ET-1500 to ET-1599.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
100 PRACTICAL FACTORS				
101 OPERATIONAL				
1. Manipulate external controls; read and interpret dials, meter indications, and cathode ray tube presentations on electronic equipment* -----	3	3	3	3
2. Utilize distribution patching system for radio transmitters, receivers, and antennas for all local and remote operating positions -----	3	3		
102 MAINTENANCE AND/OR REPAIR				
1. Demonstrate under simulated conditions the rescue of a person in contact with an energized electrical circuit, resuscitation of a person unconscious from electrical shock, and treatment for electrical and acid burns----	3	3	3	3
2. Demonstrate, while servicing equipment, safety precautions such as tagging switches, removing fuses, grounding test equipment, and using shorting bars and rubber mats-----	3	3	3	3
3. Read schematic and wiring diagrams of electrical and electronic circuits; identify and interpret electrical, electronic, and mechanical symbols shown in electronic technical maintenance publications and installation blueprints -----	3	3	3	3
4. Locate and identify components, assemblies, subassemblies, and primary and casualty power circuits of electronic equipment by reference to technical maintenance publications, block diagrams, and installation blueprints* -----	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
102 MAINTENANCE AND/OR REPAIR —Continued				
5. Interpret RETMA color coding of: Fixed capacitors and resistors; power, AF, and IF transformer connections -----	3	3	3	3
6. Inspect, clean, and lubricate electronic equipment in accordance with technical maintenance publications* -----	3	3	3	3
7. Select, use, and maintain hand tools and small portable power tools necessary for maintenance and repair of electronic equipment* -----	3	3	3	3
8. Demonstrate use of the following test equipment:				
a. Nonelectronic multimeter ----	3	3	3	3
b. Electronic multimeter -----	3	3	3	3
c. Tube tester -----	3	3	3	3
d. Oscilloscope -----	3	3	3	3
e. Capacitance-inductance-resistance bridge -----	3	3	3	3
f. AF signal generator -----	3	3	3	3
g. RF signal generator -----	3	3	3	3
h. Frequency standards -----	3	3	3	3
i. Megohmmeter -----	3	3	3	3
j. Range mark generator -----	3		3	3
k. Echo boxes -----	3		3	
9. Perform operational tests and make external adjustments on electronic equipment* -----	3	3	3	3
10. Make tests for short circuits, grounds, and continuity of interconnecting cables between components of electronic equipment* -----	3	3	3	3
11. Make electrical connections and splices including soldered joints.	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
102 MAINTENANCE AND/OR REPAIR —Continued				
12. Test and/or replace plugs, lamps, fuses, switches, electron tubes, jacks, cables, and wiring	3	3	3	3
13. Localize equipment casualties to components of a system of electronic equipment* -----	3	3	3	3
14. Inspect and clean commutators and slip ring assemblies; inspect and replace brushes-----		3	3	3
15. Take sonar beam patterns and perform range and bearing accuracy tests -----	2			3
16. Operate the following test equipment:				
a. Electronic switch -----	2	2	2	2
b. Synchroscope -----	2		2	2
c. Absorption wavemeter -----	2	2	2	
d. Grid dip meter -----	2	2	2	
e. Radio-interference field-intensity meter -----	2	2	2	
f. Spectrum analyzer -----	2	2	2	
17. Repair multimeters, oscilloscopes, test oscillators, and signal generators -----	2	2	2	2
18. Test electronic circuits for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, power, and frequency and compare with established values; use an oscilloscope to view circuit waveforms and compare with established optimum performance waveforms required in electronic equipment* -----	2	2	2	2

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
102 MAINTENANCE AND/OR REPAIR —Continued				
19. Perform tests, adjustments, and repairs necessary for proper operation of electromechanical servomechanisms and synchro control circuits including:				
a. Electrical zeroing of synchros -----	2	2	2	2
b. Testing servomotors and amplidynes -----	2	2	2	2
c. Gain, phase, and balancing adjustments -----	2	2	2	2
20. Perform sensitivity and selectivity measurements and aline circuits as necessary for optimum performance of electronic equipment* -----	2	2	2	2
21. Localize electronic equipment casualties to parts or subassemblies; repair by replacement of subassemblies or parts* -----	2	2	2	
22. Effect authorized field changes to electronic equipment in accordance with instructions and diagrams* -----	2	2	2	
23. View and compare with established standards, waveforms of the following circuits: Squaring and peaking, clamping circuits, high vacuum tube sweep generators (hard tube type), trapezoidal sweep generator, phantastrons, blocking oscillators, and counting circuits -----	1		1	

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
102 MAINTENANCE AND/OR REPAIR —Continued				
24. Aline circuits by synchronizing multivibrators or blocking oscillators with sine wave, positive pulses, or submultiples of trigger frequency, or negative pulses -----	1	-----	1	-----
25. Evaluate test equipment for correct operation; make authorized repairs and calibrations.---	1	1	1	1
26. Repair countermeasures and radiac equipment* -----	1	1	1	1
27. Analyze and evaluate electrical and electronic tests; make adjustments, calibrations, and repairs necessary for optimum performance of electronic equipment* -----	1	1	1	1
28. Adjust for traffic requirements or environmental conditions antenna arrays such as: Driven arrays (collinear), parasitic arrays, (Yagi), parabolic or corner or flat reflectors back of dipoles, phased arrays, waveguide, type antennas -----	C	C	C	-----
29. Test and evaluate for proper and secure installation and optimum performance, newly installed or overhauled components, assemblies, or subassemblies of electronic equipment*--	C	C	C	C
103 ADMINISTRATIVE AND/OR CLERICAL				
1. Locate in technical and maintenance publications information necessary for maintenance and repair of electronic equip-				

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
103 ADMINISTRATIVE AND/OR CLERICAL—Continued				
1—Continued				
ment; enter corrections to publications when changes are made -----	3	3	3	3
2. Record test data and work accomplished in required work logs, equipment histories, and checkoff lists -----	3	3	3	3
3. Take, record, and report inventories of tools and portable test equipment available for maintenance and repair of electronic equipment -----	3	3	3	3
4. Gather information for and prepare complete entries in electronic equipment failure reports -----	2	2	2	2
5. Obtain part and stock numbers from technical and supply publications for tools and replacement parts; procedures for requisitioning such material-----	2	2	2	2
6. Prepare job orders and work requests -----	2	2	2	2
7. Supervise and train personnel in maintenance and repair of:				
a. Radio equipment -----	1	1		
b. Radar equipment -----	1		1	
c. Sonar equipment -----	1			1
d. Countermeasures equipment-----	1	1	1	1
8. Prepare and complete periodic or recurring reports concerning performance and/or maintenance of electronic equipment.--	1	1	1	1

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
103 ADMINISTRATIVE AND/OR CLERICAL—Continued				
9. Inspect completed work logs and checklists; review electronic equipment failure reports, requisitions for tools and replacement parts, inventories of tools and portable test equipment, job orders, and work requests -----	1	1	1	1
10. Qualify individual operators to carry out authorized performance standards tests on electronic equipment to which assigned -----	C	C	C	C
11. Organize and administer maintenance and repair of electronic equipment -----	C	C	C	C
12. Evaluate completed electronic equipment failure reports, requisitions for tools and replacement parts, inventories of tools and portable test equipment, job orders, work requests, electronic equipment histories, and periodic or recurring reports concerning performance and/or maintenance of electronic equipment -----	C	C	C	C
200 EXAMINATION SUBJECTS				
201 OPERATIONAL				
1. Purpose of operator's controls and adjustments such as:				
a. Receiver gain, transmitter tuning, antenna tuning, loran sweep speed switch, and coarse and fine delay -----	3	3		

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
201 OPERATIONAL—Continued				
b. Intensity, focus, receiver tuning, antenna rotation, range, and IFF interrogation switch -----	3		3	
c. Receiver gain, intensity, training, keying selector, and trace sensitivity -----	3			3
2. Purpose of cathode ray tube presentations on electronic equipment* -----	3	3	3	3
3. Purpose of:				
a. Stages of a typical radio transmitter—master oscillator, modulator, power amplifier, and antenna -----	3	3		
b. Stages of a typical superheterodyne receiver—antenna, RF amplifier, oscillator, mixer, IF amplifier, detector, AF amplifier, and speaker -----	3	3		
c. Antenna and remote control patching systems -----	3	3		
4. Purpose of components of a typical pulse radar set: Timer, modulator, transmitter, antenna, receiver, and indicators -----	3		2	
5. Purpose of components of a typical sonar set: Automatic keying device, driver, transducer, receiver, and indicator -----	3			3
6. Operational capabilities and limitations of electronic equipment* -----	2	2		2
202 MAINTENANCE AND/OR REPAIR				
1. Effects of electrical shock, method of resuscitation of a person unconscious from electrical shock, and treatment for electrical and acid burns -----	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
2. Electrical and electronic safety precautions (except those applicable exclusively to line construction) as set forth in Chapter 18, U. S. Navy Safety Precautions (OPNAV 34P1) -----	3	3	3	3
3. Types of information shown and meaning of electrical, electronic, and mechanical symbols used in schematic diagrams of electronic equipment* -----	3	3	3	3
4. RMA color coding systems for: Fixed capacitors and resistors; power, AF, and IF transformer connections -----	3	3	3	3
5. System of assigning "AN" letter-number combinations as designation for electronic equipment -----	3	3	3	3
6. Define the following electrical, magnetic, and electronic terms:				
a. Volt -----	3	3	3	3
b. Ohm -----	3	3	3	3
c. Ampere -----	3	3	3	3
d. Watt -----	3	3	3	3
e. Volt-ampere -----	3	3	3	3
f. Henry -----	3	3	3	3
g. Farad -----	3	3	3	3
h. Cycle -----	3	3	3	3
i. Ampere-turn -----	3	3	3	3
j. Coulomb -----	3	3	3	3
k. Circular mil -----	3	3	3	3
l. Conductor and insulator -----	3	3	3	3
m. Field intensity -----	3	3	3	3
n. Flux density -----	3	3	3	3
o. Gauss -----	3	3	3	3
p. Permeability -----	3	3	3	3
q. Hysteresis and eddy current -----	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
r. Reactance, impedance, capacitance, and inductance	3	3	3	3
s. Self-inductance and mutual inductance	3	3	3	3
t. Electromagnetic induction	3	3	3	3
u. Power factor	3	3	3	3
v. Frequency	3	3	3	3
w. Phase	3	3	3	3
x. RC time	3	3	3	3
y. Attenuation	3	3	3	3
z. Absorption	3	3	3	3
aa. Conductance	3	3	3	3
bb. Modulation and demodulation	3	3	3	3
cc. Detection	3	3	3	3
dd. Selectivity and sensitivity	3	3	3	3
ee. Amplifier—class A, B, C, and AB	3	3	3	3
ff. Filter	3	3	3	3
gg. Intermediate frequency	3	3	3	3
hh. Heterodyne	3	3	3	3
ii. Node	3	3	3	3
jj. Resonance	3	3	3	3
kk. Nonlinear	3	3	3	3
ll. Sideband	3	3	3	3
mm. Zero beat	3	3	3	3
nn. AGC	3	3	3	3
oo. Ganged tuning	3	3	3	3
pp. Single side bands	3	3	3	3
7. Importance of using proper lubricants and solvents in maintenance of electronic equipment	3	3	3	3
8. Types and purposes of hand-tools and small portable power tools necessary for maintenance and repair of electronic equipment*	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR				
—Continued				
9. Function of the following test equipment:				
a. Nonelectronic multimeter ----	3	3	3	3
b. Electronic multimeter -----	3	3	3	3
c. Tube tester -----	3	3	3	3
d. Oscilloscope -----	3	3	3	3
e. Capacitance-inductance-resistance bridge -----	3	3	3	3
f. AG signal generator -----	3	3	3	3
g. RF signal generator -----	3	3	3	3
h. Frequency standards -----	3	3	3	3
i. Megohmmeter -----	3	3	3	3
j. Range mark recorder -----	3		3	
k. Echo boxes -----	3		3	3
10. Methods and equipment used in electrical tests for continuity, grounds, and short circuits-----	3	3	3	3
11. Method of soldering and soldering equipment used in maintenance and repair of electronic equipment -----	3	3	3	3
12. Function of the following in electrical/electronic circuits: Resistors, rheostats, potentiometers, solenoids, inductors, relays, capacitors, fuses, switches, reactors, transformers, and crystals -----	3	3	3	3
13. Function of elements used in vacuum tubes -----	3	3	3	3
14. Construction of motors, generators, and alternators; application of laws of magnetism to electrical rotating machinery----	3	3	3	3
15. Types, structure, maintenance procedures, and electrical characteristics of batteries -----	3	3	3	3
16. Relationship of resistance, inductance, and capacitance in a. c. circuits -----	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
17. Relationship of current, voltage, and impedance in a. c. circuits	3	3	3	3
18. Relationship of length and cross-sectional area to resistance of a conductor	3	3	3	3
19. Relationship of resistance, temperature, and current in an electrical conductor	3	3	3	3
20. Calculate current, voltage, and resistance in d. c. series and parallel circuits containing not more than four elements	3	3	3	3
21. Calculate current, voltage, phase angle, impedance, and resonance in a. c. series and parallel circuits containing not more than four elements	3	3	3	3
22. Function and operating principles of the following:				
a. Audio amplifiers	3	3	3	3
b. Video amplifiers	3	3	3	3
c. RF amplifiers	3	3	3	3
d. IF amplifiers	3	3	3	3
e. Oscillators—tickler-feedback, Colpitts, Ultra-audion, TP-TG, push-pull, electron-coupled, transistron, Hartley-crystal controlled, and basic multivibrator	3	3	3	3
f. Rectifiers—copper oxide, selenium, crystal, and electron tube	3	3	3	3
g. Detectors—diode and crystal	3	3	3	3
h. Tuned coupling circuits	3	3	3	3
i. Impedance matching	3	3	3	3
j. Phase shifters	3	3	3	3
k. Cathode followers	3	3	3	3

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
l. Modulators—grid, screen, and plate -----	3	3	3	3
m. Limiters and clippers -----	3	3	3	3
n. AGC circuits -----	3	3	3	3
o. Sawtooth generators -----	3	3	3	3
p. Phase inverters -----	3	3	3	3
q. Modulation—amplitude, fre- quency, phase, and pulse ----	3	3	3	3
r. Coaxial transmission lines----	3	3	3	3
23. Methods of obtaining three general types of bias: Fixed, cathode, and grid leak -----	3	3	3	3
24. Electrical characteristics of:				
a. Hertz, Marconi, and dipole antennas -----	3	3	3	-----
b. Transducers and hydro- phones -----	3	-----	-----	3
25. Cause and/or effect of sky wave, ground wave, ground- reflected wave, ionospheric re- flecting layers, and skip dis- tances -----	3	3	3	-----
26. Methods of cleaning commuta- tors and slip ring assemblies and precautions to be followed--		3	3	3
27. Procedures for taking sonar beam patterns and range and bearing accuracy tests to indi- cate performance of trans- ducers and equipment -----	2	-----	-----	3
28. Function of the following:				
a. Electronic switch -----	2	2	2	2
b. Synchroscope -----	2	-----	2	2
c. Absorption wave meter -----	2	2	2	-----
d. Grid dip meter -----	2	2	2	-----
e. Radio-interference field- intensity meter -----	2	2	2	-----
f. Spectrum analyzer -----	2	2	2	-----

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
29. Operating principles of basic meters and meter movements employing the following:				
a. D'Arsonval and electrody- nometer meter movements----	2	2	2	2
b. Shunts and multipliers ----	2	2	2	2
c. Thermocouples and rectifiers in a. c. meters -----	2	2	2	2
30. Method of connecting moving element to form voltmeter or ammeter; meaning of meter sensitivity and effect of circuit loading -----	2	2	2	2
31. Computations required to determine size of shunts and multipliers -----	2	2	2	2
32. Methods of performing sensitivity and selectivity measurements and aligning circuits for optimum performance of electronic equipment* -----	2	2	2	2
33. Application of oscilloscopic wave form analysis to location of circuit malfunctions -----	2	2	2	2
34. Function and operating principles of vacuum tubes, gas-filled tubes, cathode ray tubes, and magnetrons -----	2	2	2	2
35. Operating principles of:				
a. Differentiators and integrators -----	2	2	2	2
b. Oscillators—blocking and Wein-bridge -----	2	2	2	2
c. Trigger circuits -----	2	2	2	2
d. Coincidence circuits -----	2	2	2	2
e. Peakers -----	2	2	2	2
f. Discriminators -----	2	2	2	2

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
g. AFC circuits -----	2	2	2	2
h. Counting circuits -----	2	2	2	2
i. Clampers -----	2	2	2	2
j. Phase splitting circuits -----	2	2	2	2
k. Paraphase amplifiers -----	2	2	2	2
l. Magnetic amplifiers -----	2	2	2	2
m. Transistors -----	2	2	2	2
36. Applications and operating principles of:				
a. Wave guides -----	2	2	2	-----
b. T/R and AT/R tubes -----	2	-----	2	-----
c. Klystrons and magnetrons -----	2	-----	2	-----
d. Crystal mixers -----	2	2	-----	-----
e. Radar modulators -----	2	-----	2	-----
37. Cause and/or effect of induction field and radiation field -----	2	2	2	-----
38. Characteristics and use of synchros and servomotors; methods of setting to electrical zero; purpose of gain, phase, and balance adjustments -----	2	2	2	2
39. Operating principles and radiation characteristics of parabolic and lens antennas -----	1	1	1	-----
40. Operating principles and characteristics of, and repairs and calibrations authorized on electronic test equipment listed in items 202.9 and 202.28 -----	1	1	1	1
41. Function and operating principles of special purpose tubes such as: Traveling wave, carcinotrons, and high-powered klystron amplifiers -----	1	1	1	1

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
202 MAINTENANCE AND/OR REPAIR —Continued				
42. Effects of environmental conditions upon operation of electronic and electrical equipment and special maintenance techniques involved for equipment to be operated at extremes of temperature and humidity ----	C	C	C	C
43. Theory of single side band radio transmission and reception -----	C	C	C	C
44. Polarization and directional characteristics of antenna arrays such as: Driven arrays (collinear), parasitic arrays (Yagi), parabolic, corner or flat reflectors, phased arrays, wave guide, and type antennas--	C	C	C	C
203 ADMINISTRATIVE AND/OR CLERICAL				
1. Types of information contained in electronic technical and maintenance publications -----	3	3	3	3
2. Types of entries and information recorded in electronic equipment failure reports, work logs, equipment histories, check-off lists, and Current Ship's Maintenance Project (CSMP) --	3	3	3	3
3. Procedures for taking, recording, and reporting inventories of tools and portable test equipment used in maintenance and repair of electronic equipment--	3	3	3	3
4. Procedures for obtaining replacement parts and supplies--	2	2	2	2
5. Types of information included in job orders and work requests--	2	2	2	2

*See note on p. 833.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
203 ADMINISTRATIVE AND/OR CLERICAL—Continued				
6. Types of information reported in periodic or recurring reports concerning performance and/or maintenance of electronic equipment -----	1	1	1	1
7. Methods, techniques, and devices applicable in electronic maintenance training of teams and individuals -----	1	1	1	1
8. Procedures for organizing and administering the maintenance and repair of electronic equipment -----	C	C	C	C
9. Current bureau directives on operational and maintenance responsibilities of enlisted personnel for electronic equipment -----	C	C	C	C
10. Procedures for accounting for electronic equipment, maintaining control of inventories and work flow, and reporting equipment status and work accomplished -----	C	C	C	C

**300 PATH OF ADVANCEMENT
TO WARRANT OFFICER
AND LIMITED DUTY OFFICER**

Electronics Technicians advance to Warrant Electronics Technicians and/or to Limited Duty Officer, Electronics.

*NOTE.—Denotes items which, when applied to emergency service ratings, are limited to the equipment, tools, and test equipment included within the scope of those ratings.

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