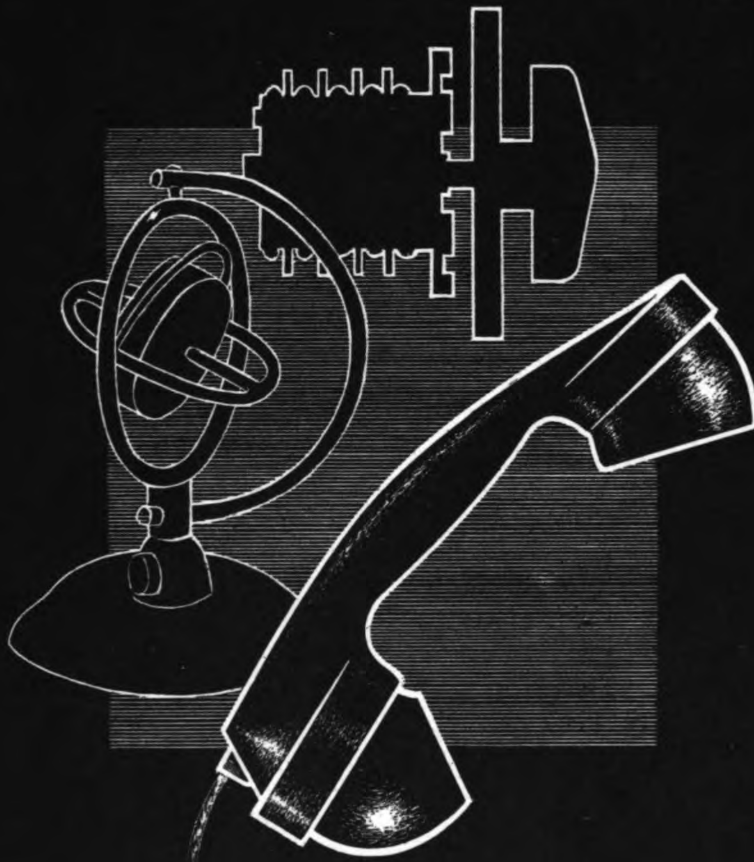




# I.C. ELECTRICIAN 3



BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10555-A

# PREFACE

This book is written for men of the Regular Navy and Naval Reserve who are interested in qualifying for advancement to IC3. Combined with the necessary practical experience, this training course will prepare the reader for the advancement-in-rating examination.

The qualifications for I.C. Electricians are listed in Appendix II. This training course contains information on each examination factor of the qualifications of IC3. Because examinations for advancement are based exclusively on these qualifications, interested personnel should refer to them frequently for guidance.

*Interior Communications Electrician 3* was prepared by the Electronics Division of the U.S. Navy Training Publications Center, which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by Navy activities cognizant of interior communications equipment and the duties of I.C. Electricians.

# THE UNITED STATES NAVY

## GUARDIAN OF OUR COUNTRY

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

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

## WE SERVE WITH HONOR

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

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

Our responsibilities sober us; our adversities strengthen us.

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

## THE FUTURE OF THE NAVY

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

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

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

Never have our opportunities and our responsibilities been greater.

# CONTENTS

# ACTIVE DUTY ADVANCEMENT REQUIREMENTS

| REQUIREMENTS * | E1 to E2 | E2 to E3 | E3 to E4 | E4 to E5 | E5 to E6 | E6 to E7 | † E7 to E8 | ‡ E8 to E9 |
|---|---|---|---|---|---|---|---|---|
| SERVICE | 4 mos. service—or completion of recruit training. | 6 mos. as E-2. | 6 mos. as E-3. | 12 mos. as E-4. | 24 mos. as E-5. | 36 mos. as E-6. | 48 mos. as E-7. 8 of 11 years total service must be enlisted. Must be permanent appointment. | 24 mos. as E-8. 10 of 13 years total service must be enlisted. |
| SCHOOL | Recruit Training. | | Class A for PR3, DT3, PT3. | | | Class B for AGCA, MUCA, MNCA. | | |
| 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. | | | | | |
| ENLISTED PERFORMANCE EVALUATION | As used by CO when approving advancement. | | Counts toward performance factor credit in advancement multiple. | | | | | |
| EXAMINATIONS | Locally prepared tests. | | Service-wide examinations required for all PO advancements. | | | | Service-wide, selection board, and physical. | |
| 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. See NavPers 10052 (current edition). | | | | | Correspondence courses and recommended reading. See NavPers 10052 (current edition). | |
| AUTHORIZATION | Commanding Officer | | U.S. Naval Examining Center | | | Bureau of Naval Personnel | | |
| | TARS are advanced to fill vacancies and must be approved by CNARESTRA. | | | | | | | |

* All advancements require commanding officer's recommendation.
† 2 years obligated service required.
‡ 3 years obligated service required.

# INACTIVE DUTY ADVANCEMENT REQUIREMENTS

| REQUIREMENTS * | FOR THESE DRILLS PER YEAR | E1 to E2 | E2 to E3 | E3 to E4 | E4 to E5 | E5 to E6 | E6 to E7 | E8 | E9 |
|---|---|---|---|---|---|---|---|---|---|
| TOTAL TIME IN GRADE | 48 | 6 mos. | 6 mos. | 15 mos. | 18 mos. | 24 mos. | 36 mos. | 48 mos. | 24 mos. |
| | 24 | 9 mos. | 9 mos. | 15 mos. | 18 mos. | 24 mos. | 36 mos. | 48 mos. | 24 mos. |
| | NON-DRILLING | 12 mos. | 24 mos. | 24 mos. | 36 mos. | 48 mos. | 48 mos. | | |
| DRILLS ATTENDED IN GRADE † | 48 | 18 | 18 | 45 | 54 | 72 | 108 | 144 | 72 |
| | 24 | 16 | 16 | 27 | 32 | 42 | 64 | 85 | 32 |
| TOTAL TRAINING DUTY IN GRADE † | 48 | 14 days | 14 days | 14 days | 14 days | 28 days | 42 days | 56 days | 28 days |
| | 24 | 14 days | 14 days | 14 days | 14 days | 28 days | 42 days | 56 days | 28 days |
| | NON-DRILLING | None | None | 14 days | 14 days | 28 days | 28 days | | |
| PERFORMANCE TESTS | | | | Specified ratings must complete applicable performance tests before taking examination. | | | | | |
| PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS) | | Record of Practical Factors, NavPers 760, must be completed for all advancements. | | | | | | | |
| NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS) | | Completion of applicable course or courses must be entered in service record. | | | | | | | |
| EXAMINATION | | Standard exams are used where available, otherwise locally prepared exams are used. | | | | | | Standard EXAM, Selection Board, and Physical. | |
| AUTHORIZATION | | District commandant or CNARESTRA | | | | | Bureau of Naval Personnel | | |

* Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for drills and training duty.

# READING LIST

## NAVY TRAINING COURSES

Basic Hand Tool Skills, NavPers 10085 (metal working skills only)

Basic Electricity, NavPers 10086

Basic Electronics, NavPers 10087 (less chapters 8-12, 14)

## OTHER PUBLICATIONS

Bureau of Ships Technical Manual, Chapters 4, 31, 45, 60, 61, 62 (sections I and II), 63, 64, 65, 66, 69, 85, and 88 (section II, Part 8 and section III).

## USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer*. The following is a partial list of those courses applicable to your rate:

### SELF-TEACHING

| Number | Title |
|---|---|
| MA 784 | Electric Wiring |
| MB 290 | Physics I (Mechanics) |
| MB 785 | Electrical Measuring Instruments |
| MB 858 | The Slide Rule |

### CORRESPONDENCE

| Number | Title |
|---|---|
| CB 290 | Physics I (Mechanics) |
| CB 785 | Electrical Measuring Instruments |
| CB 858 | The Slide Rule |

*"Members of the United States Armed Forces Reserve Components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if 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

# ORGANIZATION

## Interior Communication Electrician

The United States naval, military, and civilian organizations, including ships, aircraft, submarines, bases, yards, factories, and supply lines all together add up to the world's greatest seapower. Under emergency conditions thousands of men are processed into this astonishingly large organization within months and weeks. The methods and facilities used to convert civilians into Navy men and Navy men into competent seamen and technicians are as varied as the number of jobs to be accomplished. Training facilities include self-study courses, textbooks, training aids, and practical training in operating and maintaining the actual equipment in service schools as well as aboard ship. The average enlisted man of today is a young man with a few years of service. No matter how complex the organization and ships become, he is still the most important factor in the effective operation and maintenance of the equipments and the ships of the Navy. This training course is designed to meet the needs of the Navy I.C. Electrician.

I.C. men perform both military and professional duties. The military duties are the same as those of other petty officers irrespective of the professional or specialty ratings. The professional duties include a variety of tasks that require many specialized skills and techniques. In order to accomplish these specialty duties, the I.C. man must have a good working knowledge of the basic principles of electricity and electronics, as well as a working knowledge of practical mathematics.

### REQUIREMENTS FOR ADVANCEMENTS

The military requirements and the professional qualifications for all ratings are listed in the *Manual of Qualifications for Advancement in Rating* (Revised), NavPers 18068, commonly known as the Quals Manual. The Quals Manual is periodically revised to reflect organizational and procedural changes in the Navy that affect the rating structure, and to incorporate additional skills and techniques required by the development and installation of new equipment.

### PROFESSIONAL QUALIFICATIONS

A reprint of the professional qualifications for advancement for the Interior Communication rates are presented in appendix II of this training course. These qualifications are current through change 14, dated Feb 1960. Personnel preparing for any examination subsequent to the date of this change should refer to the latest revision of the Quals Manual.

The rating of the I.C. Electrician's Mate consists of one general service rating. General Service I.C. Electricians stand watch on I.C. switchboards and gyro compasses. They maintain and repair I.C. systems, gyro compass systems, amplified voice systems, alarm and warning systems, and their related equipments.

The qualifications that apply to the particular rates and grades are indicated in the applicable rates column of the excerpted qualifications in appendix II. This column indicates the lowest rate for which a particular qualification applies. The qualifications for advancement to the higher rates also include those of the lower rates.

The qualifications in appendix II are separated into two primary divisions consisting of PRACTICAL FACTORS and EXAMINATION SUBJECTS. The individual qualification items under these primary divisions are further divided into appropriate subject matter areas that indicate the required skills and knowledges.

The PRACTICAL FACTORS are qualifications that include particular tasks performed on the job and tested by practical demonstrations with materials, tools, and equipment. The EXAMINATION SUBJECTS are qualifications that include the minimum knowledge required for the work performed. You will be tested with a written examination.

A man qualifying for the next higher rate must complete all of the military and professional practical factors before he can be recommended to take the advancement examination. As the candidate shows proficiency in each practical factor a record of its completion is entered on the RECORD OF PRACTICAL FACTORS, NavPers 760 (IC), which is a standard form used for this purpose.

The Record of Practical Factors provides a standard checkoff list of both military and professional practical factors required to be demonstrated in each rate as a prerequisite for advancement. The supervising petty officer initials and enters the date of completion of each practical factor in the appropriate column provided on the form. Each division maintains a Record of Practical Factors for each enlisted man in pay grades E-2 through E-6 (apprentice through first class). When an enlisted man is transferred, the signed copy of the form is inserted in the correspondence side of the Enlisted Service Record, which is forwarded to the man's new duty station. In this way, the man's record is kept up to date and used on a continuing basis as he progresses in his rating.

## MILITARY REQUIREMENTS

The I.C. Electrician, in addition to his technical duties performs military duties. Underway he must man general quarters stations, which may include (1) being a member of a repair party or (2) standing watch on an I.C. switchboard. In port he may be assigned such military duties as shore patrol, security watches, or taking charge of a draft of men and being responsible for their safe transportation and delivery.

As previously mentioned, the military requirements, as well as the professional qualifications are listed in the *Manual of Qualifications for Advancement in Rating* (Revised), NavPers 18068. The military duties are not included in this training course. They are discussed in *Basic Military Requirements*, NavPers 1005[illegible] in *Military Requirements for Petty Officers 3 and 2*, NavPers 10056; and in *Military Requirements for Petty Officers 1 and Chief*, NavPers 10557.

## REFERENCE MATERIAL

The I.C. striker or the IC3 in preparing for advancement in rating must study certain publications in addition to this training course. The Reading List in the front of this book is especially useful as supplementary study material. The references listed under the headings, Navy Training Courses and Other Publications, are of particular importance because questions on the examination for advancement may be based on material contained in these courses and publications as well as on material in this training course.

These references are taken from *Training Publications for Advancement in Rating*, NavPers 10052-G which is an annual bibliography published by the Bureau of Naval Personnel. This bibliography lists the current Navy training courses and other publications that have been prepared for the use of all enlisted personnel concerned with advancement in rating examinations. This bibliography is used by examining authorities in preparing military and professional examinations for advancement in rating and also by personnel preparing to take these examinations.

In addition to the basic Navy training courses contained in the Reading List, *Mathematics*, Vol. 1, NavPers 10069-B and *Basic Electronics* (chapters 2 and 3), NavPers 10087 should be included as supplementary study material. *Mathematics*, Vol. 1 will help you to acquire the necessary knowledge of shop mathematics.

Navy training courses can be obtained by application to your Information and Education Officer. He is also in a position to help you acquire other publications that may not be readily available. If you need any study material in preparing for your advancement, do not hesitate to inform your I and E officer.

## LEADERSHIP

In satisfying the military requirements for advancement in rating you are required to study *Military Requirements for Petty Officers 3 and 2*, NavPers 10056, which contains a chapter entitled, Military Command and Leadership. After reading that chapter you should begin to think of ways to apply the information to your duties as an IC3.

When you become a petty officer you become a link in the chain of command between the officers of your division and your men. Your responsibilities are more than just giving orders and seeing that work is accomplished. You also have a responsibility for sharing your knowledge with others. When the Navy promotes you it expects you to bear some of the burden of training others.

Many books have been written on the subject of leadership, and many traits have been listed as a necessary part of the makeup of a leader. Whether you are a successful leader or not will be decided, not by compiled lists of desirable traits, but for the most part by the success with which you stimulate others to learn and to perform.

Self-confidence is one of the keys to leadership, but it must be supported by enthusiasm and especially by knowledge. For example, if you are supervising a group in performing preventive maintenance on a piece of electrical equipment you should not only know the necessary procedures thoroughly, but also be ready to pitch in and help do the job yourself if necessary. Your men will respect you as a man who has demonstrated his know-how and skill in his profession.

A cooperative attitude is a requirement of leadership. Do not let knowledge of your job techniques make you unreasonable and overbearing with lower rated men whom you may have to instruct. Your attitudes will have a definite effect on the attitudes and the actions of these men.

Be competent in your instruction of others; the opportunity to acquire knowledge and to master new skills was not given to you solely for your own benefit, but also for the benefit of the Navy as a whole. As new types of tools and equipment for use in your rating are made available, you should be the first to learn about their operation and maintenance.

## LIMITED-DUTY OFFICER

The paths of advancement from enlisted ratings to limited-duty officer (LDO) classifications are difficult to set forth because they are so varied. In the LDO classification, the commissioned ranks follow from ensign through commander.

## HOW TO STUDY

The general methods of study are the same for everyone, but the real art entails discovery of the methods that are most advantageous for the individual. It is always best to study about a particular equipment while working on it. With a piece of equipment available, the student should study the technical manual and relate the physical location and size of the component. On the job, he should learn by doing.

### PLAN OF STUDY

When studying theory or operational material, it is very important to set up some plan of study. Study must be made a habit. It must be done under conditions and surroundings that will not distract the student. It is important that learning be done in an orderly fashion so that the acquired bits of knowledge will serve as stepping stones in the process of learning. The material at hand should be read and studied with as much concentration as possible.

### RULES OF STUDY

Some basic rules for studying are:

1. A comfortable, quiet, and well-lighted location should always be used if possible. With pencil and paper handy for recording notes, the student should start to read.
2. A portion of a chapter and the number of pages to be studied should be decided upon, depending upon the subject.
3. The material should be read quickly in order to get the main point of the subject.
4. Then the material should be reread carefully.
5. When the material has been reread, the book should be put aside.
6. The main points should be listed.
7. With the book open, the student should check the main points.
8. The material should then be reread more slowly. This time the student should try to remember the details and connection of each part.
9. When he has finished reading, the student should write a detailed summary of what he has learned, using the book only if necessary.
10. When the details of the material have been thoroughly digested, the student should turn to the end of the chapter and answer as many questions as possible without referring to the text.

11. The answers should be checked and corrections should be made.

This general method should be of great benefit to those who find it difficult to learn and retain what they have read. It should be remembered that electricity cannot be learned in a hurry. However, a consistent application of effort over a period of time will bring a man to his goal sooner than he thinks.

## READING WITH UNDERSTANDING

Technical matter should not be read with the idea of covering a specific number of pages or chapters without regard for the complexity of the subject matter. It is better to read a small amount of material and digest it thoroughly than to cover a large number of pages and have only a rough idea of what is going on. Basic material should be read in order to get a thorough background before proceeding to more difficult material. It is easier to grasp new knowledge with a good background of fundamentals. In order to work out problems that are not fully clarified, the student should always have pencil and pad handy while studying.

Quizzes should be used to give an indication of the amount of information retained. Oftentimes textbooks have questions and problems at the end of each chapter. Answering these questions is a good way to review the chapter. Another suggested way is to read the chapter or section, close the book, and then try to summarize it.

The student should keep a notebook on all the publications that deal with the I.C. Electrician and the petty officer in general. He should list the title of the publication, its short title, the bureau or civilian agency responsible for publishing it, its location aboard ship, and summary of its contents. This record will be invaluable in assisting personnel to readily find information on a given subject.

## SCOPE OF IC3 TRAINING COURSE

The IC3 training course is designed to aid the I.C. striker in preparing for advancement to IC3. The text is written to cover the examination subjects and, where practicable, the practical factors in the I.C. Electrician's Rating (group VII) of the *Manual of Qualifications for Advancement in Rating* (Revised), NavPers 18068.

The first chapter of this training course explains the qualifications and requirements for advancement and lists useful reference material. It also includes the organization of the electrical division in a large ship and a resume of the duties and responsibilities of I.C. Electricians.

The second chapter describes preventive maintenance, safety precautions, and application of various instruments and meters.

Chapter 3 introduces gear ratios and defines the different types of gears and differential units. The uses and operation of mechanical and synchro followup units are described.

The fourth chapter covers the construction, principles of operation, and use of switches and protective devices.

Chapter 5 describes the various types of switchboards, the construction, operations, and maintenance of components.

The sixth chapter describes the power distribution system, the rigging of casualty power, the maintenance, and the safety precautions.

Chapter 7 deals with maintenance of motors and generators.

The eighth chapter explains the operation of the alarm and warning systems, their components, and equipment.

Sound-powered phones, their construction, principles of operation, handling, stowage and preventive maintenance are described in chapter 9. The use of blueprints in locating troubles is emphasized.

Chapter 10 describes the free gyroscope, its principles, the properties of the earth that affect the gyroscope, and the methods of making it a north-indicating compass.

The principles of saturable reactors (magnetic amplifiers) are covered in chapter 11. The discussion includes the components that comprise a magnetic amplifier and an analysis of the basic half-wave and full-wave circuits with various values of control voltage.

Chapter 12 describes the flight deck landing, electromagnetic log, and closed circuit television systems.

# Assignment of Personnel

The complement and allowance of personnel of Navy ships are established by both the Chief of Naval Operations and the Chief of Naval Personnel. The Chief of Naval Operations determines the number of men required for a particular ship for certain jobs, and the Chief of Naval Personnel determines the ranks and ratings of these officers and men.

## COMPLEMENT

The complement of a combat ship is based on the number of personnel required to (1) man the stations for battle, (2) perform the basic administrative requirements, and (3) maintain the continuous watches required under wartime conditions of readiness. The complement is, therefore, a fixed number based on the mission of the ship and its installed equipment.

## ALLOWANCE

The allowance of a combat ship is based on a percentage of the complement necessary to maintain and operate the ship under peacetime conditions. The allowance is a flexible component in personnel administration based on the national policy and budgeting limitations. It should be understood that a ship with peacetime allowance is still a very effective fighting unit. However, in the event of an emergency the prevailing allowances of ships are expanded to wartime complements as quickly as possible.

## SECTIONS

For wartime organization, each division is divided into three approximately equal sections, each being adequate to maneuver and fight the ship under emergency conditions. The section is the primary organization unit of the ship for administration of condition watches, watch standing, liberty, and messing and berthing. Each section should include an adequate number of qualified rated and nonrated personnel to man all required stations in emergencies, including those stations for getting underway and proceeding to sea for limited operations as may be required by the weather, surprise hostile activity, or other emergency situations.

Two primary considerations in the assignment of personnel in the organization structure are the number and qualifications of the available personnel that must be employed in the various battle, watch, and administrative billets to effectively fulfill the mission of the ship, department, or division.

## ENLISTED ASSIGNMENTS

The assignment of enlisted personnel is accomplished through the use of divisional, sectional, watch, and billet number assignments. Assignments to the various billets prescribed by the Ship's Battle Bill, Ship's Watch Organization, Ship's Organization Bills, and departmental and divisional administrative and watch organizations are published in the division Watch, Quarter, and Station Bill (fig. 1-1) and supplementing watch and duty lists.

Ships seldom experience the ideal conditions presented by the Personnel Allocation List because of unavoidable fluctuations in the ranks and ratings onboard and because of differences in (1) capabilities of individuals, (2) material resulting from improvements and alterations, and (3) operating conditions. Hence, division officers will be required to modify assignments of personnel to stations and duties in places where these inconsistencies occur. Necessary appraisals and revisions must be made continuously of the various assignments to achieve maximum operational efficiency and optimum utilization of personnel.

The division officer's notebook and individual watch, quarter, and station cards are used to advantage for controlling, recording, and disseminating information on such assignments. The procedures for the use of these techniques are published in *Shipboard Procedures*, NWP50 (Naval Warfare Publication) and the division officer's guide.

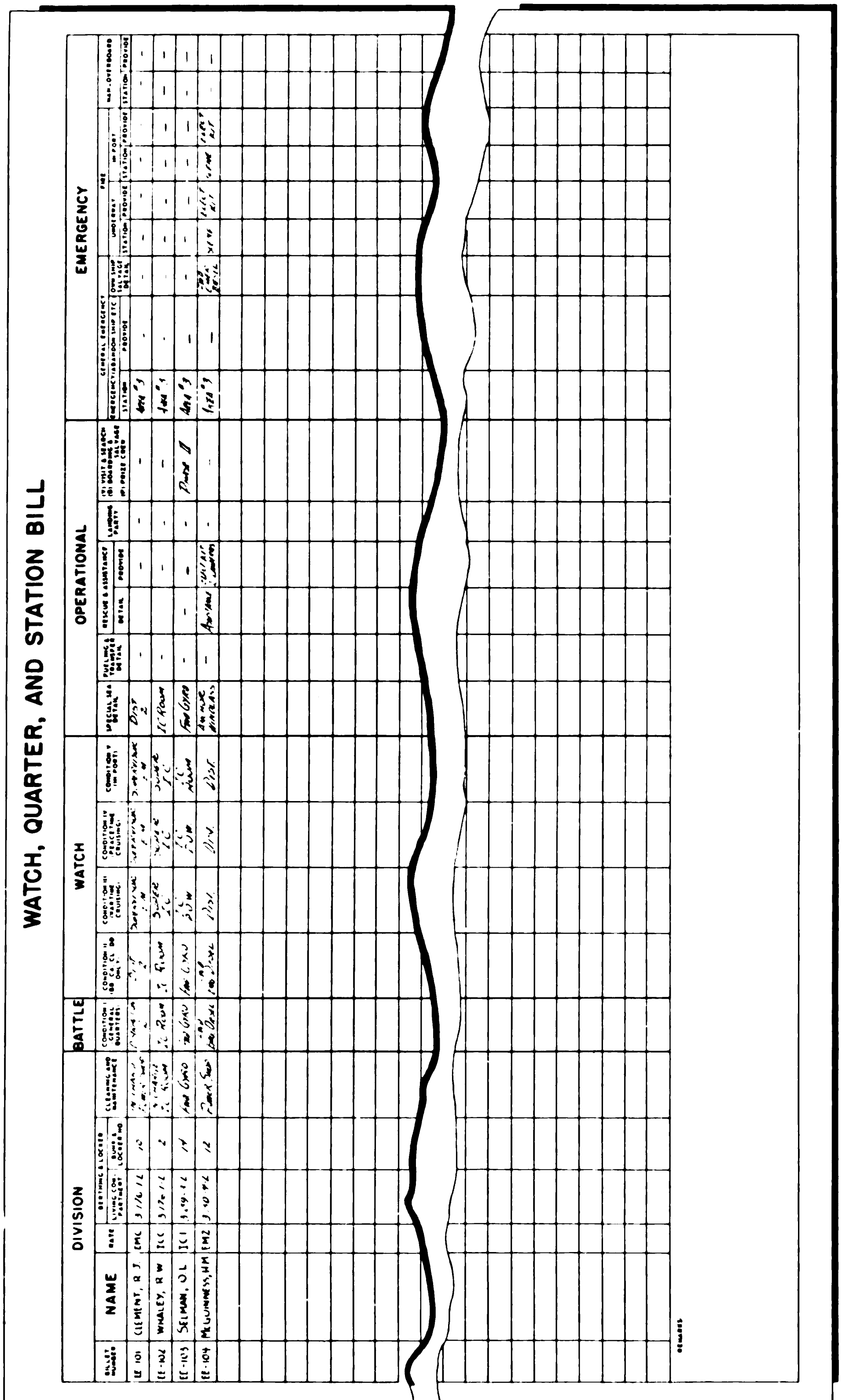



Figure 1-1.—Watch, Quarter, and Station Bill.

# Ships Organization

Navy ships are operated under standard administrative and battle organizations to facilitate quick expansion (without major change) from peacetime to wartime status. This organization divides the ship's personnel into the (1) operations, (2) navigation, (3) gunnery, (4) engineering, (5) supply, (6) medical, and (7) dental departments. Aircraft carriers and seaplane tenders have, in addition, an air department, and repair ships have a repair department.

The scope of this training course does not permit a description of the entire ship's organization, which is published in *United States Navy Regulations* and more specifically in the Ship's Organization and Regulations Manual. However, a brief description of the engineering department is included with particular emphasis on the electrical division and the duties and responsibilities of I.C. Electricians.

# Engineering Department

The engineering department is under the direct supervision of the engineer officer. It normally consists of five divisions, as illustrated by the organizational chart in figure 1-2. The machinery and boiler divisions are under the supervision of the main propulsion assistant; the electrical division is under the electrical officer; and the repair and auxiliary divisions are under the damage control assistant. These officers are charged primarily with the operation, maintenance, and repair of the machinery and equipment allotted to their divisions, and they also act as assistants to the engineer officer in the performance of his duties.

## ADMINISTRATIVE ORGANIZATION

The electrical division is under the supervision of the electrical officer. In large ships the electrical division consists of several groups (fig. 1-2), each of which is under the direct supervision of a first class of chief petty officer. The I.C. Electricians assigned to these groups are responsible for the operation, maintenance, and repair of the specific electrical equipment and circuits included in the respective groups.

### ELECTRICAL OFFICER

The electrical officer is responsible, under the engineer officer, for the organization, administration, and operation of the electrical division and its assigned personnel and material in support of the over-all mission of the ship. He is responsible for the operation, maintenance, and repair of the electrical machinery and I.C. systems throughout the ship, except those assigned to another department.

### JUNIOR DIVISION OFFICER

The junior division officer assists the division officer in coordinating and administering the functions of the division. He must develop a thorough understanding of the functions, operation, organization, and equipment of the division so that he can assume the duties of the division officer.

### MATERIAL OFFICER

The material officer is responsible, under the electrical officer, for the readiness of all assigned electrical equipment and the administration of the electrical material maintenance program.

## WATCH ORGANIZATION

When the watch organization is established, extreme care is used to ensure that all personnel thoroughly understand their duties, responsibilities, authority, and organizational relationships. Personnel assigned to watchstanding duties are entrusted with the safety of the ship, machinery, and personnel. Confusion or conflict among the watch personnel concerning the responsibilities or authority could result in

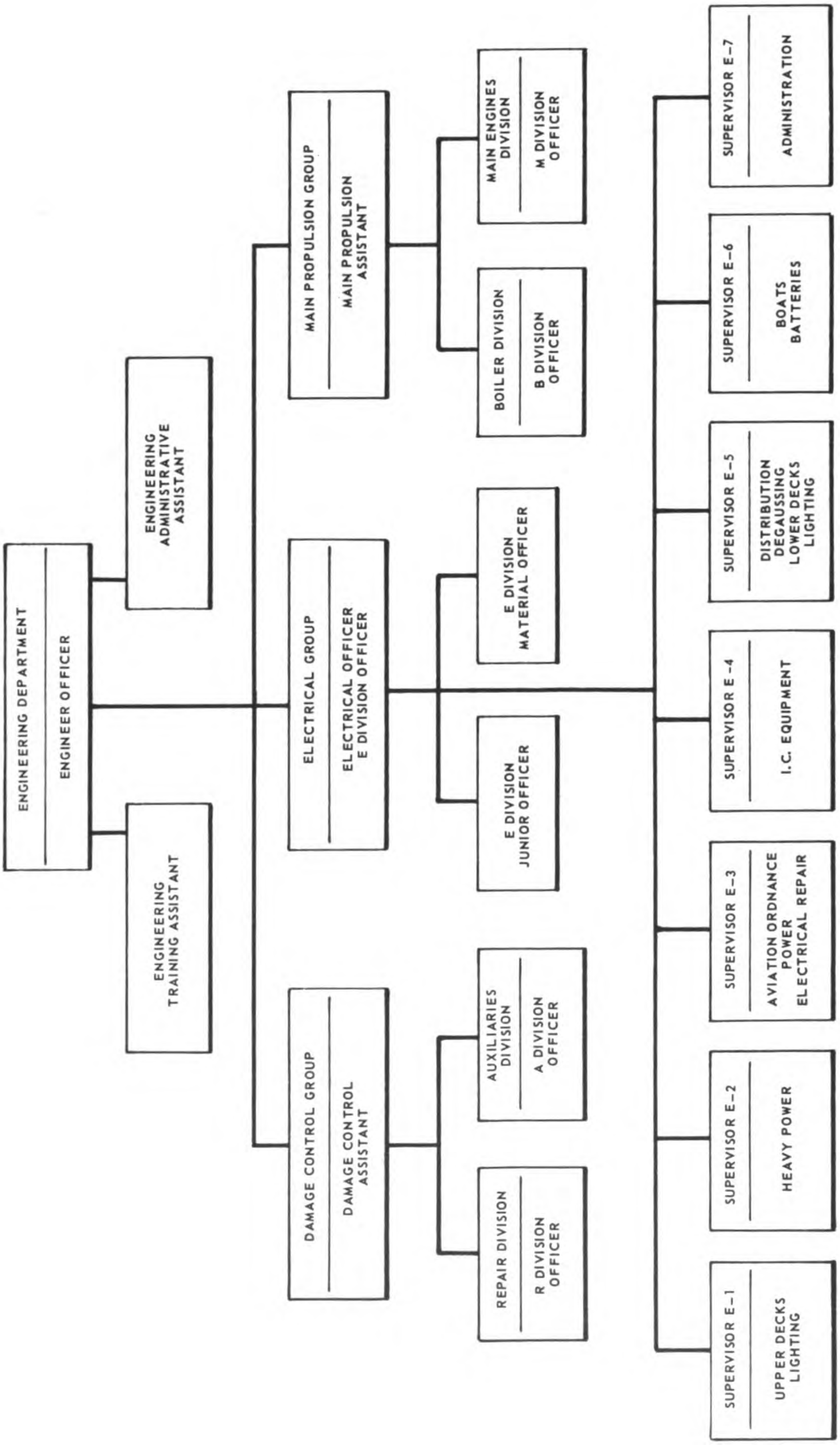



**Figure 1-2.—Engineering department organization.**

disaster, such as collision, grounding, or even loss of the ship. In some instances of naval disasters, certain watch personnel were held accountable for failing to take proper action because they were not aware of their duties and responsibilities or because they did not think they had the authority to act. Conversely, in many instances, serious damage and loss of life have been averted by the timely action of watchstanders working together as a coordinated and an integrated team.

An effective watch organization is based on sound organizational principles applied to tactical and operational requirements and published in the form of operational charts for the guidance and control of the personnel who will stand the watches. Because of the major differences in the functions and relationships of watch officers and other watchstanders when underway and in port, the watch organization is considered separately for the two situations.

Watches in port or at sea are normally of four hours duration. The day's duty in port or at sea extends from 0800 to 0800 the following day, unless otherwise directed by the engineer officer. The change from IN-PORT to UNDERWAY conditions occurs at the time the steaming watch is set. The change from UNDERWAY to IN-PORT conditions occurs at the time the auxiliary watch is set.

## UNDERWAY

The main propulsion assistant prepares the underway watch list (fig. 1-3) and submits it to the engineer officer for approval.

The engineering officer of the watch (EOOW) is in charge of the underway engineering watch and is primarily responsible for the operation of the main organization/propulsion plant and auxiliaries during his watch. He is responsible for the operation of all other engineering department machinery and equipment in general and for the progress of the engineering department routine.

The engineering junior officer of the watch (EJOW) when assigned, assists the engineering officer of the watch in the performance of his duties and must be prepared to assume the duties of the engineering officer of the watch.

The underway key watchstanders consist of the (1) engineroom supervisors, (2) boilerman of the watch, (3) electrical petty officer of the watch, (4) interior communications petty officer of the watch, (5) damage control petty officer of the watch, and (6) petty officers in charge (fig. 1-3).

The electrical petty officer of the watch is stationed at the control of the distribution switchboard. He exercises control of the electrical distribution system and all distribution boards and operating generators through the petty officers in charge in each such space.

The interior communications petty officer of the watch is stationed in the designated interior communication room. He exercises control of the operating interior communication systems and equipment through the petty officer in charge in each such space.

Watch personnel in performing their duties shall:

1. Promptly obey all orders issued to them by the engineering officer of the watch or other competent authority.
2. Carry out applicable provisions of the *BuShips Technical Manual*, Ship's Organization and Regulations Manual, Ship's Instructions and Notices, Engineering Organization Manual, Engineering Instructions and Notices, Machinery Operating Instructions and Safety Precautions, and all other directives issued by competent authority.
3. Not leave their posts without being properly relieved.
4. Ensure that gages and meters are read correctly; that no loose rags, tools, or other material are adrift that might fall into machinery, cause an accident, or create a fire hazard; that proper settings of valves, switches, and safety devices are maintained; and that oil flow through bearings is uninterrupted.
5. Be able to detect any unusual sound or vibration of machinery, and investigate any abnormalities immediately.
6. Immediately investigate smells of hot oil, burning insulation, and smoke.
7. Visualize casualties and emergencies, which might occur and visualize the steps that should be taken to remedy them.
8. Know all safety precautions, operating instructions, and casualty control procedures of their assigned station.

## IN PORT

The engineer officer prepares the duty list for in-port watches (fig. 1-4). The in-port duty list must cover the routine administration of

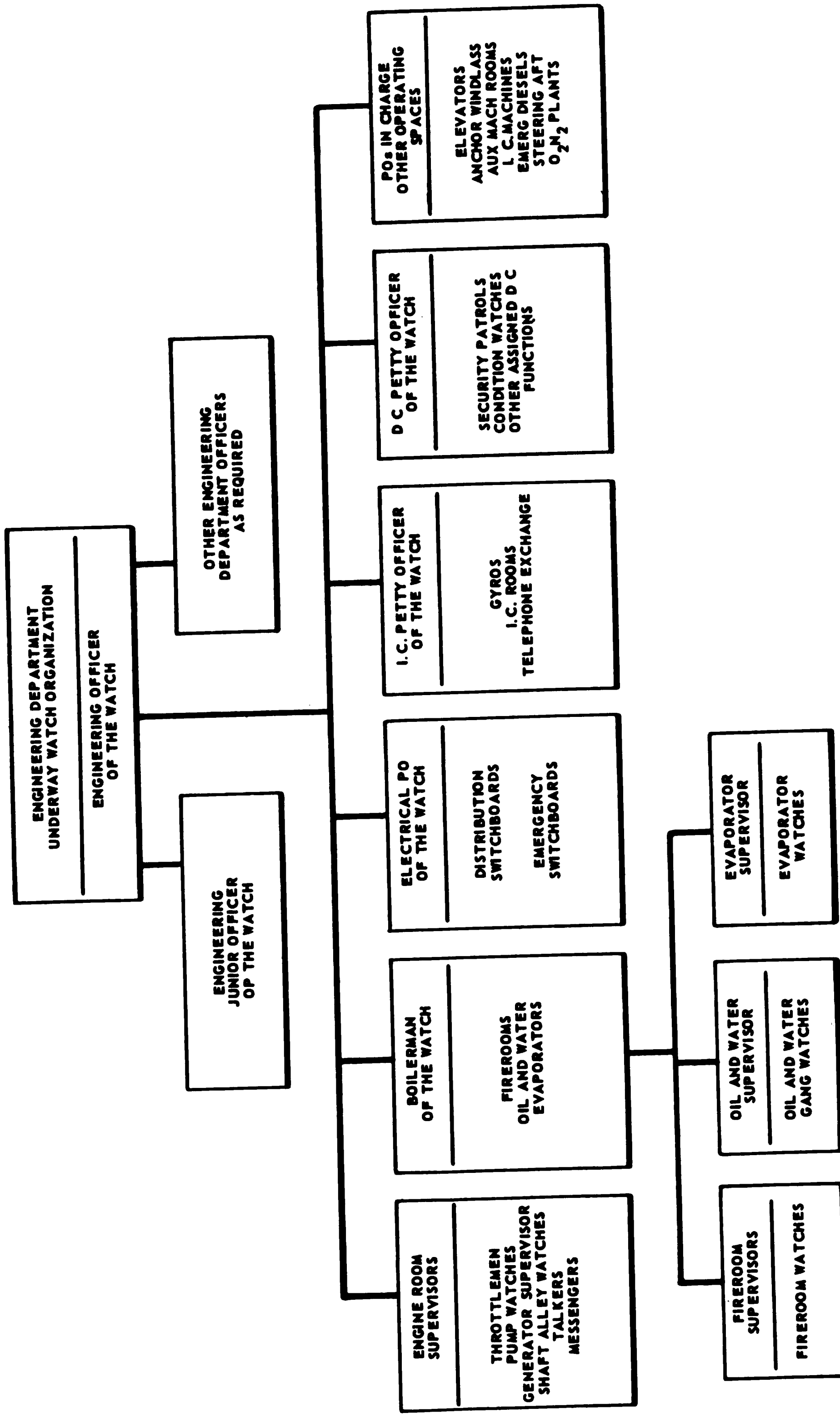



Figure 1-3.—Engineering department underway watch organization.

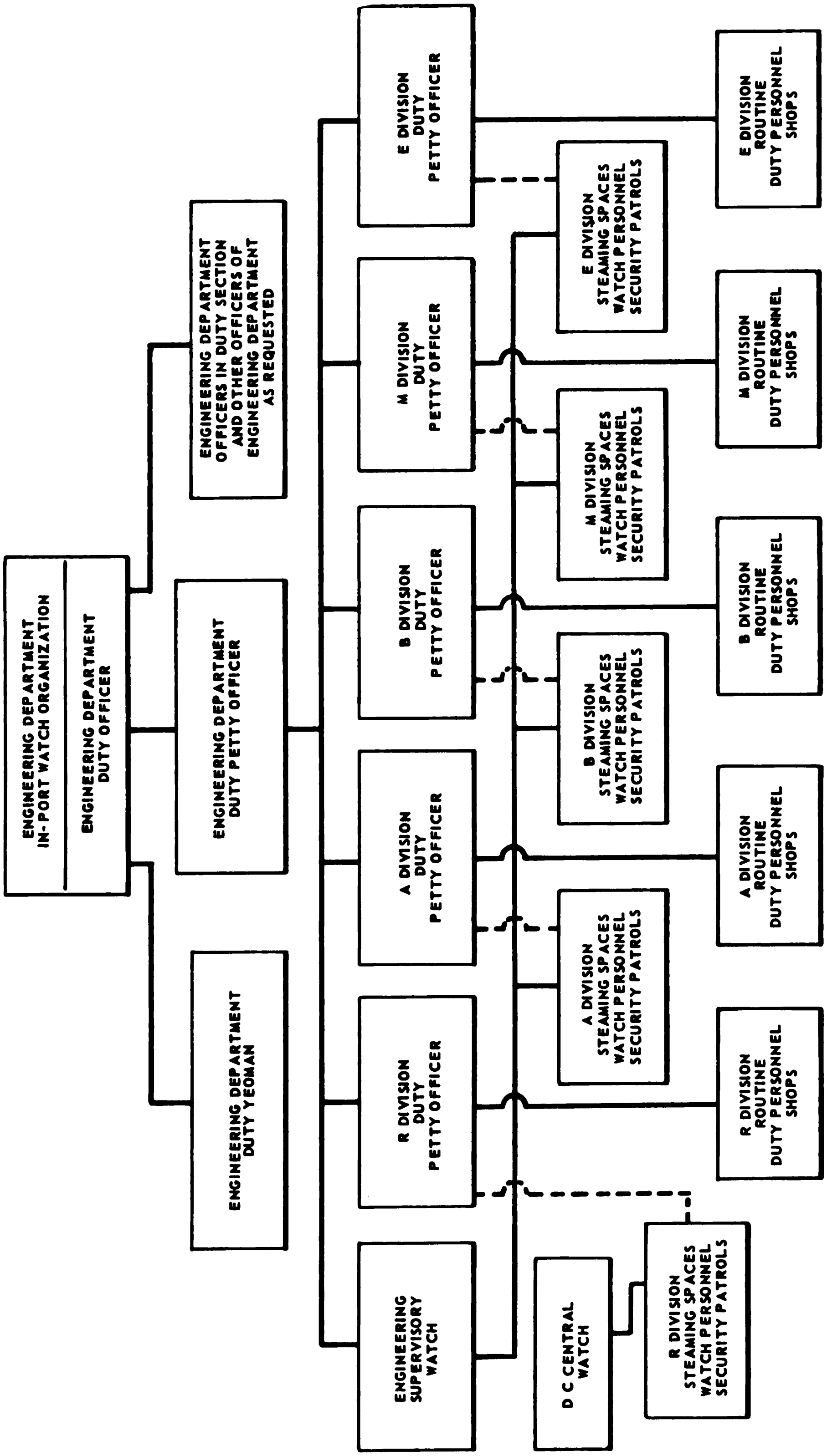



Figure 1-4.—Engineering department watch organization.

main propulsion, damage control, and electrical matters as well as emergency situations, such as emergency getting underway, fire, and rescue and assistance.

The engineering department duty officer is designated by the engineer officer to stand a day's duty and supervise the routine of the engineering department during a particular day in port. While on duty and during the absence of the engineer officer, he shall act on behalf of the engineer officer in all routine departmental matters and is responsible for the security and proper functioning of the department.

The engineering department duty petty officer is responsible to the engineering department duty officer for the security of departmental spaces and the proper functioning of engineering department personnel during a particular day in port. This watch shall be stood by a senior petty officer in each duty section (when his section has the duty) as a day's duty.

The engineering supervisory watch is responsible to the engineering department duty officer for the operation of departmental machinery and equipment, and the proper functioning of assigned personnel. This watch shall be stood by qualified petty officers, as designated by the main propulsion assistant and scheduled by the engineering department administrative assistant.

# Records

Naval vessels are required to maintain certain records, which are an important part of your job as an I.C. Electrician. They provide an effective means of keeping the engineer officer posted on the status of the material in all parts of the plant and on the performance of all divisions of the department.

## REVISED INDIVIDUAL ALLOWANCE LIST

The revised individual allowance list (RIAL), which supersedes the machinery index, is a listing of all machinery and equipment except electronic equipment installed aboard a naval vessel. The RIAL for each item of equipment includes the (1) material group number, (2) complete nameplate data, (3) manufacturers' technical manual number, and (4) location in the ship. This data is required by the Bureau of Ships to provide adequate repair parts, battle damage components, and replacement equipment for the forces afloat.

The electronic installation record serves the same purpose for electronic equipment as the RIAL serves for all other units.

## MATERIAL HISTORY

The engineer officer is responsible for maintaining the ship's material history. The material history, which supersedes the machinery history and hull repair record books, consists of cards filed in loose-leaf binders. The following four types of cards form the basis of the ship's material history:

1. Machinery History Card (NavShips 527).
2. Material History Card–Electrical (NavShips 527A).
3. Electronic Equipment History Card (NavShips 536).
4. Hull History Card (NavShips 539).

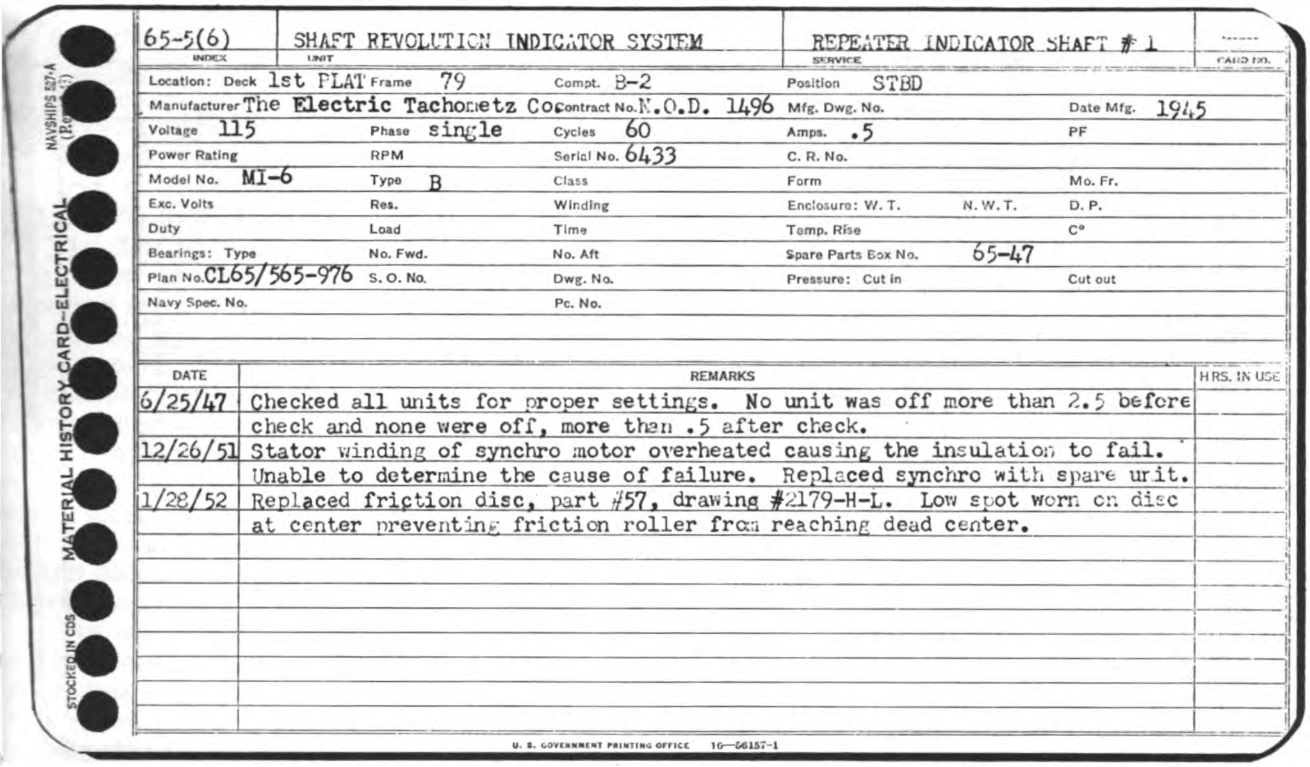
The purpose of these cards, when properly used, is to provide a comprehensive record of the items concerned. They must be kept up to date and available for inspection at all times and are integrated into preventive maintenance programs, such as the Current Ship's Maintenance Project (CSMP).

### MATERIAL HISTORY CARD–ELECTRICAL (NAVSHIPS 527A)

The electrical officer is responsible for maintaining the Material History Card–Electrical, which is the basic maintenance history card for electrical equipment (fig. 1-5). It provides for recording failures and other information pertaining to electrical equipment. An appropriate card is filled in for each item in the RIAL.

### RESISTANCE TEST RECORD (NAVSHIPS 531)

The Resistance Test Record (fig. 1-6) is provided with each piece of electrical equipment to record periodic insulation-resistance readings. The card is inserted in the material history binder adjacent to the applicable equipment history card.



NAVSHIPS 527-A

MATERIAL HISTORY CARD—ELECTRICAL

STOCKED IN CDS

| INDEX | UNIT | SERVICE | CARD NO. |
|---|---|---|---|
| 65-5(6) | SHAFT REVOLUTION INDICATOR SYSTEM | REPEATER INDICATOR SHAFT # 1 | |

| | | | | |
|---|---|---|---|---|
| Location: Deck 1st PLAT | Frame 79 | Compt. B-2 | Position STBD | |
| Manufacturer The Electric Tachometz Co | | Contract No. N.O.D. 1496 | Mfg. Dwg. No. | Date Mfg. 1945 |
| Voltage 115 | Phase single | Cycles 60 | Amps. .5 | PF |
| Power Rating | RPM | Serial No. 6433 | C. R. No. | |
| Model No. MI-6 | Type B | Class | Form | Mo. Fr. |
| Exc. Volts | Res. | Winding | Enclosure: W. T. N. W. T. | D. P. |
| Duty | Load | Time | Temp. Rise | C° |
| Bearings: Type | No. Fwd. | No. Aft | Spare Parts Box No. 65-47 | |
| Plan No. CL65/565-976 | S. O. No. | Dwg. No. | Pressure: Cut in | Cut out |
| Navy Spec. No. | | Pc. No. | | |

| DATE | REMARKS | HRS. IN USE |
|---|---|---|
| 6/25/47 | Checked all units for proper settings. No unit was off more than 2.5 before check and none were off, more than .5 after check. | |
| 12/26/51 | Stator winding of synchro motor overheated causing the insulation to fail. Unable to determine the cause of failure. Replaced synchro with spare unit. | |
| 1/28/52 | Replaced friction disc, part #57, drawing #2179-H-L. Low spot worn on disc at center preventing friction roller from reaching dead center. | |

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**Figure 1-5.—Material History Card—Electrical (NavShips 527A).**

## CURRENT SHIP'S MAINTENANCE PROJECT

The CURRENT SHIP'S MAINTENANCE PROJECT (CSMP) provides a current record of maintenance, modifications, and repairs to be accomplished by the ship's force, shipyard, or tender during availabilities. The following three basic cards comprise the CSMP:

1. Repair Record, NavShips 529 (blue).
2. Alteration Record, NavShips 530 (pink).
3. Record of Field Changes, NavShips 537 (white).

As a repair is required, or an alteration or field change is authorized, the applicable card is filled in and placed in the material history binder adjacent to the appropriate history card. As the binder is examined, the distinctive colors of the CSMP cards readily indicate outstanding work. When the work has been completed and notations to this effect entered on the material history card, all the cards except the Record of Field Changes are removed from the binder and placed in a "completed work" file.

Repair Record Cards and Alteration Record Cards are retained for a period of two years after the work is completed and entries made in the material history. After the two-year period, these cards may be destroyed at the discretion of the commanding officer. When a ship is decommissioned or placed out of service, the active cards are retained onboard the ship.

Electronic Equipment History Cards, NavShips 536, and Record of Field Changes remain with the equipment referred to on the Cards. If the equipment is transferred, these cards are transferred with it.

## LEGAL RECORDS

The Engineer's Bell Book and the Engineering Log are official legal records. They can be used in any military or civilian court as final proof of any action taken on or by the ship, and as evidence for or against any officer or enlisted man of the ship's crew who may be brought before the court or board.

The Engineer's Bell Book (NavShips 116) is a record of all bells, signals, and orders, and of the time they are received regarding the

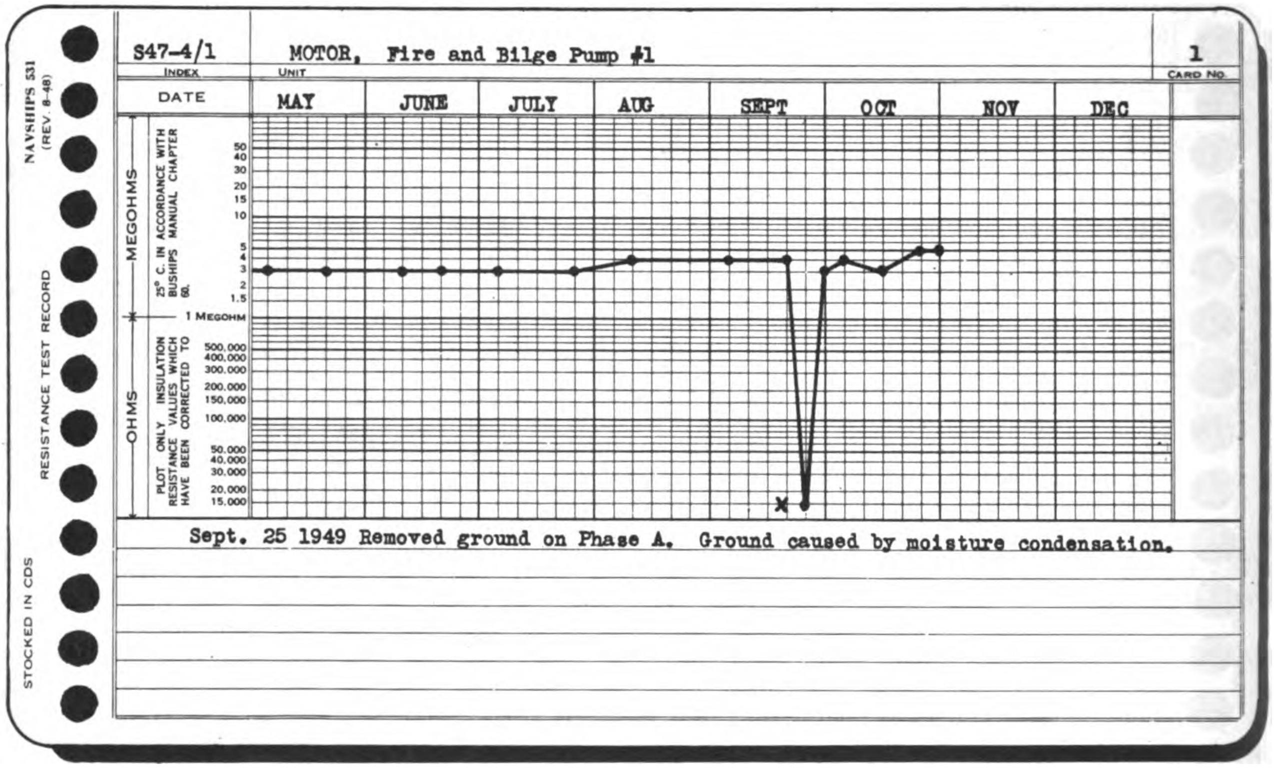


Figure 1-6.—Resistance Test Record (NavShips 531).

movement of the ship's propellers. The entries are generally made by the throttleman. However, when entering or leaving port, or during any maneuvering activity the entries should be made by an assistant. This procedure permits the throttleman to give full attention to the signals.

The engineering officer of the watch, before going off duty, must sign the Bell Book in the line following the last entry for his watch and the next officer of the watch must continue the record immediately thereafter. In machinery spaces where an engineering officer of the watch is not stationed, this record must be signed by the senior petty officer of the watch. Alterations or erasures are not permitted. An incorrect entry must be corrected by drawing a single line through it and making the correct entry on the following line. Such deleted entries must be initialed by the engineering officer of the watch, senior petty officer of the watch, or O. O. D. (in the case of ships and craft equipped with controllable reversible pitch propellers) as appropriate.

The records for each throttle control station for each day must begin with a new sheet, and the day's records for all stations must be clipped together and filed as a unit.

The Engineering Log (NavShips 117) is a midnight-to-midnight daily record of the ship's engineering department. It is a complete daily record, by watches, of important events and data pertaining to the engineering department and the operation of the ship's propulsion plant. The log must show the average hourly speed in revolutions and knots, the total engine miles steamed for the day, and all major speed changes; draft and displacement; fuel, water, and lubricating oil on hand, received and expended; the engines, boiler, and principal auxiliaries in use, and all changes therein. All injuries to personnel occurring within the department and casualties to material assigned to the department, and such other matters as may be specified by competent authority, are entered into the engineering log.

The original entries in the log, neatly prepared in pencil or ink, is the legal record. The remarks must be prepared and signed by the engineering officer of the watch before leaving his station or being relieved. Any errors must e overlined and initialed by the person preparing the original entries.

The engineer officer must verify the accuracy and completeness of the entries and sign the log daily. The commanding officer must sign the log on the last calendar day of each month, and on the date of relinquishing command.

The Engineer's Bell Book and the Engineering Log must be preserved as a permanent record onboard for a three-year period unless they are requested by a naval court or board, or the Navy Department. In such a case, a copy (preferably photostatic) of such sheets that are sent away from the ship are prepared and certified as a true copy by the engineer officer for the ship's files. At the end of the three-year period these records may be destroyed. When a ship is stricken, if either record is less than three years old, it should be forwarded to the nearest Naval Records Management Center.

The electrical log (fig. 1-7) is a complete daily record (from midnight to midnight) of the operating conditions of the ship's service electric plant. The log sheet must be kept clean and neat. Any corrections or additions for a watch must be made by the man that signs the log for that watch. However, corrections or additions must not be made after the log sheet has been signed by the engineer officer without his permission or direction. The station logs are turned into the log room every morning for the engineer officer's signature and for filing.

## MAINTENANCE RECORDS

In addition to the records mentioned, Electricians are required to maintain a number of maintenance records at their assigned duty stations. These records include Gyro Service Record Book, Gyro Compass Log, Daily Ground Test Sheets, Storage Battery Tray Record (NavShips 151), Storage Battery Charging (Discharging) Record, Ships Memorandum Work Request, and others. The maintenance records are of two types—official NavShips forms prepared by the Bureau of Ships and ship's forms prepared by the Engineering department of the individual ship.

### DAILY GROUND TEST SHEET

Ground detector voltmeter tests are made daily, as outlined in *BuShips Technical Manual*, ART. 65-39 and the readings are recorded on the Daily Ground Test Sheet (fig. 1-8). When the ground tests are completed, compare the results with the previous readings recorded on the test sheet and note any low readings. A sudden drop in insulation resistance must be investigated immediately and the trouble corrected. A comparison of the readings on the daily ground test sheet will show the difference in readings due to the normal deterioration of the cable and machinery insulation and those caused by a sudden ground.

### STORAGE BATTERY TRAY RECORD (NAVSHIPS 151)

The Storage Battery Tray Record (fig. 1-9) is a complete history of each lead-acid battery aboard ship. This record, which is kept up-to-date by the battery electrician, lists the (1) battery number, (2) nameplate data, and (3) record of service, repairs, charges, and test discharges. The information contained in this record shows the true condition of a battery and often indicates trouble in advance of battery failure.

### SHIP'S MEMORANDUM WORK REQUEST

The Ship's Memorandum Work Request (fig. 1-10) is an interdepartmental form used by any department that requires work to be performed by another department. This memorandum ensures the proper routing of work requests between heads of departments. The work requests, or job orders, list the work to be done and include an estimate of the man hours and material required to complete the job. Space is provided also for the shop that performs the work to list the material used, the manhours expended, the date of completion, and the approximate cost. Similar forms are filled in when a ship requires work to be done by a shipyard or tender.

### EQUIPAGE CUSTODY RECORD (NAVSANDA 306A)

Tools and portable test equipment are equipage for which custody signatures are required. This equipage is listed on the Equipage Custody Record (fig. 1-11), which is signed by the engineer officer when he receives it from the supply officer. The E division material officer signs a duplicate set of custody record cards when he receives the tools and test equipment from the engineer officer. The material officer, in turn issues this equipment (when required) to I.C. Electricians who then are responsible for it.

**ELECTRICAL LOG—SHIP'S SERVICE ELECTRIC PLANT**
NAVSHIPS 3649 (4-49)

PAGE 20

U. S. S. SPEEDWELL CV-3333 Turbine Driven DATE 15 November , 19

GENERATOR NO. 2 1250 KW

NOTES: *Cross out inapplicable headings for prime mover.*
*** Additional column for amperes on vessels having 3-wire D. C. generators.*

| HOUR | TURBINE DRIVE: TURBINE – STEAM PRES-SURE P.S.I. / DIESEL DRIVE: TACH. | STEAM TOTAL TEMP. °F. / TEMPERATURES – INJ. °F. | VACUUM / FRESH WATER IN °F. | TEMP. EXHAUST TRUNK °F. / FRESH WATER OUT °F. | INJECTION TEMP. °F. / LUB. OIL IN °F. | OVER-BOARD TEMP. °F. / LUB. OIL OUT °F. | CONDENSATE – PRESSURE P.S.I. / NUMBER AND TEMP. HOTTEST CYL. °F. | TEMP. °F. / PRESSURES – L.O. TO ENGINE P.S.I. | SALINITY IN E.P.M. * / F.O. TO ENGINE P.S.I. | BOOST DISCH. PRES. P.S.I. / F.W. PUMP DISCH. P.S.I. | LUB. OIL – TO COOLER °F. / S.W. PUMP DISCH. P.S.I. | FROM COOLER °F. / SCAVENGING AIR P.S.I. | 3-PHASE A.C. FREQ. | P.F. | AMPS. | VOLTS | K.W. | D.C. AMPS. | VOLTS | ** | TOTAL KILOWATTS A.C. | D.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 580 | | 29 | | 55 | 67 | 38 | 95 | .01 | | 135 | 115 | 60 | .79 | 850 | 450 | 525 | | | | | |
| 0100 | 580 | | 29 | | 55 | 67 | 38 | 95 | .01 | | 135 | 115 | 60 | .79 | 825 | 450 | 550 | | | | | |
| 0200 | 580 | | 29 | | 55 | 66 | 36 | 95 | .01 | | 135 | 115 | 60 | .78 | 825 | 450 | 550 | | | | | |
| 0300 | 570 | | 29 | | 55 | 67 | 38 | 95 | .01 | | 135 | 115 | 60 | ,79 | 800 | 450 | 525 | | | | | |
| 0400 | 590 | | 29 | | 55 | 70 | 35 | 97 | .01 | | 135 | 115 | 60 | .79 | 800 | 450 | 525 | | | | | |
| 0500 | 590 | | 29 | | 55 | 70 | 35 | 95 | .01 | | 135 | 115 | 60 | .78 | 800 | 450 | 525 | | | | | |
| 0600 | 590 | | 29 | | 54 | 70 | 39 | 96 | .01 | | 135 | 115 | 60 | .80 | 900 | 450 | 600 | | | | | |
| 0700 | 580 | | 29 | | 54 | 71 | 39 | 97 | .01 | | 135 | 115 | 60 | .84 | 1000 | 450 | 700 | | | | | |
| 0800 | 590 | | 29 | | 54 | 71 | 39 | 96 | .01 | | 135 | 115 | 60 | .83 | 1075 | 450 | 750 | | | | | |
| 0900 | 580 | | 29 | | 54 | 71 | 36 | 105 | .01 | | 135 | 115 | 60 | .80 | 1150 | 450 | 750 | | | | | |
| 1000 | 590 | | 29 | | 54 | 71 | 36 | 105 | .01 | | 135 | 115 | 60 | .80 | 1200 | 450 | 975 | | | | | |
| 1100 | 590 | | 29 | | 54 | 71 | 36 | 105 | .01 | | 135 | 115 | 60 | .79 | 1200 | 450 | 775 | | | | | |
| 1200 | 590 | | 29 | | 54 | 71 | 36 | 105 | .01 | | 135 | 116 | 60 | .84 | 1100 | 450 | 750 | | | | | |
| 1300 | 590 | | 29 | | 54 | 72 | 36 | 105 | .01 | | 135 | 116 | 60 | .83 | 1025 | 450 | 700 | | | | | |
| 1400 | 590 | | 29 | | 54 | 73 | 36 | 105 | .01 | | 135 | 116 | 60 | .80 | 1150 | 450 | 750 | | | | | |
| 1500 | 590 | | 29 | | 54 | 73 | 36 | 105 | .01 | | 135 | 116 | 60 | .81 | 1100 | 450 | 750 | | | | | |
| 1600 | 590 | | 29 | | 54 | 72 | 36 | 105 | .01 | | 135 | 115 | 60 | .81 | 1125 | 450 | 750 | | | | | |
| 1700 | 590 | | 29 | | 54 | 72 | 36 | 104 | .01 | | 135 | 115 | 60 | .83 | 1025 | 450 | 700 | | | | | |
| 1800 | 590 | | 29 | | 54 | 70 | 36 | 104 | .01 | | 135 | 115 | 60 | .84 | 1100 | 450 | 750 | | | | | |
| 1900 | 590 | | 29 | | 54 | 70 | 37 | 104 | .01 | | 135 | 115 | 60 | .82 | 925 | 450 | 625 | | | | | |
| 2000 | 590 | | 29 | | 54 | 70 | 35 | 104 | .01 | | 135 | 115 | 60 | .81 | 850 | 450 | 575 | | | | | |
| 2100 | 580 | | 29 | | 54 | 70 | 35 | 105 | .01 | | 135 | 114 | 60 | .82 | 875 | 450 | 600 | | | | | |
| 2200 | 580 | | 29 | | 54 | 72 | 35 | 105 | .01 | | 135 | 114 | 60 | .81 | 825 | 450 | 575 | | | | | |
| 2300 | 580 | | 29 | | 54 | 72 | 35 | 105 | .01 | | 135 | 114 | 60 | .81 | 850 | 450 | 600 | | | | | |
| 2400 | 580 | | 29 | | 54 | 72 | 35 | 105 | .01 | | 135 | 114 | 60 | .81 | 850 | 450 | 575 | | | | | |
| | | | | | | | | | | | | | | | | | | | | | 15,900 AC | |

GENERATOR NO.

| HOUR | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2200 | | | | | | | | | | | | | | | | | | | | | | |
| 2300 | | | | | | | | | | | | | | | | | | | | | | |
| 2400 | | | | | | | | | | | | | | | | | | | | | | |

REMARKS

TIME: ZONE DESCRIPTION ______ SET CLOCKS AHEAD OR BACK ______ MINUTES AT ______

| 0000—0400 | 0400—0800 | 0800—1200 |
|---|---|---|
| Number 2 generator in operation. 0200 shifted and cleaned lube oil strainers. Carried out routine auxiliary watch. Dun, A., EM3 Lon, J. MM3 | As before. Carried out routine auxiliary watch. Smith, B. EM3 Hill, M. MM3 | As before. 0600 shifted and cleaned lube oil strainers. Carried out routine auxiliary watch. Jones, W. EM3 Cross, T. MM3 |
| **1200—1600** | **1600—2000** | **2000—2400** |
| As before. Carried out auxiliary watch routine. Dun, A., EM3 Lon, J. MM3 | As before. 1500 shifted and cleaned lube oil strainers. Carried out routine auxiliary watch. Smith, B. EM3 Hill, M. MM3 | As before. Carried out routine auxiliary watch. Jones, W. EM3 Cross, T. MM3 |

**E. P. M. (equivalents per million) of CHLORIDE = 0.261 × METER READING in G. P. G. (grains per gallon) of SEA SALT (see chapter 56 of BuShips Manual)*

*List Auxiliary Machinery in Operation*
*For Additional Remarks Use Other Side*

CHECKED Mathews, R. F. C. M. M. APPROVED Henry F. Scucchi, LCDR ENGINEERING OFFICER, U. S. N.

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*(Replaces Forms NBS 120, 1 ... a period of two years after which time it may be destroyed. This form is stocked in CDS.)*

Figure 1-7.—Electrical Log-ship's Service Electric Plan (NavShips 3649).

MAIN BOARD

OHMS

T = THOUSANDS
M = MILLIONS

| | | + | − |
|---|---|---|---|
| FB 134 | Sump Pump #2 | | |
| FB 188 | F. O. Centrifuge Pump | 100T | 100T |
| FB 111 | Drinking Water | 10M | 10M |
| FB 116 | F. O. Transfer Pump #1 | 800T | 800T |
| FB 124 | S. W. Sanitary Pump #2 | 1M | 1M |
| FB 123 | Lub. Oil Cooler | 25M | 25M |
| FB 122 | F. W. Sanitary Pump #2 | 75T | 75T |
| FB 121 | F. W. Sanitary Pump #1 | Running | |
| FB 103 | Lub. Oil Transfer #1 | Inf. | Inf. |
| FB 104 | Lub. Oil Transfer #2 | Inf. | Inf. |
| FB 102 | Boiler Feed Pump | Running | |
| FB 101 | Spare | | |
| FB 108 | Power Panel Refrig. | Inf. | Inf. |
| FB 107 | Hot Water Heater | Inf. | Inf. |
| FB 106 | H. W. Heater Circ. Water Pump (Lower Level) | 0 | 0 |
| FB 10[illegible] | Lub. Oil Purifier | 25M | 25M |

**Figure 1-8.—Daily Ground Test Sheet.**

Any loss of accountable equipment must be reported to the E division material officer immediately so that a survey report can be made.

## PUBLICATIONS

Publications pertinent to the operation and maintenance of electrical equipment and systems are kept in the log room, which is the office of the engineering department. Refer to the applicable publications before working on any equipment or circuits with which you are not thoroughly familiar.

Publications of primary interest to I.C. Electricians Mates are (1) manufacturer's instruction books, (2) *Bureau of Ships Technical Manual*, (3) *Bureau of Ships Bulletin of Information*, (4) Bureau of Ships Technical Bulletins, (5) *Ship Information Book*, and (6) ship's plans.

## TECHNICAL MANUALS

Manufacturers' technical manuals contain technical information and instructions for the operation and maintenance of specific apparatus. This information usually includes a general description of the equipment, principles of operation, installation instructions, operating data, maintenance procedures, and safety precautions.

In most ships technical manuals are issued to responsible personnel who must sign custody receipts. This procedure is necessary because

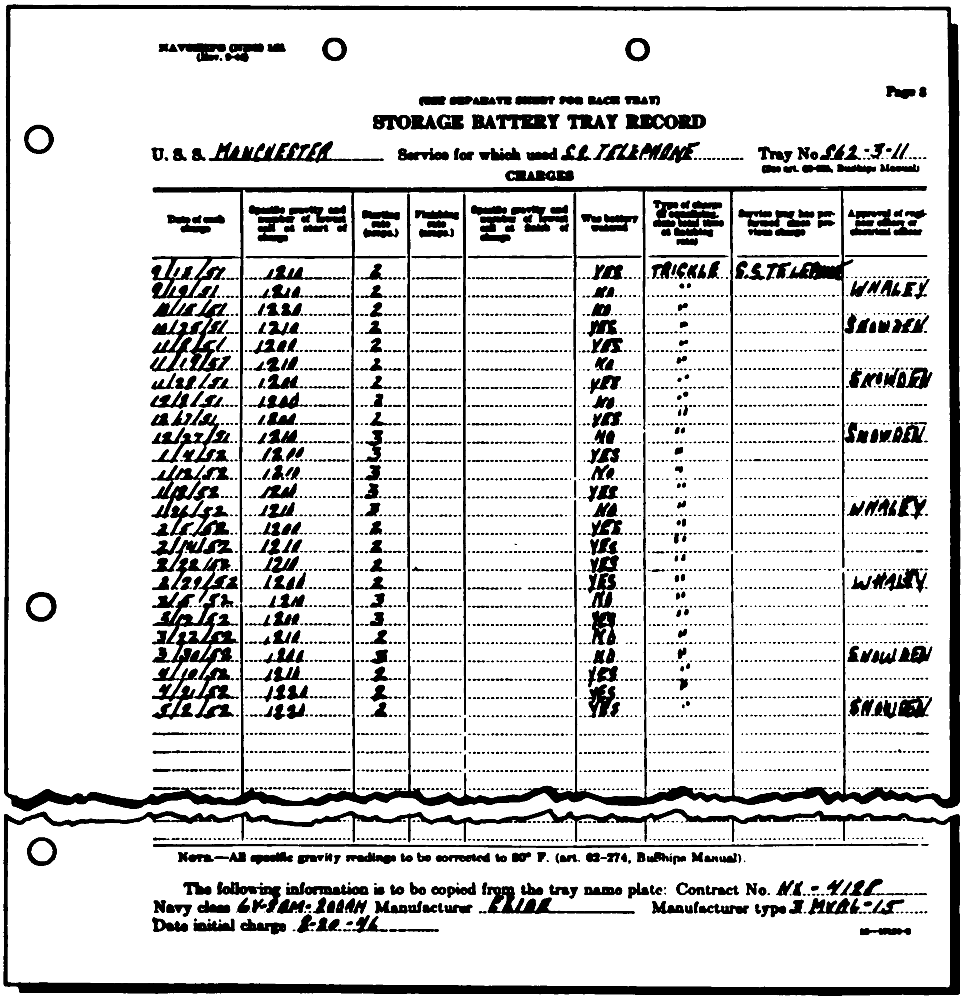


Figure 1-9.—Storage Battery Tray Record (NavShips 151).

the number of copies allotted to each ship is small and the replacement of missing copies is very costly.

## BUREAU OF SHIPS TECHNICAL MANUAL

The *Bureau of Ships Technical Manual* is the most important Bureau of Ships publication. This manual contains the administrative and engineering instructions for the use of the engineering department. It describes methods of conducting tests, procedures for making repairs, and many helpful maintenance suggestions. It is the official authority on operating procedures.

As an I.C. Electrician you should be familiar with the following chapters of the *Bureau of Ships Technical Manual*.

| Chapter | Title |
|---|---|
| 4 | Allowance, surveys, and requests fo[r] material |
| 6 | Inspections, records, and reports |
| 24 | Ship control equipment (section I, parts 1 and 2) |
| 31 | Repair parts |
| 45 | Lubricants and lubrication systems |
| 60 | Electric plant—general |
| 62 | Electric power distribution, sections I and II |
| 63 | Electric motors and controllers |
| 64 | Lighting |
| 65 | Interior communication installation |
| 66 | Searchlights |
| 69 | Electrical measuring and test instruments |
| 88 | Damage control (section II, parts 1... 8; section III, part 2) |

CL83 FORM 301

U.S.S. MANCHESTER (CL83)
WORK REQUEST
(SHIP'S FORCE)

CL83 - 6/24/49

Date 7 May 19—

FROM: Electrical Officer

TO: Repair Off., R Div. Off., First Lt. or CHBOSN.

1. It is requested that the following work be accomplished.

| Item upon which work is to be done: | Location: | J.O. Number: |
|---|---|---|
| Battle Telephone System - 49 JY | Mount 40-7 | 413-52 |

Work to be done: (Furnish sketch, dimensions, plans, etc., where applicable.)

Cut off old 20 wire connection box mounted on gun shield. Manufacture brackets to fit new switch box and weld in place. Dimensions of brackets to be taken from work.

Work to be inspected / ~~received~~ by: Whaley I.C.C.

R. Christopher
Signature

CRElect
Rank ~~or Rate~~

Priority: (1) 2 3 Urgent Deferred

(XX) Approved
( ) Disapproved

Entered in Repair Office Work Log RRK

W. K. Belvins
Repair Off., R Div. Off., First Lt. or CHBOSN.

Shop Routing:

( ) Carpenter Shop
(XX) Shipfitter Shop
( ) Electrical Workshop
( ) Steam Fitters & Htg.
( ) W.T. Integrity Force
( ) Plumbers
( ) Sail Locker
( ) Paint Locker
( ) Machine Shop
( ) Bosn's Locker

Date work started 9 May 19—
Date work completed 10 May 19—
Man hours 8
Signature shop CPO Blount

Work received/completed R. W. Whaley ICC

Weight added/removed None | Lbs. Tons

Entered in Machinery History Report RWW    CSMP ____________

Repair Record Book R.K.K.    Master Weight Record ____________

____________ YN

Figure 1-10.—Ship's Memorandum Work Request.

**EQUIPAGE CUSTODY RECORD**
NAV. S. AND A. FORM 306A
(REV. 10-48)

| CARD No. | DEPARTMENT | ALLOWANCE | STOCK No. | UNIT | ALLOWANCE LIST No. |
|---|---|---|---|---|---|
| 124 | ENG. | 4 | 40D339-5 | EACH | GROUP 624 PAGE 7 LINE 11 |

DRILL, ELECTRIC, protable, light-duty, type-A

| DATE | REC. | EXP. | BAL. | LOCATION | SIGNATURE OF CUSTODIAN |
|---|---|---|---|---|---|
| 9/16/49 | 4 | 0 | 4 | Electrical tool room | R.W. Whaley I.C.C. |
| 10/2/49 | 0 | 1 | 3 | Transfered to "A" Div. | R.W. Whaley I.C.C. |
| 11/15/49 | 0 | 0 | 3 | Electrical tool room | B. J. Wildermuth |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

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Figure 1-11.—Equipage Custody Record (NavSandA 306A).

## BUREAU OF SHIPS BULLETIN OF INFORMATION

The *Bureau of Ships Bulletin of Information* contains data concerning the maintenance and operation of naval vessels. This information includes analysis of casualties, research, developments, and reports concerning tests on material, equipment and apparatus.

## BUREAU OF SHIP'S TECHNICAL BULLETINS

Bureau of Ships Technical Bulletins and similar publications are for the dissemination of information concerning the (1) design and construction of ship's machinery and equipment, (2) technical developments, and (3) accomplishments in the field of research.

## SHIP INFORMATION BOOK

The General Specifications for Ships of the United States Navy require that the contractor furnish copies of the *Ship Information Book*, which consists of several volumes, to each ship built in accordance with these specifications. Volume 5 of the *Ship Information Book* covers the interior communication and fire control system, and replaces the Record of Electrical Installations and Electrically Operated Auxiliaries, previously required. Volume 5 contains a general description, and design information of each electrical auxiliary and equipment including the interior communication systems.

## DAMAGE CONTROL BOOKS

Damage Control Books are issued by the Bureau of Ships to the larger ships of the fleet, and contain information and instructions concerning the ship's damage control systems. A detailed description of the Damage Control Library is contained in Chapter 88, Section II of the *Bureau of Ships Technical Manual*. Requests for additional copies of chapter 88 should be directed to the Bureau of Ships.

## SHIP'S PLANS

A complete file of standard plans and blueprints is available in the log room for reference study. At the time a vessel is delivered, the shipbuilder furnishes a set of blueprints to the commanding officer via the supervisor of shipbuilding. These blueprints are in accordance with a list of working plans corrected to show the equipment, as installed. Two copies of the ship's plan index are also furnished to the ship. This index lists all plans under the cognizance of the Bureau of Ships, which apply to the vessel concerned.

The plans furnished to the ship include elementary and isometric wiring diagrams of all circuits. Each time an alteration is completed, the yard accomplishing the work furnishes the ship a copy of the plans that show the alteration. A revised copy of the ship's plan index also is furnished, which shows all plans including the latest alteration numbers that apply to the ship. Copies of the latest alterations of Bureau of Ships standard plans applicable to the equipment installed in the ship must be carefully safeguarded. If these plans are lost, replacement plans might be for a later alteration that is not applicable to the equipment actually installed.

# QUIZ

1. What are some of the methods for converting civilians into Navy men and Navy men into competent seamen?
2. What two broad general classes of duties do I.C. Electricians perform?
3. Which Navy publication lists the military requirements and the professional qualifications for all enlisted ratings?
4. As a man shows proficiency in each practical factor a record of its completion is entered in what Navy form?
5. Which Navy publication lists an annual bibliography of current Navy training courses and other publications that have been prepared for the use of all enlisted personnel concerned with advancement in rating examinations?
6. How can you obtain copies of the Navy training courses?
7. Whether you are a successful leader or not will be decided not by compiled lists of desirable traits, but, for the most part, by what final result?
8. How should study about a particular equipment be arranged in relation to actual work on the equipment?
9. What is a good way to review your knowledge of the material contained in each chapter of a training course?
10. The complement of a combat ship is based on the number of personnel required to perform which three general functions?
11. For wartime organization, each division is divided into how many sections?
12. Each section should be able to perform which two important functions under emergency conditions?
13. Assignments to the various billets prescribed by the Ship's Battle Bill, Ship's Watch Organization, Ship's Organization Bills, and departmental and divisional administrative and watch organizations are published in what division bill?
14. Normally, how many divisions comprise the engineering department of a Navy combat ship?
15. Watches in port or at sea are normally how long?
16. Where aboard ship is stationed the electrical petty officer of the watch?
17. Which list supersedes the machinery index and is a listing of all machinery and equipment, except electronic equipment, installed aboard a naval vessel?
18. Which card provides for recording failures and other information pertaining to electrical equipment?
19. Which record card is provided with each piece of electrical equipment to record periodic insulation-resistance readings?
20. The Repair Record, Alteration Record, and Record of Field Changes cards comprise what project?
21. What are the two operating records normally maintained by the electrical division?
22. Maintenance records that the Electrician's Mates are required to maintain at their duty stations are of what two general types according to where they originate?
23. A daily study of what record will show the difference between readings due to the normal, slow deterioration of the cable and machinery insulation, and those due to a sudden ground?

24. What interdepartmental form is used by any department that requires work to be performed by another department?

25. Custody signatures for tools and equipment are required on what form?

26. Where aboard ship are the publications kept that are pertinent to the operation and maintenance of electrical equipment a[illegible] systems?

27. In most ships, technical manuals are iss[illegible] to responsible personnel on what type [illegible] receipts?

28. What manual contains the administrative a[illegible] engineering instructions for the engineer[illegible] department?

# CHAPTER 2

# INSTRUMENTS AND METERS

## Introduction

As an IC3 you will use instruments and meters to check the performance of equipments under your care. It is most important that you know how to use the various instruments and how to protect them from damage. It is equally important that you know how to protect yourself from injury while making test runs and routine measurements.

Carelessness is the cause of a high percentage of personal injuries. How often have you heard someone say, "I knew better but I thought I could get by with it."? The more tragic comment is, "He knew that that circuit was hot, I wonder why he touched it." The answer to the question is that he was careless.

The truth is that all moving machinery and all electrical circuits are potential killers. Only by knowing and observing all of the safety precautions can you avoid becoming a statistic! For this reason, we are going to begin this chapter with a list of safety precautions. Do not pass over these lightly. Instead, study them and commit them to memory. Most important of all, observe them every time you work on equipment.

## Safety Precautions

The safety precautions in this chapter are applicable to all kinds of power tools and electrical measurement devices. If there is the slightest doubt in your mind regarding the safe procedure, consult your senior petty officer.

### HOUSEKEEPING

The areas surrounding machines should be kept clear. Loose gear must not be left on the deck or benches. All test equipment and tools must be properly stowed when not in use. The deck must be clean and clear of oil or grease.

Compressed air jets are used to remove dust and dirt particles from equipment. When using a compressed air jet, wear properly fitted goggles or a face mask. In general, a compressed air jet should not be used to remove small metal particles because of the danger of blowing a chip into a spot where it could cause a short circuit. Never point a compressed air jet at another person. There are recorded instances of painful injury and even death resulting from horseplay with an air jet.

Tools must be kept clean and in good condition. Avoid the use of improper tools for the job. When tools must be available for repair work, they must be kept clear of rotating equipment. Do not leave tools on the deck where you or one of your shipmates can step on them. Many persons have been injured when they stepped on a screwdriver and it rolled on the deck, causing them to lose balance and fall.

### PROTECTIVE CLOTHING

Loose or torn clothing, gloves, neckties, or long sleeves shall not be worn around moving machinery. Remove rings, identification bracelets, and wrist watches before you start to work on machines or electrical circuits.

Goggles or face shields shall be worn during grinding operations and whenever there is the slightest chance of flying particles.

Gloves are NOT to be worn when operating rotating machinery.

### PRELIMINARY PRECAUTIONS

Do not attempt to operate a machine with which you are unfamiliar, and never start a machine unless you are reasonably sure it will operate properly.

No one should operate electrical or mechanical equipment without immediate supervision or another person in the immediate vicinity.

Before starting or operating a machine, make sure that you have plenty of light.

### REPAIRING MACHINERY

Machinery in need of repairs must be reported. Do not attempt any repairs until they are authorized by your senior petty officer. All test equipment is assigned to senior personnel for safe keeping.

Never repair, oil, or clean machinery while it is in motion. Shut off all power to machines during repairs. A warning tag, "Do not close–your name–working on circuit–description and number, and the date," must be filled in and attached to the power control for that machine. If more than one gang is working on a circuit, there must be a tag for each gang. The senior man shall make sure that he removes his tag only and no other. The circuit should not be closed until the last tag is removed.

### WIRING

Do not use electrical equipment or machines with frayed or worn insulation.

All electrically driven equipment, portable as well as fixed, must have the frame grounded to the ship structure.

### SHIELDS AND GUARDS

All guards and shields will be kept in place while machinery is operating. If it is necessary to remove a guard or shield to work on a machine, replace the guard before the machine is put back in commission.

A careful study of these safety rules will show that they are based on sound, common-sense principles. They are not intended to make your job harder. Instead, they are intended to save you or your shipmates from injury or death. Follow them religiously.

## Speed Measurement

Interior Communications metering and indicating equipment, the gyro, and the associated equipment require regulated voltages and frequencies with small tolerances. Some equipment operates more economically at one speed than at others so that it is important to know the speed at which the equipment is running. Normally, the method used to measure speed will be determined by the physical arrangement of the equipment.

Speed indicators are called tachometers. Several types of tachometers are available for use in making speed measurements. The rotating counter, the chronometric, and the continuous indicating tachometers as well as the Strobotac (an electronic flash type) are usually available aboard ship.

### ROTATING COUNTER

The least expensive rotating counter is shown in figure 2-1. It can be used when the end of the rotating shaft is accessible. The counter is furnished with two rubber tips–one flat and the other conical. The conical tip is used when the shaft is center drilled, as for lathe work.

Before speed is measured with the rotating counter, the machine must be stopped and the

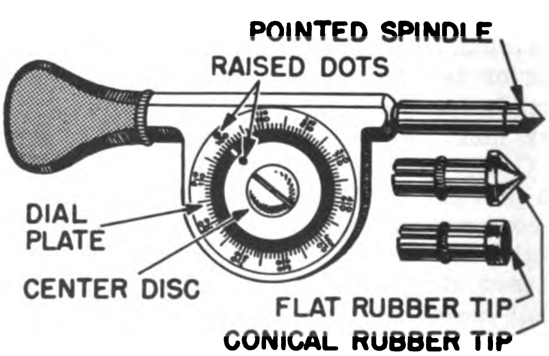



Figure 2-1.–Rotating revolution counter.

urface to which the tip is to be applied care-ully cleaned. At the same time, decide which ubber tip you are going to use. After the end f the shaft has been cleaned and the proper ip selected, start the machine.

The dial plate of the counter is calibrated or both clockwise and counterclockwise rota-ion. The dial plate is part of the counter frame nd does not rotate. The center disk goes hrough one complete revolution for every 100 evolutions of the spindle. The disk is spring oaded and can be moved on its axis for rapid lignment of the two raised dots. The counter indicating mark should be set to 100 before you start to measure the shaft speed.

You need a watch, preferably one with a sweep second hand, in addition to the counter. Place your thumb over the two raised dots so that there is pressure on the dots.

To determine the speed of rotation, place the speed indicator in the position shown in figure 2-2. Press the tip against the rotating shaft so that the spindle rotates at the shaft speed. Because the center disk of the counter is spring loaded, your thumb pressure will maintain the zero (100) setting, though the spindle is turning. Maintain thumb pressure until the second hand on the watch is at the start of the timing interval, which is usually one minute.

At the start of the minute, raise your thumb just enough to permit the center disk to rotate and to permit you to feel the raised dot as it passes beneath your thumb once for every 100 revolutions of the spindle. In this way, you can count the hundreds of revolutions by feel during the timing minute. At the end of the minute, quickly pull the tip away from the rotating shaft.

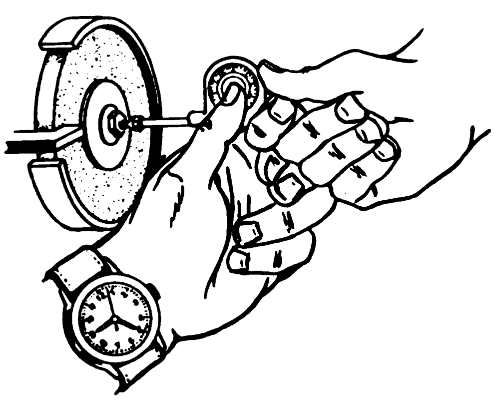


Figure 2-2.—Correct position of speed indicator.

Then read on the dial the number of revolutions the shaft has made in addition to the number of hundreds that were counted by feel. This number, added to the number of hundreds, is the rpm (revolutions per minute) of the shaft.

## CHRONOMETRIC TACHOMETER

The chronometric tachometer (fig. 2-3) gets its name from the fact that it contains a built-in watch movement and is calibrated in feet per minute. Therefore, it will give an automatic time period and revolution count. The time and speed can be read at any time after contact is broken between the shaft and spindle. Both time and speed indicators must be manually reset to zero after the measurement is completed.

The chronometric tachometer has conical and cylindrical shaped tips and, in addition, a rubber tired wheel (fig. 2-3) that may be used for certain special measurements.

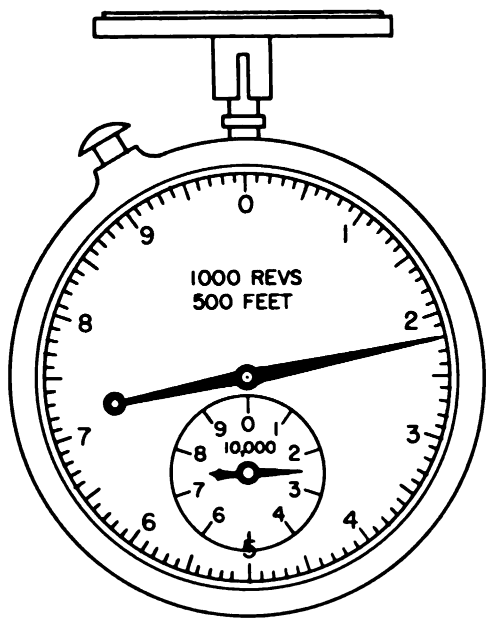



Figure 2-3.—Chronometric counter.

## CONTINUOUS INDICATING TACHOMETER

The continuous indicating tachometer (fig. 2-4) is equipped with a gear-shifting mechanism to provide coverage for a wide range of shaft speeds. Speeds from 50 to 50,000 rpm can be measured. The instrument is supplied with an extension rod to increase the length of the shaft, conical and cylindrical tips, and a rubber tired wheel.

When the tachometer is coupled to a rotating shaft, the indicator shows rpm directly. No counting or timing is necessary.

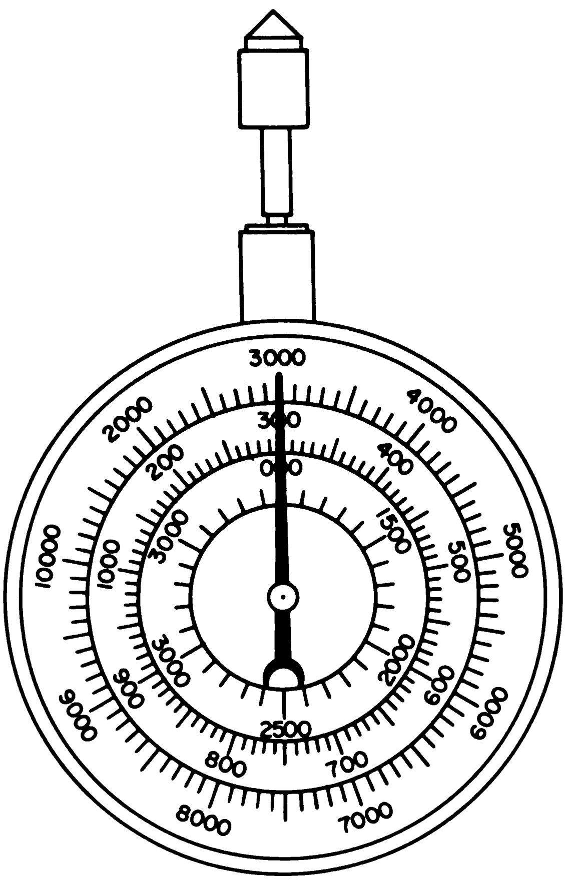



Figure 2-4.—Continuous indicating tachometer

## STROBOSCOPIC TACHOMETER

The stroboscope is an instrument that permits rotating or reciprocating objects to be viewed intermittently and produces the optical effect of slowing down or stopping motion. For example, electric fan blades revolving at 1800 rpm will apparently be stationary if viewed under a light that flashes uniformly 1800 times per minute. At 1799 flashes per minute, the blades will appear to rotate forward at 1 rpm, and, at 1801 flashes per minute, they will appear to rotate backward at 1 rpm.

Because the human eye retains images for an appreciable fraction of a second, no flicker is seen except at very low speeds. The apparent slow motion is an exact replica of the original higher speed motion, so that the motion of a high-speed machine can be analyzed under normal operating conditions.

When the flashing rate of the light is adjustable, the control can be calibrated in flashes (or revolutions) per minute. The stationary image seen when the flashing rate of the lamp and the rotational rate of a shaft are equal permits very precise speed measurements to be made.

The Strobotac is an electronic flash device in which the flash duration is very short (of the order of a few millionths of a second), which allows very rapid motion to be arrested.

Figure 2-5 is a photograph of the Strobotac. The box contains a strobotron lamp in a parabolic reflector, an electronic pulse generator to control the flashing rate, and a power supply that operates from the a-c power line. The flashing rate is controlled by the large knob (see photo), and the corresponding speed in rpm is indicated on an illuminated drum dial on the top face of the unit. The flashing rate can also be controlled from an external generator, contactor, or the a-c power line.

The normal speed range is from 600 to 14,400 rpm. An additional low range extends down to 60 rpm. Speeds greater than 14,400 rpm can be measured by using flashing rates that are simple submultiples of the speed to be measured.

At speeds below 600 rpm, flicker becomes pronounced because the human eye cannot retain successive images long enough to create the illusion of continuous motion. The flicker and the low average level of illumination set 600 rpm as the lower limit of speeds used for slow-motion studies. If slow speeds are to be checked, it is necessary to use an external flash with higher intensity than the built-in flash in order to raise the average level of illumination.

## MAINTENANCE

The life of the strobotron tube is approximately 250 hours if used at flashing speeds of less than 5000 rpm, or 100 hours if used at higher speeds.

If the Strobotac is operated continuously at the higher speeds, the strobotron cathode emission may eventually be reduced to the point where the tube is inoperative. When this happens, the tube usually glows with a dull red color, but

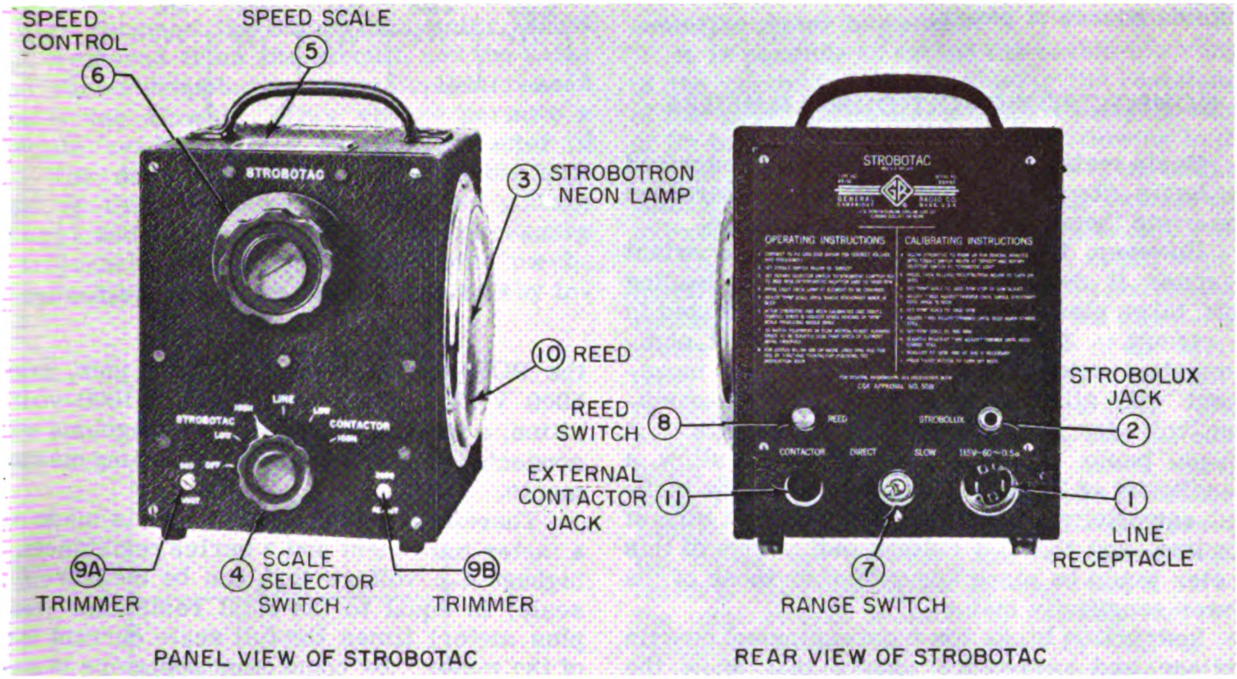



**Figure 2-5.—Strobotac.**

will not flash. Flickering is another symptom of low cathode emission.

It is sometimes possible to restore operation by running the tube at low speeds for several hours. Eventually, however, the tube becomes completely inoperative and must be replaced.

### PRECAUTIONS (FREQUENCY)

The Strobotac is standardized, in terms of the a-c line frequency, by using a metal reed that projects through the lamp reflector. This reed is driven from the a-c power line, and with a 60-cycle supply vibrates 7200 times per minute, or twice for each cycle of line voltage. When the Strobotac flashing rate corresponds to the reed vibration rate, a multiple of it, or a submultiple of it, the reed will appear to stand still. The points on the Strobotac dial at which this occurs can then be used to standardize the dial calibration. The absolute accuracy of this calibration depends on the accuracy to which the line frequency is maintained at the power plant.

If the line frequency is other than 60 cps, it will be necessary to calibrate the instrument according to the calibrating instructions on the back of the case.

## Multimeters

The I.C. Electrician measures voltage, resistance, and current many times during the performance of his duties. Some equipments have the necessary meters built in. Other equipments have jacks permanently connected to give access to the circuits for measurement purposes. Usually, a portable meter is connected to the jacks to measure electrical values.

Separate meters could be used for d-c voltage, a-c voltage, d-c resistance, direct current, and alternating current measurements. However, a separate meter for each type of measurement would require a large number of meters. Because the same meter movement will serve for all types of measurements, an instrument, called a multimeter, has been developed. This meter is easily portable and does not require an outside source of power.

## NONELECTRONIC VOLT-OHM-AMMETERS

Basic meter movements have been described in *Basic Electricity*, NavPers 10086; therefore the basic theory will not be repeated here.

However, the meter sensitivity is important because it determines the amount of loading that takes place when the meter is connected in a circuit. A nonelectronic VOA (volt-ohm-ammeter) using a 0-1-ma basic meter movement will allow a sensitivity of 1000-ohms-per-volt for d-c voltage measurements. A 50-μa basic meter movement will allow a sensitivity of 20,000-ohms-per-volt. The highest sensitivity meter will give the least circuit loading, and the d-c voltage indications of this meter would be more accurate than those of the lower sensitivity meter.

Instruction books for most equipment contain voltage and resistance charts that show the values to be expected at various terminals. These charts usually show the sensitivity of the meter used in obtaining the values. If the meter you use has lower sensitivity than the meter used to obtain the chart values, you can expect lower voltages. If your meter has higher sensitivity, the values measured will be higher than those shown on the chart.

### DESCRIPTION

A selector switch provides a means of switching in various functions and ranges. Figure 2-6 shows the schematic diagram for a simple d-c voltmeter that has six voltage ranges and a sensitivity of 20,000-ohms-per-volt. The 2-k resistance shown between meter terminals is the internal resistance of the meter. This resistance must be taken into account when the amount of series resistance needed to give full scale meter deflection at the desired voltage value is determined.

When leads are connected to the jacks, marked POS and NEG, and S1 is in the 2.5-volt position, the total resistance connected to a voltage source will be 50 k. Moving S1 to the 10-volt position adds another 150 k to the circuit, and the total resistance connected to a voltage source will be 200 k. For 5000-volt measurements, the test lead is removed from

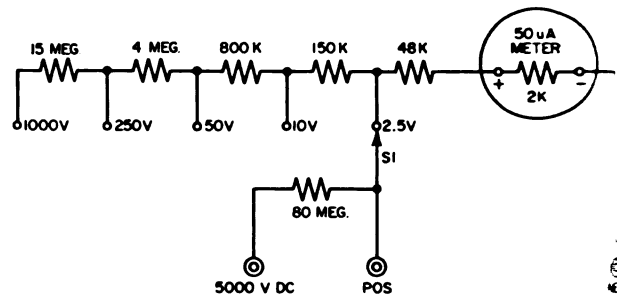



Figure 2-6.—Simplified diagram, d-c voltmeter.

the POS jack and connected to the jack, marked 5000 V DC. Then, with S1 in the 1000-volt position, a total resistance of 100 megohms will be connected to the voltage source during measurements.

Therefore, any d-c voltmeter is made up of a meter movement and a series resistance. The highest d-c voltage that can be measured (full scale) is equal to the total resistance (series plus meter) times the full scale current rating of the meter. By connecting resistors in series and then tapping in different values with a switch, the same meter movement can be used for several ranges. Normally the meter scale is marked for one or two ranges and a scale multiplier used for other ranges.

The ohmmeter section of the multimeter is used to measure resistance. Ohmmeters are of two separate types: series and shunt. In the series type (fig. 2-7A) the unknown resistance is connected in series with the meter circuit. In the shunt type (fig. 2-7B) the unknown resistance is in shunt with the meter circuit.

In the series type ohmmeter, midscale deflection is obtained when the current drawn by the meter is one-half the value of the current at full-scale (zero ohms) deflection, and this condition exists when the resistance being measured is equal to the total meter circuit resistance. Full-scale meter deflection takes place when the meter probes (fig. 2-7A) are shorted together. The zero adjust resistance permits the meter pointer to be adjusted to full scale with the probes shorted, and thus compensates for battery aging. If an unknown resistance value is connected at X (fig. 2-7A) the meter will read less than full scale.

The series ohmmeter scale is nonlinear, and the values are compressed near the meter zero (infinite ohms) value. Greatest accuracy occurs near midscale. The meter shunt, Rs (fig. 2-7A) limits the current through the meter or low resistance measurements. To extend the high range of the series ohmmeter, shunt Rs is removed from the circuit, and the value of the series dropping resistor, Rc, is increased (usually ten times). This change permits a midscale reading with a multiplying factor of 10. The only limitations on the usable high range of the ohmmeter are the fixed voltage (battery) and the sensitivity (current necessary for full-scale deflection) of the meter mechanism. A higher range can be obtained by increasing the battery voltage or by using a more sensitive meter movement.

It is possible to extend the usable low range of the ohmmeter by decreasing the resistance of the meter shunt, Rs, and decreasing the value of Rc to a point where the current flowing in the circuit and the internal resistance of the battery limit the range. However, possible damage due to excessive current could result to components.

The shunt-type ohmmeter (fig. 2-7B) is primarily used for measurement of low and medium resistance values. The scale of the shunt-type meter is calibrated in the reverse of the series type. That is, full scale deflection of the meter is obtained with the probes separated. Midscale deflection occurs when one-half the combined parallel resistance of the meter and the shunt Rs are equal to Rx, the unknown resistance. Limitations that prevent a further decrease in the range are the internal resistance of the battery, which becomes an appreciable part of the total circuit resistance, causing errors in readings to increase with battery age; the excessive current drain, which decreases the life of the battery and could cause damage to components under test; and the resistance of the test leads and contacts.

Figure 2-8 shows the schematic diagram of an ammeter section in a representative multimeter. It uses shunt resistors to provide current ranges of 100 $\mu$a, 10 $\mu$a, 100 ma, 500 ma, and 10 amperes. Notice that the resistance of the shunt decreases, bypassing a larger amount of current around the meter movement, as the higher current ranges are used. On the 100-$\mu$a range, the current flow is equally divided between the meter and the shunt. When very high

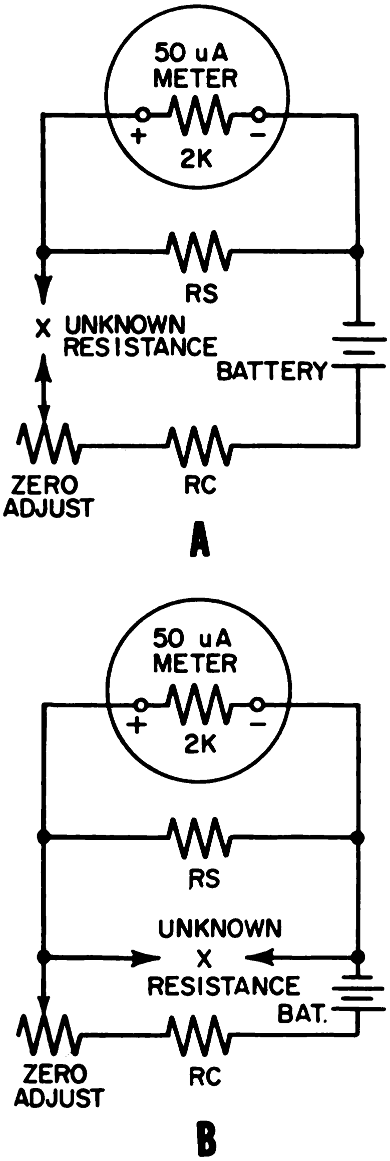



Figure 2-7.—Series and shunt ohmmeters.

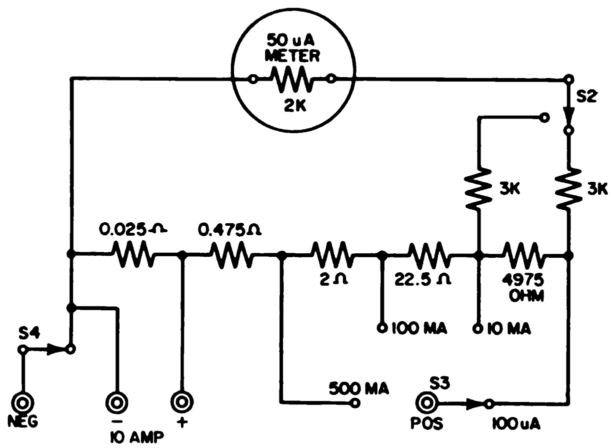



Figure 2-8.—Ammeter section.

values of current are to be measured, provisions must be made to reduce or eliminate switch contact resistance, which may be appreciably greater than the shunt resistance involved, and therefore cause inaccurate readings. Switch contact resistance is eliminated on the 10-ampere range of the circuit in figure 2-8 by using separate jacks for connection of the leads.

Our discussion of multimeters has thus far been confined to d-c measurements. When a-c voltages are to be measured, it is necessary to rectify the voltage before applying it to the meter. Figure 2-9 shows an a-c voltmeter with the same ranges as the d-c voltmeter in figure 2-6. Two copper oxide rectifiers are used. One rectifier unit supplies half-wave output to the meter. The other rectifier unit bypasses the meter on alternate half cycles of the a-c input so that the front-to-back ratio (forward-to-reverse resistance) of the meter circuit can be maintained when multipliers are switched into the circuit.

The front-to-back ratio of a good rectifier unit is approximately 1000 to 1. If the rectifier unit were the only component in series with the meter, the current ratio would be approximately 1000 to 1. If a 10 k resistor is connected in series with the meter and a single rectifier, the front-to-back ratio of the circuit as a whole would be approximately 10,000 to 11,000, or about 1 to 1. The amount of conduction would be practically the same in both directions, and there would be no resultant deflection of the meter.

By adding a second rectifier unit to the circuit, the reverse current will flow around (instead of through) the meter, and the front-to-back ratio of the meter circuit will be maintained very close to the original ratio (1000 to 1.) Unless the second rectifier unit is used, the meter will not operate when the voltage multipliers are switched to select one of the voltage ranges. The series-calibrating resistor and the shunt-calibrating resistor are precision units and must be calibrated for the rectifier unit with which they are used. The sensitivity for a-c measurements is 1000-ohms-per-volt.

This completes the description of the individual sections of the multimeter. When all sections are incorporated into one unit, switching is accomplished by a multiposition, multipole switch.

## USE

A multimeter of the type just described can be used for most of the measurements that an I.C. Electrician will be called upon to make. Connections to various test points are normally made with test leads. Before you attempt to use a multimeter for tests, be sure the ranges are suitable and that the connection of the meter will not upset the circuit operation.

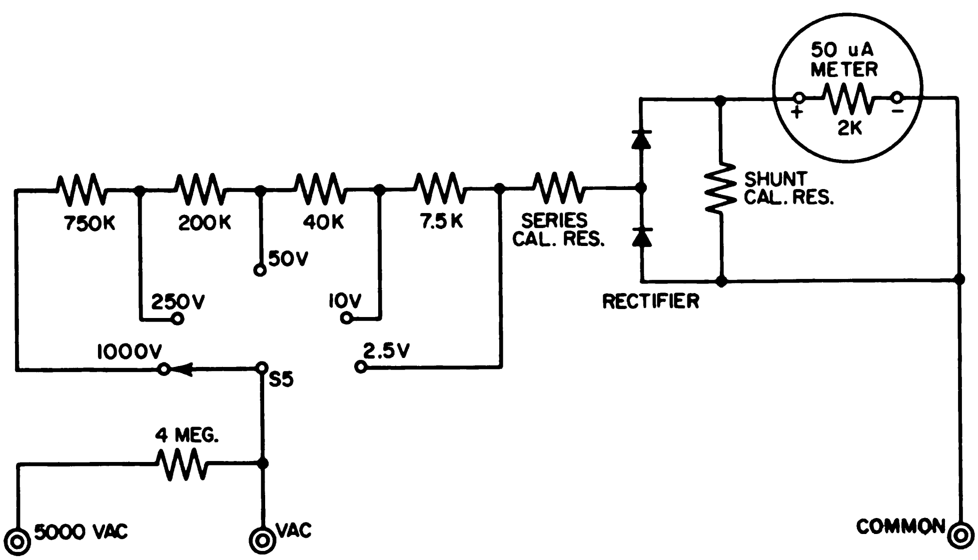



Figure 2-9.—A-c voltmeter.

## PREVENTIVE MAINTENANCE

Replacement of the ohmmeter battery is the only maintenance required for the multimeter. It is extremely important that the battery deliver rated voltage when resistance measurements are to be made. Because high current is drawn from the battery during low resistance measurements, the meter should not be connected to such circuits for periods longer than that required for the measurement. In making zero adjustments, leave the test leads shorted only long enough to make any necessary correction.

## SAFETY PRECAUTIONS

Never touch exposed metal tips of test leads or the meter pointer adjusting screw while the meter is connected to an electrical circuit.

If leads are to be connected to parts of a circuit that are above 300 volts, the circuit should be deenergized before the leads are connected. After the leads are connected, turn the circuit on long enough to make the measurement, and then turn it off again to disconnect the leads.

Most test leads have insulated probe handles that protect the operator when he is making spot checks of voltage at specific circuit points. The probes should always be held by the insulated handles, and extreme care should be used to keep the fingers from touching the exposed metal tips.

If you do not know the approximate voltage that should be present at test points, switch the meter to the highest range. Then, if you see that a lower range will give a more accurate indication, disconnect the test leads and switch to a lower range. It is necessary to disconnect the leads to avoid burning switch contacts. This is particularly true in the case of current measurements.

Never disconnect test leads at the multimeter and never leave the other ends of the leads connected to the circuit test points.

Never use the ohmmeter section on a circuit that is energized.

# ELECTRONIC VOLT-OHM-AMMETERS

In the discussion of nonelectronic volt-ohm-ammeters, we brought out the fact that the meter would load the circuit under test. The sensitivity of the meter governed the amount of loading. From these facts it may be reasoned that the higher the meter sensitivity the greater the accuracy and the smaller the circuit loading. However, this is not always true.

## VOLTMETER ERRORS

Most meters used in multimeters have a full-scale accuracy of ±2 percent. At less than full scale the error becomes greater as zero is approached. Another source of error is in the tolerance of series and shunt resistors. Low cost multimeters may use resistors with 5 percent tolerance, which means they may be as much as 5 percent above or below the marked value. If the tolerance of the meter and the tolerances of the resistors were all at the high limit, the meter would indicate considerably more voltage than was actually present.

Generally the cost of the meter furnishes a clue to its accuracy. Precision resistors are expensive, which greatly increases the cost of the finished product. However, the use of precision resistors does not lessen the loading problem, which led to the development of an electron tube type of voltmeter.

## ELECTRON TUBE VOLTMETER

Figure 2-10 is the block diagram of the AN/USM-34 Multimeter. It is an electron tube type device that can be used for the measurement of peak-to-peak and rms voltages; d-c voltmeter, ohmmeter, and milliammeter that can be used to make voltage resistance, and current measurements; r-f voltage measurements from 1 kc to 100 mc; a-c measurements from 50 cps to 50 kc; and current measurements up to 1000 ma.

The meter circuit (fig. 2-10) is the heart of the instrument. Two dual triode tubes are used in an electronic bridge circuit. Voltages are applied to the grid of one tube, and the meter is connected in the plate circuits so that its deflection is proportional to the voltage applied to the grid. The second dual triode tube is connected as a cathode follower to isolate the meter circuit from the voltage divider.

The voltage divider network (fig. 2-10) is used to divide the input voltage so that only a small portion will be applied to the grid of the tube, regardless of the type of measurement being made.

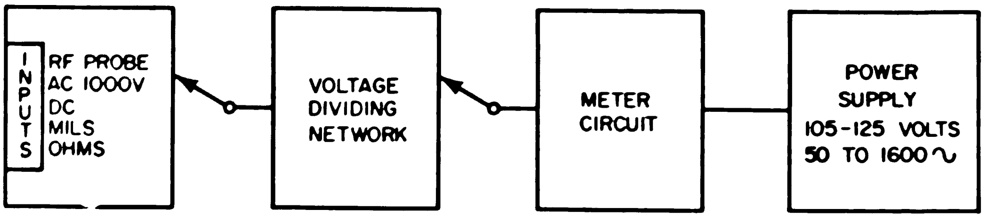



Figure 2-10.—Block diagram, AN/USM-34 Multimeter.

The r-f voltmeter uses a probe containing a miniature diode tube as a rectifier. The probe is connected at the point of measurement. The radio frequency is then rectified and filtered before it is fed through the cable to the meter section. Thus, only d-c voltage is applied to the voltage divider. At high frequencies, this action prevents standing waves on the cable. The probe components and voltage divider sections are chosen to show the rms value of the r-f voltages being measured.

The a-c voltmeter section will handle voltages up to 1000 volts. Voltages from this section are applied to a tube through a voltage divider. The tube is connected as a voltage doubler, and the resulting d-c voltage is applied to the metering circuit through a voltage divider. Calibration of the meter circuit is such that an indication is based on the peak-to-peak value of a-c voltage being measured.

In the ohmmeter circuit, the 6.3-volt, a-c filament voltage is rectified by a selenium unit, and the d-c output is used in connection with a voltage-dividing network to permit the measurement of resistances throughout the range of the equipment. The voltage output from this dividing network is applied to the metering circuits and the indication made proportional to the value of the resistance being measured.

Current readings up to 1000 ma are made by measuring the voltage drop across the calibrated shunts. The voltage across the shunt is then applied to the input of the meter circuit. The OHMS-MILS-AC VOLTS probe and COMMON leads are used for current measurement.

The power supply section contains a selenium rectifier (used as a half-wave rectifier) to supply d-c operating voltages to the metering circuit. A 6.3-volt filament winding supplies the pilot light and the filament voltages for the tubes as well as the a-c voltage rectified and used in the ohmmeter circuit for resistance measurements. The primary winding of this transformer is protected by fuses located on the front panel for easy access. A ballast tube is used in series with the line and primary winding to maintain a more nearly constant input voltage to the primary.

## CIRCUIT ANALYSIS

Figure 2-11 shows the basic meter circuit for all measurements. A dual triode, V1, is connected as a cathode follower and another dual triode, V2, is connected in a bridge circuit. With no voltage applied to the grid of V1A the zero adjust control, R8, is set so the meter reads zero. With a negative voltage applied to the grid of V1A, there is a decrease in current through that triode section, and the cathode voltage decreases. The cathode of V1A is directly coupled to the grid of V2B. Therefore, the decrease in voltage at the cathode of V1A causes a decrease in the positive voltage at the grid of V2B, and the current through V2B decreases. The decrease in current through V2B causes an increase in the voltage at the plate of V2B and a decrease in the voltage across R4. The decrease in voltage across R4 decreases the negative bias of V2A (the drop across R2 is constant), and the V2A plate current increases. Thus, the V2A plate voltage decreases. The combination of an increase in the plate voltage of V2B and a decrease in the plate voltage of V2A causes an unbalance, and current flows through the meter, causing it to read upscale. If a positive voltage were applied to the grid of V1A, the meter would read in the reverse direction.

The grid of V2A is connected to the cathode of V1B. This is done in order that fluctuation in the B voltage will affect both sections of V2 in the same manner. Thus, errors due to a difference in potential on the two grids with no signal applied are prevented. This eliminates the need for readjusting the zero set should a variation in B+ occur.

Separate calibration resistors are used for calibration of +d-c, -d-c, a-c, r-f volts, and

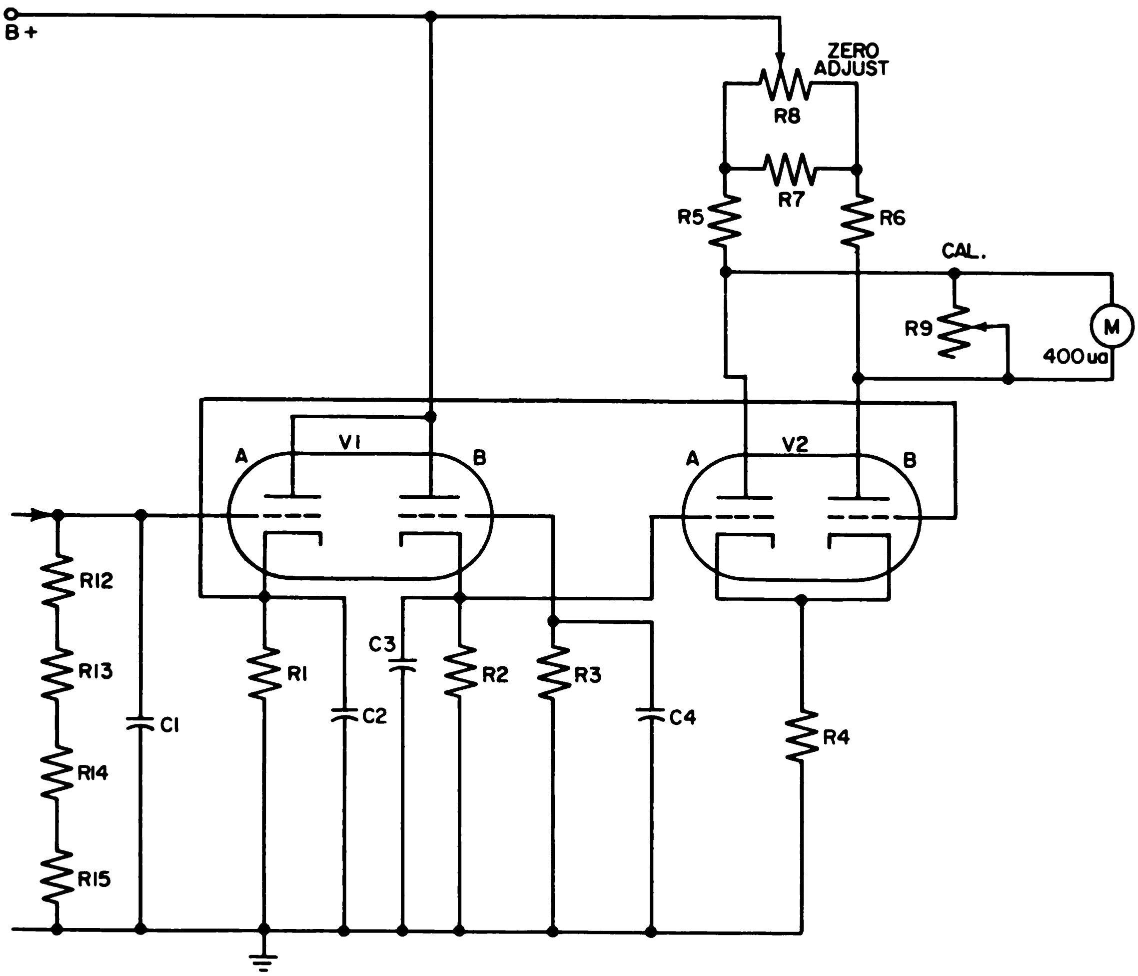



Figure 2-11.–Basic meter circuit.

MILS measurements. Therefore, the ohmic value of R9 depends upon the position of the function selector switch.

The purpose of C1 (fig. 2-11) is to prevent any stray r-f from reaching the meter circuit and affecting the calibration.

## D-C VOLTMETER CIRCUIT

D-c voltages up to 1000 volts are applied directly through the d-c probe (fig. 2-12). R11 is an isolating resistor to prevent capacitive loading of the circuits under test. A separate high voltage multiplier (h-v probe) may be screwed on the end of the d-c probe for 3000-volt, d-c measurements. Voltages to be measured are applied to the voltage divider network made up of R12, R13, R14, and R15. Voltages are selected from this network by S1 and applied through S1 to the grid of V1A (fig. 2-11). Negative d-c voltages are measured by reversing the meter by means of S2.

## R-F VOLTMETER CIRCUIT

A-c voltages up to 100 volts may be measured by using the r-f probe (fig. 2-13) in circuits where capacitance cannot be tolerated. Generally, the r-f probe should be used for the measurement of a-c voltages ranging in frequency from about 1 kc to 100 mc. The r-f probe (fig. 2-13) contains a coupling capacitor, C5, that blocks the d-c voltage, which is present at the point of measurement; a diode, V3, that serves as a half wave rectifier; and a resistor, R18, that provides decoupling and some filtering. The d-c output of the probe is applied to the voltage dividing-network composed of R21, R19,

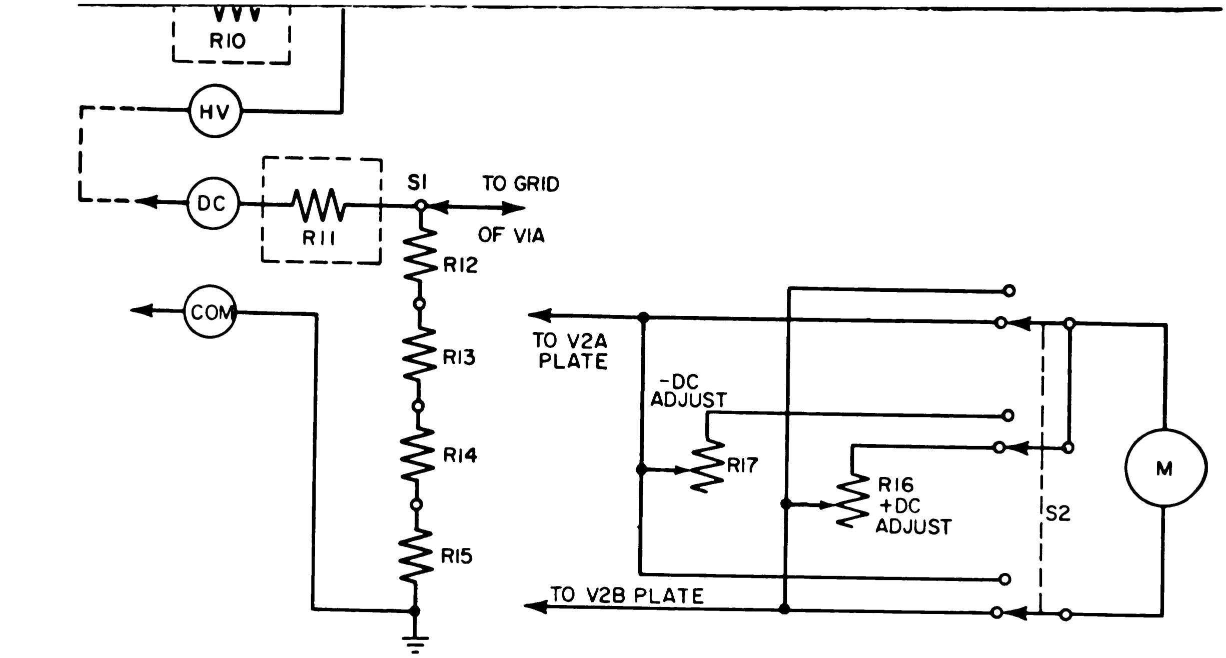



Figure 2-12.—D-c voltmeter circuit.

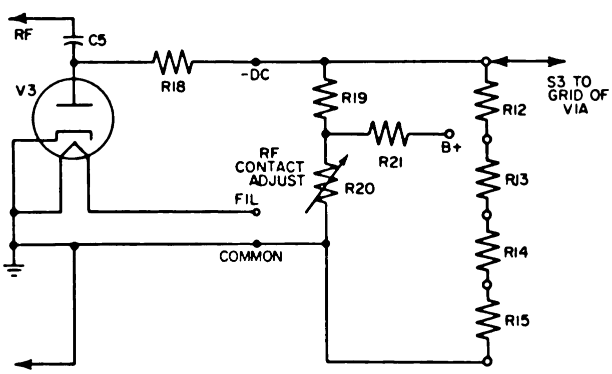



Figure 2-13.—R-f probe circuit.

and R20. R20 is adjusted so that a bucking voltage balances out the contact potential developed at the plate of V3. Therefore, it is not usually necessary to readjust R8 (fig. 2-11) when changing ranges.

## A-C VOLTMETER CIRCUIT

A-c voltages up to 1000 volts may be measured with the use of the OHMS-MILS-AC VOLTS probe circuit shown schematically in figure 2-14A. The probe may be used for a-c measurements from 50 cps to 50 kc. A-c voltage is applied through C6 to a first voltage dividing network (R26, R27). No voltage division takes place on the X1, X10, and X100 positions, but full voltage is applied to V4, which is connected in a voltage doubler circuit.

Assume that the positive portion of the a-c voltage being tested appears across the input during the first half cycle. During this time, C6 charges to the peak value of the voltage under test through V4A and with a negative polarity on the right-hand plate. C6 remains charged at this peak value during the next half cycle. During the same (negative) half cycle, the peak voltage applied to the input is in series addition with the voltage across C6, and the V4A plate is negative. V4A acts as an open circuit at the same time the V4B plate is positive, V4B conducts, and C9 charges with the upper plate negative to twice the peak value of the voltage under test. This value is equal to the peak-to-peak voltage under test. This d-c potential is then applied to the grid of V1A through a series of voltage dividers, depending upon the range being used.

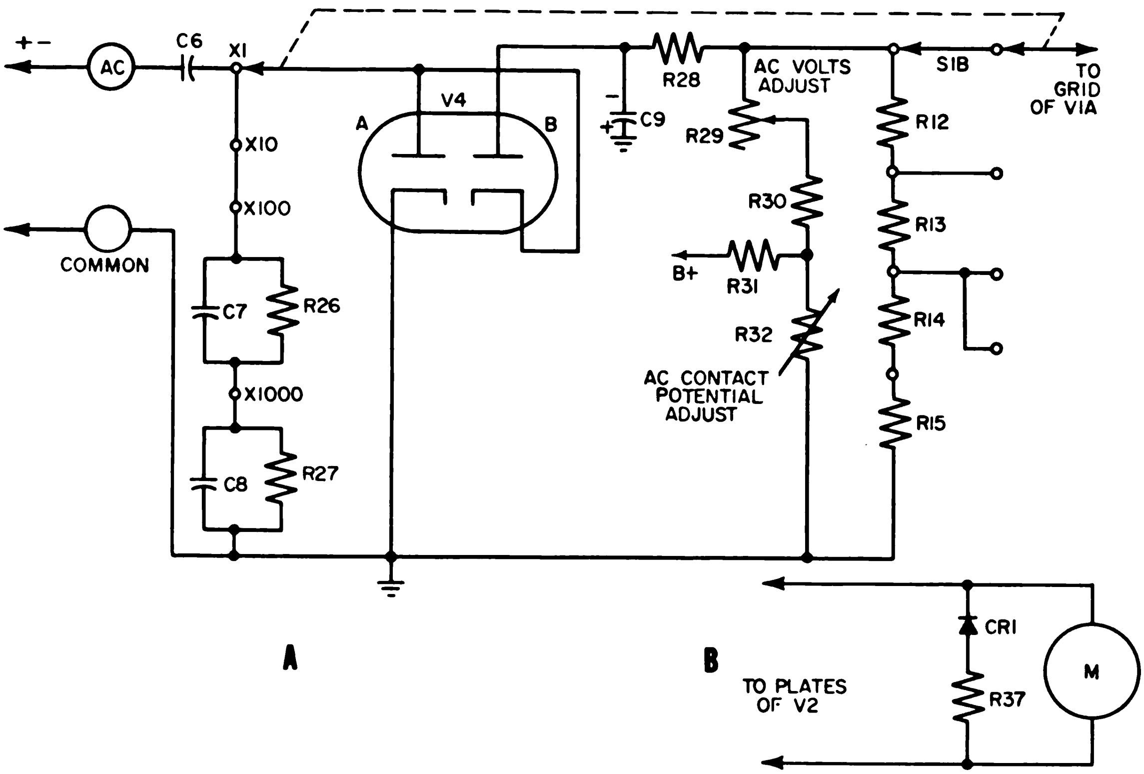



Figure 2-14.—OHMS-MILS-AC VOLTS probe circuit.

Because of the direct relationship between rms and peak-to-peak values of a sine wave (rms is peak-to-peak divided by 2.82) when the a-c input is a sine wave, the rms value may be read on the 0-1-volt scale, using the same multiplier as the peak-to-peak range. If the wave is nonsinusoidal, the rms indication will not be correct. However, only peak-to-peak indications are important for this waveform.

A bucking voltage is applied at the top end of S1B to the tap between R29 and R12 to neutralize contact potential at the V4B plate. Contact potential causes electron flow through V4 even though no voltage is being applied at the probes. This action makes the V4B plate slightly negative to ground. The magnitude of the contact potential varies with the amount of resistance connected between the V4A plate and ground. Changing the a-c range may change the magnitude of this resistance and thus change the amount of contact potential. R32 is adjusted so that the contact potential developed at the plate of V4B is effectively bucked out. As a result, it is unnecessary to readjust the zero adjust control (R8, figure 2-11) when changing ranges. The probes should be shorted when adjusting R32 to prevent any stray pickup of voltage. The meter curve correction circuit (fig. 2-14B) corrects the curve on the X10 range for r-f and a-c voltage measurements.

## OHMMETER CIRCUIT

The OHMS-MILS-AC VOLTS probe and the COMMON leads are used for resistance measurements.

Figure 2-15 shows the schematic diagram for the ohmmeter power supply circuit. The power supply composed of T1, CR2, R42, R43, and C10 supplies a negative one and one-half volt potential through a series of reference resistors (R39, R40, and R41) to the grid of V1A. The reference resistor in use is determined by the position of the range selector switch, S1C.

Any unknown resistor placed across the ohms and common test leads would provide for a return to ground for the negative potential on the grid of V1A and divide this voltage in proportion to the ratio of the reference resistors being used and the unknown resistor. R44 (fig. 2-15B) is the full-scale ohms adjustment.

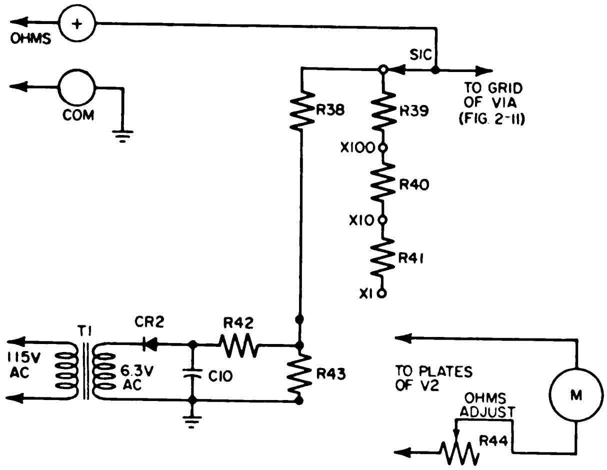



Figure 2-15.—Ohmmeter power supply circuit.

MILLIAMMETER CIRCUIT

The milliammeter circuit (fig. 2-16A) will measure current to 1000 ma. Current is applied to the voltage divider circuit, and the resulting voltage drop is fed to the grid of V1A of the meter circuit. The meter, M, is not connected directly into the circuit as a milliammeter, and therefore excessive currents accidentally applied will not damage the meter. Figure 2-16B, shows the full-scale mils adjust, R50, which is used to properly calibrate the meter for current measurements.

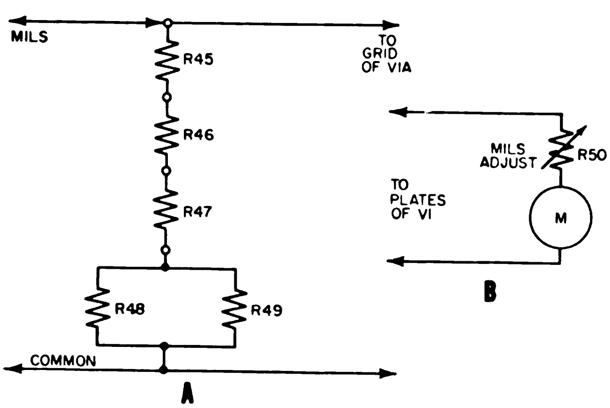



Figure 2-16.—Milliammeter circuit.

POWER SUPPLY CIRCUIT

All operating voltages, including the a-c supply for the ohmmeter circuit, are obtained for the power supply (fig. 2-17). No batteries are required. The primary of T1 is connected to the 115-volt supply line through fuses F1, F2; on-off switch (S4), and the ballast resistor. The ballast tube maintains the primary voltage at approximately 95 volts.

The selenium rectifier, CR3, serves as a half-wave rectifier to rectify the output of the high voltage secondary of T1. C11 and R51 filter the output of CR3. R30, R31, and R32 form a voltage divider network for the a-c contact potential bucking voltage. As previously mentioned, R32 is adjustable in order that the meter can be adjusted to zero before making a-c measurements. R55, R56, and R57 form another voltage divider used to balance out contact potentials before making r-f voltage measurements. R57 is the variable element of this divider.

The single, 6.3-volt secondary winding supplies enough current to operate the pilot lamp, tube filaments, and the ohmmeter d-c supply circuit.

The AN/USM-34 is designed to operate from any supply line that will furnish an a-c voltage between 105 and 125 volts at any frequency between 50 and 1000 cycles.

MAINTENANCE

Maintenance of the AN/USM-34 Electronic Multimeter consists of periodic inspection, checking, cleaning and tightening of contacts and components. No lubrication is required.

Before starting any cleaning, the power cable should be disconnected from the source of power. After the instrument has been removed from its case, the capacitors should be discharged, using approved discharging tongs.

The chassis may be cleaned by blowing it out with dry compressed air or by using a clean, dry cloth and a soft, dry paint brush of suitable size. It may be necessary to use dry-cleaning solvent (14OF) to clean ceramic high voltage insulators. A clean, soft cloth should be moistened with the solvent and then rubbed over the surface to be cleaned. The dry cleaning solvent should not be used on the chassis because of the danger of softening the tropicalizing paint on the chassis. All dust should be completely removed from the inside and outside of the chassis.

A careful inspection should be made during the cleaning operation. Cleaning sometimes

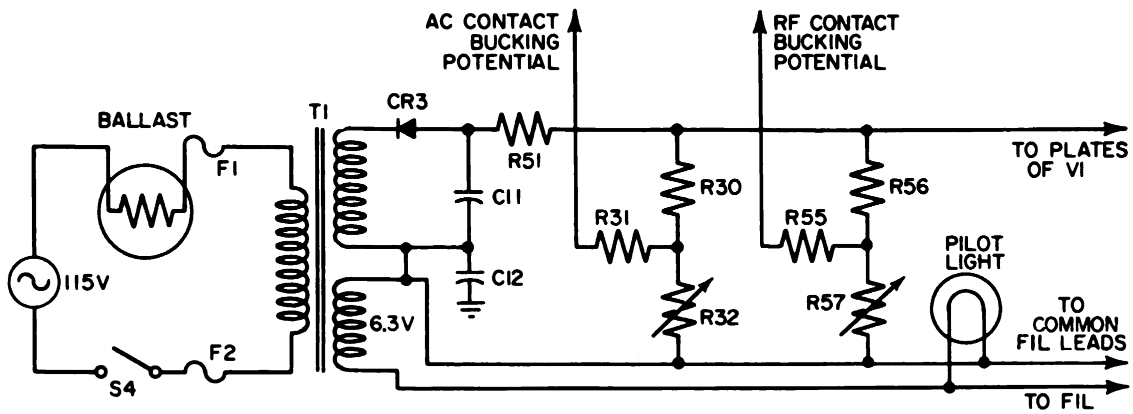



Figure 2-17.—Power supply circuit.

breaks or loosens a connection. All exposed lug and screw connections, plug and socket connections, and electron tube pins should be checked for tightness. Cable ends should be properly dressed to prevent short circuits or strain on wires and lugs.

During the inspection you should look for evidences of heating or breakdown such as carbonized surfaces, over-heated resistors with discolored surfaces, and discolored metal parts. Any of these can cause a breakdown later on. Therefore, it is to your advantage to eliminate possible trouble spots as soon as they are known.

All knobs should be checked for loose set screws. The set screws should be kept tight because loose knobs may fail to turn the shaft on which they are mounted and thus give the impression of a faulty control.

Rough handling will sometimes jar parts or wires out of position or wear through insulation. Any such damage should be repaired. Rust or corrosion on painted surfaces should be cleaned and sanded smooth, and the spot covered with touchup paint. Unpainted surfaces will not ordinarily corrode unless exposed to salt water or some other corrosive agent. If corrosion occurs, it should be cleaned off thoroughly, taking care not to let scrapings fall into the unit. The cleaned spot should then be touched up with clear varnish or tropicalizing paint. Paint or varnish should not be used close to switch or tube socket contacts.

Compressed air or a brush will usually serve to remove dust from tubes. Be sure to clean tubes that operate at high temperatures because a layer of dust will act as an insulator and interfere with heat radiation from the tube. This raises the operating temperature and may cause damage. After cleaning the tubes, make sure they are properly seated in their sockets and all tube clamps locked. Any dirt or corrosion found around tube socket pins should be removed with crocus cloth.

Fuses should be removed and checked for corrosion and looseness, either of which can cause trouble. A clean cloth moistened with dry-cleaning solvent will usually suffice for cleaning the fuses and clips. However, in some cases, it may be necessary to use crocus cloth or fine sandpaper. When replacing the fuses, make sure they are tight in their clips.

## SAFETY PRECAUTIONS

The safety rules given for the use of the nonelectronic multimeter apply to the electronic multimeter as well. In addition, some other rules apply to the electronic multimeter. Both radio frequency and audio voltage can cause painful injury or death. Many people do not realize it but an audio voltage of 115 volts, 60 cycles has exactly the same characteristics as the usual power line. Radio-frequency voltages are of a higher frequency and tend to travel on the surface of the skin so that painful burns are produced. Therefore, audio and r-f voltages must be treated just the same as conventional a-c and d-c voltages.

# Megger

A megger is a special type of ohmmeter. It is widely used to measure insulation resistance, such as the resistances between windings and the frame of electric machinery, and the insulation resistance of cables, insulators, and bushings.

The megger may consist of a hand-driven, d-c generator and a permanent-magnet, moving-coil type of meter without control springs having a divided circuit (fig. 2-18). A true megohmmeter measures resistance independently of the test voltage and requires no adjustment.

The permanent magnet provides the field for both the generator and the ohmmeter. The moving element of the ohmmeter consists of two coils, A and B, positioned so that they develop opposing torques. These coils are mounted rigidly on a pivoted shaft, which is free to rotate over a stationary, C-shaped iron core. Coil B is connected in series with resistance R across the generator, G. Coil A is connected in series with resistance R' between one generator terminal and the line terminal.

When the generator is operated with the terminals open (corresponding to infinite resistance) no current flows through coil A. The current through coil B causes the coil to align its axis with the main field. This action moves the pointer to the extreme counterclockwise, or infinite-resistance, position on the scale. Thus, coil B governs the movement of the moving element on open circuit.

When the generator is operated with the terminals short-circuited (corresponding to zero-external resistance) the current through coil A produces a torque in the opposite direction, which overcomes the torque of coil B. This new torque moves the pointer to the extreme clockwise, or zero-resistance, position on the scale. Resistor R' prevents an excessive flow of current through coil A under this condition.

When an unknown resistance is connected between the terminals, the opposing torques of coils A and B balance each other so that the pointer comes to rest at some intermediate point on the scale, directly indicating the value of the resistance being measured. The moving element may rest in any position over the scale when the generator is not operated because no restoring force is exerted upon the moving element. The guard ring prevents errors in reading caused by leakage currents between the terminals.

Meggers provided aboard ship usually are rated at 500 volts. To avoid excessive test voltages, most meggers are equipped with friction clutches. When the generator is cranked faster than its rated speed, the clutch slips, and the generator speed and output voltage are not permitted to exceed their rated values.

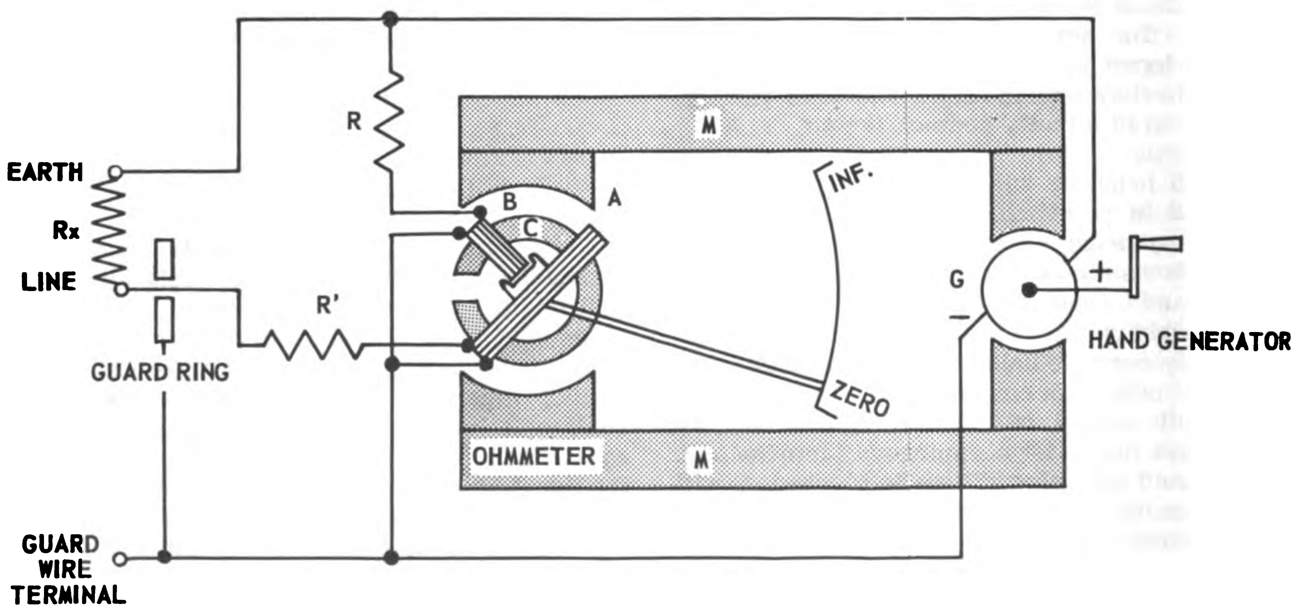



Figure 2-18.—Megger.

### USE

The megger is used only on deenergized circuits. It is used principally to (1) measure the insulation resistance from an electric circuit to ground, (2) measure the insulation resistance between two separate conductors or circuits, and (3) test the continuity of a circuit. The test leads of the megger are well insulated to prevent leakage of currents, and the terminals of the test leads usually have spring clips or pointed prods. Before using the megger, these leads are shorted together while the megger crank is turned. A zero reading indicates that the leads and megger are in good condition. In testing for grounds in a machine, it is first necessary to ground one of the megger test leads.

To test the ground connection of this test lead (1) connect one test lead to the bare metal of the ship's hull, and (2) touch the other lead to another bare section of the ship's hull while cranking the megger. A zero reading on the meter indicates a good ground connection.

To test a circuit for grounds (1) deenergize the circuit, (2) connect one megger test lead to ground, (3) connect the other lead to a test point in the circuit, and (4) crank the megger at its rated speed until a steady reading is obtained. This reading is the insulation resistance in ohms between the part of the circuit under test and ground.

To test a cable for continuity (1) disconnect the cable at both ends and ground all of the conductors at one end, and (2) at the other end of the cable, take megger readings between each conductor and ground. A zero reading indicates that there are no breaks or opens in the conductor, whereas a high-resistance reading indicates an open of high-resistance connection in the conductor.

To test the insulation resistance between the conductors of a cable (1) disconnect the cable at both ends, (2) arrange the ends of the cable so they do not touch each other, (3) take a megger reading between one conductor and all the other conductors twisted together, and (4) repeat this test for each conductor in the cable. A reading of several megohms on the megger indicates that the insulation between the conductors in the cable is in satisfactory condition. Test the faulty wire against the remaining conductors, one at a time, to isolate the shorted conductors. In some cases, it may be necessary to pull in a completely new cable in order to remedy the short circuit. In other cases, the cable may contain spare or unused wires that can be used to replace the defective conductors.

## Tube Testers

Although rigid controls reduce tube failures considerably, tube testers provide some means of determining the condition of tubes that have been in use for some time, as well as the condition of new tubes that are to be placed in equipment. The Electron Tube Test Set TV-10A/U is used for these tests.

Tube tests are classed according to method. The two principal methods are the mutual conductance test and emission test. The type TV-10A/U tube tester employs the dynamic mutual conductance test method. The mutual conductance is the ratio of the change in plate current to the change in grid potential producing it, under the condition of constant plate voltage. Mutual conductance is expressed in micromhos, and the condition of the tube is indicated on the meter scale directly in micromhos. The symbol, Gm, is used to represent mutual conductance in various mathematical representations of tube characteristics.

In addition to the mutual conductance test, the tube tester must provide a means of testing for short circuits between elements and for excessive gas content.

In the case of tubes of the diode type (tubes having no grid) it is necessary to use a straight emission test instead of a mutual conductance test.

Some means of adjusting the voltage input to the tester must be provided to maintain the proper test potentials at all tube elements under varying conditions of line voltage. All of the requirements are taken care of by the circuitry in the Model TV-10A/U Tube Tester.

### DESCRIPTION

The block diagram (fig. 2-19) shows the sections of the complete tube tester. The power source may be any line that furnishes 105 to

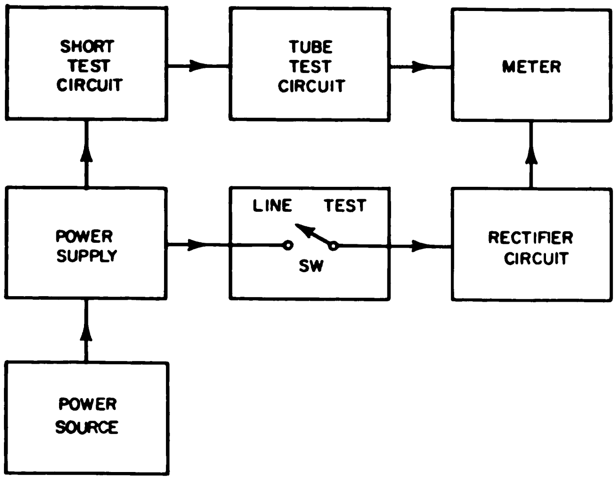



Figure 2-19.—Block diagram, tube tester.

125 volts at any frequency between 50 and 1000 cps. The power supply section contains a transformer that has seven secondary windings in addition to the primary winding. One of these secondaries is tapped at several points to supply the filament voltage for all types of tubes. Other secondary windings supply filament and plate voltages to rectifier tubes in the tester. The d-c output of these tubes is used for the electrode supply voltages for tubes under test.

The line test is used to adjust the meter indication to the line voltage. Normally, with the meter pointer over the line test mark, the rms voltage across the transformer primary will be 93 volts.

The rectifier circuit is used to test rectifier tubes and diode detector tubes. Only an emission test is required, and the circuitry of this section is very simple.

The short test circuit is used to detect short circuits and leakage between tube elements.

The tube test section applies the proper d-c grid and plate voltages to the tube under test. An a-c voltage is applied in series with the grid bias to swing the grid in positive and negative directions from the d-c bias value, thereby producing the grid voltage required for a dynamic test.

The plate voltage is furnished by another full-wave rectifier. The meter is connected in the negative return of this circuit and indicates the change in plate current.

The gas test will show the presence of abnormal amounts of gas in tubes. In making this test, normal filament, grid, and plate voltages are applied to the tube to cause a definite value of plate current to flow. This current is shown on the meter. Pressing the gas test button inserts a resistance in series with the grid circuit. If grid current is flowing because of the presence of gas in the tube, a voltage drop will take place across the series resistor. This voltage drop will reduce the grid bias, and the plate current will rise. The rise will be shown by an increase in meter reading. A slight increase in meter reading (no more than one scale division) is permissible.

## USE

The TV-10A/U panel is shown in figure 2-20. The tube sockets are grouped along the top edge and in the upper left-hand section of the panel as follows: Along the top edge reading from the left are test sockets for SUBMINIATURE tubes; 7 pin MINIATURE tubes; 9 pin NOVAL base miniature tubes; LOCTAL and OCTAL tubes; a combination large and small radius socket for standard 7 pin tubes, which also provides a pilot lamp test receptacle; and sockets for standard 6, 5, and 4 pin tubes. An acorn tube socket designed to accommodate all tubes of this type now in use is located at the right of the filament voltage switch.

For tubes having top grid connections, top plate connections, or both, it is necessary to use the test leads supplied with the tester. Lighthouse tubes can be tested by using another test lead that has a special connector on one end. These test leads are kept in the cover of the case.

The fuse lamp serves both as a protective fuse and an overload indicator. This lamp will flash brightly when an overload is placed on the tube tester or on the tube under test. When this occurs, turn off the equipment immediately. A continued or excessive overload will, of course, burn out the fuse lamp, and a replacement will be necessary. A 1-ampere cartridge fuse protects the other side of the a-c line.

The bias fuse lamp protects the bias control. An accidental overload will cause the lamp to glow. If the lamp glows, turn the shorts-micromhos switch to position number 5 immediately. An overload due to a shorted tube is indicated. An excessive or prolonged overload will burn out the fuse lamp, and replacement will be necessary.

Power input to the tube tester is controlled by the power switch. The pilot lamp serves as an on-off indicator.

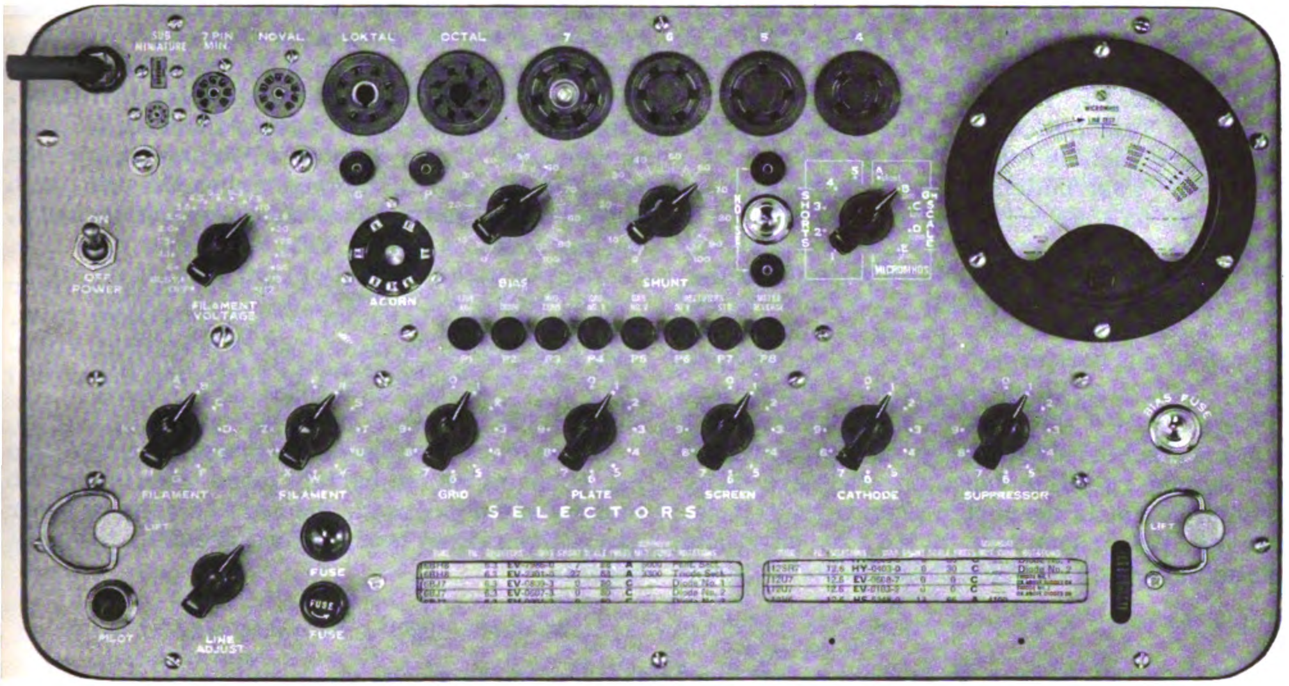



Figure 2-20.—Tube tester panel.

The line adjust controls the input voltage to the power transformer so that voltages for the tube test circuits are standardized.

The roll chart provides information regarding proper settings of the various controls. The chart is operated by a phenolic gear that protrudes through the panel in the lower right hand corner. Column headings on the panel above the index window provide easy reference to the tube test data printed on the roll chart.

The filament voltage switch selects the proper filament or heater voltages from 0.6 volts through 117 volts, alternating current in 18 steps. Another position on this switch, marked BLST provides for testing ballast tubes. An OFF position is also provided.

Proper switching of the internal circuits to apply correct test voltages to the various pins of the tube under test is provided by two filament voltage selectors; one grid, one plate, one screen, one cathode, and one suppressor selector.

The bias control is used to adjust the bias voltage to the proper value for the tube under test.

The shunt control is a potentiometer that controls the sensitivity of the meter circuit to the proper level for testing rectifier and diode type tubes.

The shorts-micromhos switch selects the proper range of mutual conductance in micromhos for the tube under test, as indicated on the roll chart. When this switch is set in the A, or SHUNT, position, the shunt potentiometer is connected into the circuit and must be set, as indicated by the chart. This position of the switch is used when testing rectifier or diode type tubes. The letters, A, B, C, D, and E, at the five positions of the micromhos switch indicate the meter scale on which the reading is to be made. In positions B, C, D, and E fixed shunt resistors are connected across the meter, and proper signal voltages are selected for the various ranges of micromhos. This switch also has five, short test positions, which connect the various elements of the tube under test to the short test circuit containing the neon indicator lamp.

Push button switches located in the center of the panel actuate the final circuit selector switches for the type of test to be made as follows:

(1) P1: Line adjust test button.
(2) P2: Test button for detector type diodes such as 6H6.

(3) P3: Red test button for mutual conductance test of amplifier tubes only. NEVER USE THIS BUTTON WHEN TESTING RECTIFIER TUBES.
(4) P4 and P5: Test buttons for gas test.
(5) P6: Test button for cold cathode rectifiers such as type OZ4.
(6) P7: Test button for rectifiers such as type 5Y3, 6X4, 83 etc.
(7) P8: Test button for reversing polarity of voltage applied to the meter when testing certain types of tubes.

### MAINTENANCE

It may become necessary to replace fuses, pilot lamps, rectifier tubes, or the neon short indicator lamp, in the tester from time to time. However, the proper use of the tube chart and instruction book will prevent accidental damage to tube tester components. The rectifier tubes in the tester should operate for a much longer time than the same type of tube used in continuous service. Failure of the type 83 rectifier tube can be detected without opening the case. This tube supplies plate voltage, and its failure is indicated if the pointer of the meter moves sharply off scale to the right when the red push button is pressed (with no tube in the test sockets, but the controls set for tube test).

The type 5Y3 rectifier tube furnishes d-c screen and bias voltages for the tube under test. The Instruction Book will show how these voltages can be checked without removing the panel from the case.

Dangerous voltages are present at the top cap connections for certain tubes when test push buttons are depressed. Be sure to remove your hands from these leads before pressing the test buttons.

## Review of Safety Precautions

Statistics show that at least 75 percent of all accidents are the result of carelessness. A careless moment can cause serious personal injury or death. Safety precautions are not something that has been thought up to make it tougher for you. Instead, they are designed to teach you to think and act in terms of safety. It is absolutely necessary that you think that every wire is carrying a lethal voltage. Never take it for granted that a circuit is deenergized; make sure by using approved test equipment before going to work.

Before using portable equipment, check the plug connections on the tool for correct wiring. This check is made by measuring the insulation of the tool by a resistance measuring instrument. Connect one instrument test lead to the exposed metal case of the tool and the other instrument lead to the ground contact of the plug. The reading should be zero ohms. Then, with one instrument lead still connected to the metal case, shift the other lead to either line contact of the plug. If the ground wire is connected properly, the normal insulation resistance indicated by the instrument will be well in excess of 1 megohm.

Repeat these tests with the instrument connected to the metal case of the tool and to the other line contact of the plug, or to each of the other line contacts if there are more than two. The instrument will indicate normal insulation resistance in each case if the ground wire is properly connected. Do not use the tool unless it has satisfactory insulation resistance.

Never apply power to equipment known to be faulty. Always check to make sure all personnel are in the clear before energizing a circuit.

Do not work around moving machinery or electrical circuits while wearing loose or torn clothing, neckties, gloves, identification bracelets, or wrist watches.

## Review of Operating Precautions

Electrical maintenance or repair is normally performed on deenergized circuits and equipment. However, military requirements or the safety of the ship may require work to be done on energized circuits. When this happens, extreme safety precautions must be used. Such work must be done only by properly supervised personnel who are fully informed of the dangers involved. The following precautions are taken when applicable:

1. Provide ample illumination.
2. Insulate the person performing the work from ground.
3. Remove rings, wrist watch, and other metal objects from the person performing the work.
4. Be certain the clothing and shoes are dry.
5. Cover metal tools with rubber tape as far as practicable.
6. Provide insulating barriers between the work and adjacent metal parts.
7. Use only one hand, if practicable, when performing the work.
8. Use rubber gloves on both hands, if possible, when performing the work.
9. Station men at circuit breakers or switches to deenergize the circuit in case of emergency.
10. A man qualified to administer artificial respiration should be immediately available while the work is being done.

Study carefully the operating and safety precaution sections of the Instruction Books for all equipment under your care. Know what you are doing before you do it. Learn what should happen when you turn a certain knob or switch. Then, if something goes wrong, you will not mistake the wrong action for the correct action.

## QUIZ

1. What is the cause of a high percentage of personal injuries?
2. What precaution should be taken when using a compressed air jet?
3. What articles of jewelry should be removed while working on rotating machinery?
4. What name is applied to speed counters?
5. What is the normal timing interval for speed measurements?
6. What do the letters rpm mean?
7. What optical effect is produced by the stroboscopic tachometer?
8. What is the normal speed range of the Strobotac?
9. What is a symptom of low cathode emission of the Strobotac lamp?
10. Why is meter sensitivity important?
11. What must be taken into account when determining the series resistance required for full scale meter deflection of a voltmeter?
12. What are two types of ohmmeters?
13. What is the purpose of the meter shunts in an ammeter?
14. How is switch contact resistance eliminated on the ammeter 10-ampere range?
15. What is the front-to-back ratio of a good rectifier?
16. When is the highest current drawn from the ohmmeter battery?
17. Should an ohmmeter be used on an energized circuit?
18. How are current readings obtained with the AN/USM-34 Multimeter?
19. What is the purpose of R11 (fig. 2-12)?
20. How are negative voltages measured with the d-c voltmeter?
21. What is the purpose of C5 (fig. 2-13)?
22. Why is R20 (fig. 2-13) adjusted?
23. What is the purpose of R50 (fig. 2-16B)?
24. What is the main use for a megger?
25. What is the usual voltage rating of a megger?
26. What are the two principal tube test methods?
27. What kind of test is required for diode tubes?
28. What should you do before using portable tools?
29. What is the normal insulation resistance of a tool in good condition?
30. What conditions may require work on an energized circuit?

# CHAPTER 3

# BASIC MECHANISMS

## Introduction

I.C. systems are to a large extent assemblies of relatively simple mechanical and electromechanical components, which are combined to solve problems or to transmit intelligence. These components are called basic mechanisms and include shafts, gears, cams, ratchets, springs, and friction disks with roller assemblies. This chapter introduces gear ratios and defines the types of gears and differential units. The uses and operation of mechanical and synchro followup units are described. As an I.C. Electrician, you will be working with these mechanisms during your entire naval career.

## Shafts

Shafts are usually solid or hollow cylindrical metal rods. They are used to support pulleys, gears, and other rotating parts and to transmit power or motion by rotation.

### SHAFT VALUES

The rotation of a shaft can represent a quantity, such as direction in degrees, distance in yards, or speed in knots. When a shaft is turned, the magnitude of the quantity represented is changed. Rotation in one direction increases the value of the quantity; whereas, rotation in the opposite direction decreases the value. An increase in the quantity is considered positive; decrease negative.

Almost every shaft has a zero position at which the values of the quantity represented by the shaft is zero. One revolution of a shaft can represent any convenient unit value of the particular quantity. For example, one revolution can represent a direction of 3°, a distance of 100 yards, or a speed of 5 knots. A shaft having any one of these values would have a shaft value of 3°, 100 yards or 5 knots respectively. SHAFT VALUE, therefore, is the value that a shaft develops in one revolution—that is, the value per revolution.

A dial attached directly to a shaft with its zero position matched to the zero position of the shaft (fig. 3-1A) will indicate only the fraction, or degree, of turn up to one complete revolution. For example, if the shaft has a shaft value of 10° and is turned 1/2 revolution away from the zero position, the value indicated by the dial will be 5°. If the shaft is then turned 1 complete revolution farther, and in the same direction, the dial will again indicate 5° although the shaft is 1 1/2 revolutions away from its zero position and the total value of the shaft turn is now 15°.

A counter can be driven by a shaft in such a way that the counter will indicate the number of turns or fractions of a turn in the same units as shaft value. The counter must be adjusted so that it reads zero at the shaft's zero position. If the shaft is turned 1/2 revolution in the positive direction from its zero position, and if the shaft value is 10°, the counter will read 5° (fig. 3-1B). If the shaft is then turned 1 complete revolution farther, and in the same direction, the counter will read 15°. If the shaft is now turned 1 1/2 revolutions in the opposite direction from the last resting position to decrease the total value, the counter will again read 0° because the shaft has been returned to its zero position. The counter may be set to any useful multiple or fraction of shaft rotation by suitable aring, as can be understood from the next ction, Gears.

The TOTAL VALUE always depends on the mber of revolutions that the shaft is turned from its zero position. In other words, the total value is the product of the shaft value and the number of revolutions that the shaft is turned from its zero position.

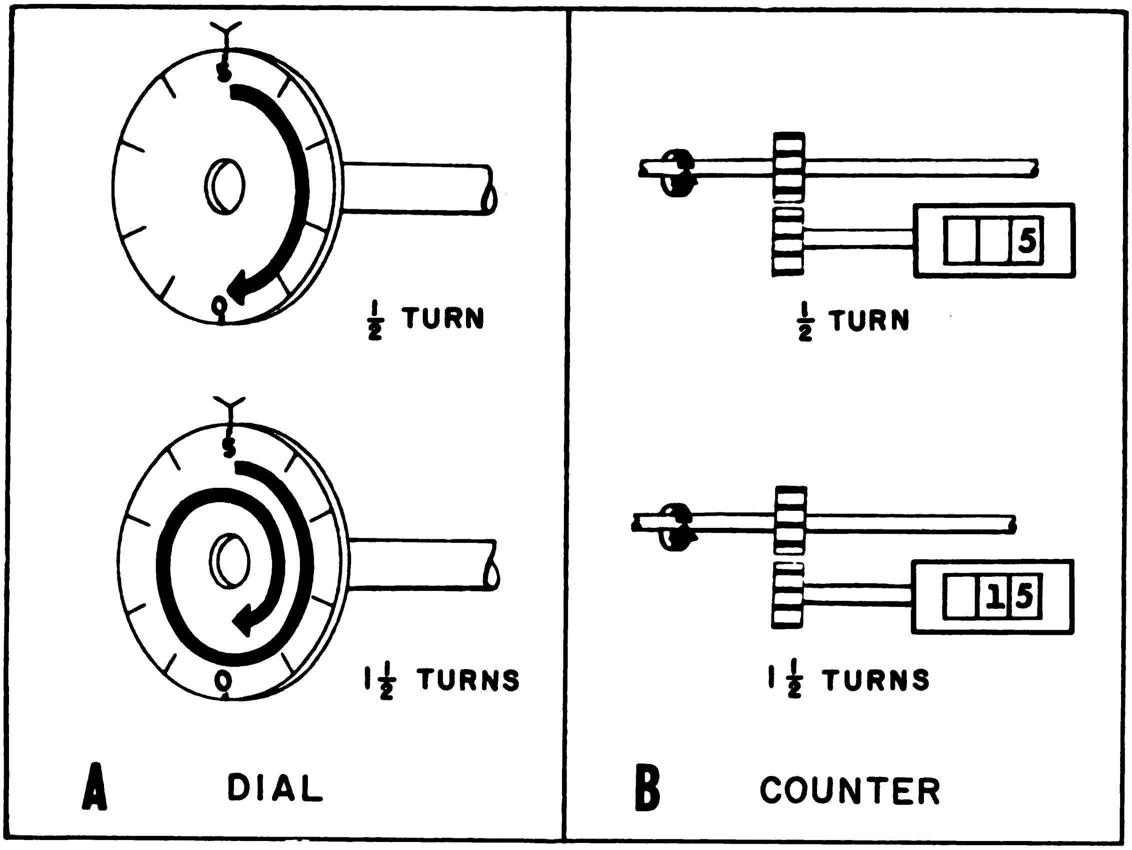



Figure 3-1.—Shaft values.

## Gears

Gears are wheels with mating teeth cut into them so that one gear can turn another gear without slippage. When a gear positions another gear it transmits rotary motion.

If two mating gears are the same size, they will have the same number of teeth. One revolution of the driving gear will turn the driven gear one revolution because each tooth of the driving gear will push a corresponding tooth of the driven gear an equal distance across the centerline of the two gears. If two gears are of different sizes, the smaller gear is usually called a PINION. When a gear and a pinion mesh together, their shafts turn at different speeds.

### SPUR GEARS

Spur gears are used to transmit rotary motion between parallel shafts. These gears have either straight teeth or helical teeth, as illustrated in figure 3-2.

In the STRAIGHT SPUR GEAR (fig. 3-2A) the teeth are cut parallel to the axis of rotation. The faces of the teeth are not flat but have the form of an involute curve. The entire length of

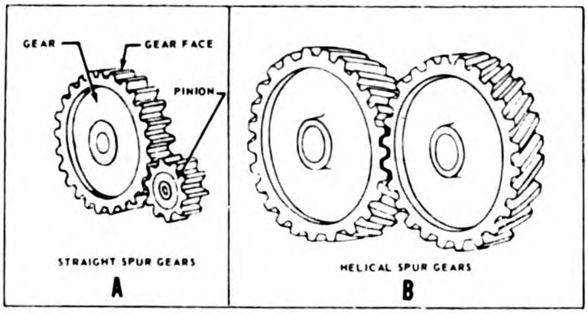



Figure 3-2.—Spur gears.

one tooth comes into contact with its mating-gear tooth along the line of tangency between the two faces. In this way rolling action occurs between the two surfaces as the gear teeth come into mesh and sliding friction is eliminated.

In the HELICAL SPUR GEAR (fig. 3-2B) the teeth are cut with a lead angle across the face of the gear blank to form a cylindrical helix like the thread of a screw. One end of each tooth lies ahead of the other end; that is, each tooth has a leading end and a trailing end. Therefore the teeth are cut at some angle, other than parallel, to the axis of gear rotation. The leading ends of two teeth come into line contact at one time with the mating gear and move progressively across the face of the gear until the trailing ends of the teeth are in contact. Because of the lead-angle cut of the teeth, more than one tooth is in mesh at a time. This meshing action permits the use of higher torque with gears of the same size and results in quiet, smooth operation. When a spur gear is meshed with a rack (fig. 3-3) rotary motion is converted into linear (straight line) motion. The change in position of the rack is a measure of the linear distance the rack has moved from the zero position. The rack may also be used to position a spur gear and convert linear motion into rotary motion.

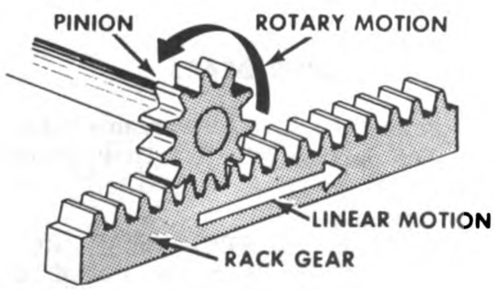



Figure 3-3.—Rack and pinion.

## BEVEL GEARS

Bevel gears are used to transmit motion between two or more shafts that are not parallel. In other words, they can be designed to operate at any desired angle between the two shafts. By the use of bevel gears, one shaft can be made to drive several shafts mounted at different angles.

Bevel gears have either straight teeth or helical teeth, as illustrated in figure 3-4. The teeth of the STRAIGHT BEVEL GEAR (fig. 3-4A) are cut straight across the face of the gear tapering toward the axis of rotation. As in the straight spur gear, the entire length of one tooth comes into line contact at one time with the mating gear.

The teeth of the SPIRAL BEVEL GEAR (fig. 3-4B) are cut with a lead angle across the face of the gear blank. As in the straight bevel gear the teeth taper toward the axis of rotation. As in the helical spur gear, the teeth have leading and trailing ends and have more than one tooth in mesh at one time with the mating gear. If two bevel gears are of equal size and their shafts are at right angles to each other, they are called MITER GEARS.

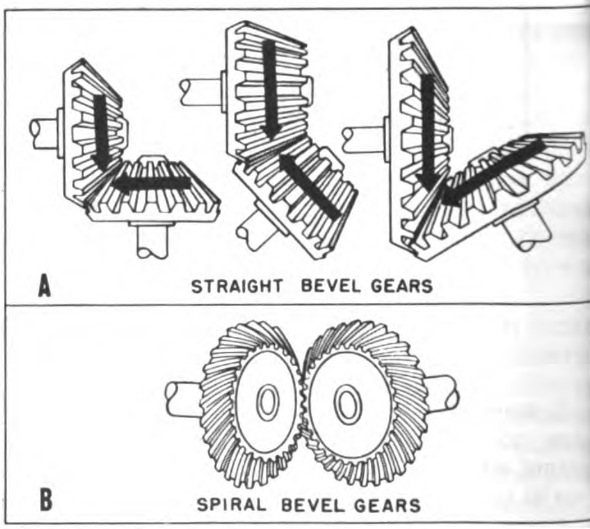



Figure 3-4.—Bevel gears.

## INTERNAL GEARS

Internal gears have their teeth cut on the inside circumference of a ring parallel with the axis of rotation, as illustrated in figure 3-5.

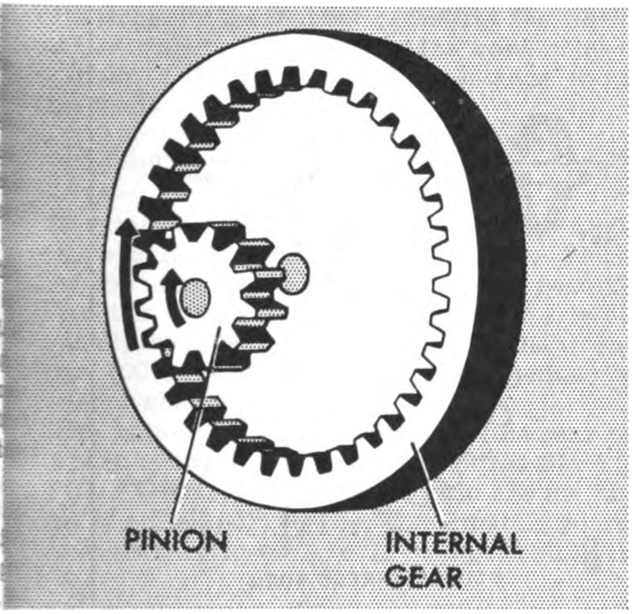



Figure 3-5.—Internal gear.

In order to have an internal gear mesh with an external gear or pinion, the axis of the external gear is parallel to, but offset from, the axis of the internal gear. Either the external or the internal gear can be the driving gear.

## WORM AND WORM WHEEL

A worm and worm wheel consists of a helical screw called the WORM and a straight spur gear called the WORM WHEEL, as illustrated in figure 3-6. The helical screw thread of the ordinary worm is a groove around the body of the screw that makes a constant angle with the axis of the cylinder. The worm wheel is a straight spur gear. The worm usually drives the worm wheel. However, if the worm wheel is to drive the worm, the slope of the worm threads must be between 45° and 60° to prevent the gears from locking.

The amount that the worm wheel turns for one turn of the worm is always equal to the LEAD. The lead, L, is the distance between corresponding points on the same thread, irrespective of the number of threads, as indicated in figure 3-6. In a SINGLE THREAD WORM there is only one groove running around the body of the cylinder and the lead is equal to the pitch, P. The pitch is the distance between corresponding points on adjacent grooves, for example, from the center of the top of one thread to the center of the top of the next thread. In a DOUBLE THREAD WORM there are two grooves running around the body of the cylinder and the lead is the width of two teeth. Hence, a single-thread worm (fig. 3-6A) advances its worm wheel one tooth for each revolution of the worm, and a double-thread worm (fig. 3-6B) advances its worm wheel two teeth for each revolution of the worm. The black sectors denote the amount that the worm wheels are turned by one revolution of the worms respectively for a single-thread worm and a double-thread worm. Thus, in a single-thread worm the lead is equal to the pitch. In a double-thread worm the lead is equal to twice the pitch and in a triple thread worm lead is equal to three times the pitch.

Worms are used generally where great reductions in speed are required.

## GEAR RATIOS

The ratio between the number of teeth on the driving gear and the number of teeth on the driven gear is called the GEAR RATIO. If a driving gear has 24 teeth and the driven gear has 12 teeth, 1 revolution of the driving gear turns the driven gear two revolutions. Thus, the gear ratio is 2 to 1 and the driven gear rotates twice as fast as the driving gear. If the driving gear has 10 teeth and the driven gear has 60 teeth, the gear ratio is 1 to 6 and the driving gear completes six revolutions for each revolution of the driven gear.

Gear ratios for spur gears, bevel gears, and internal gears can be determined by one of three methods—

1. $\text{gear ratio} = \dfrac{\text{number of teeth on driving gear}}{\text{number of teeth on driven gear}}$;

2. $\text{gear ratio} = \dfrac{\text{circumference of driving gear}}{\text{circumference of driven gear}}$;

3. $\text{gear ratio} = \dfrac{\text{diameter of driving gear}}{\text{diameter of driven gear}}$.

The relative directions of rotation of meshing spur gears are shown in figure 3-7. Any two mating spur gears turn in opposite directions (fig. 3-7A).

If a shaft is required to turn another shaft in the same direction, an IDLER GEAR must be used between the driving gear and the driven gear (fig. 3-7B). The idler turns in a direction opposite to that of the driving gear and turns

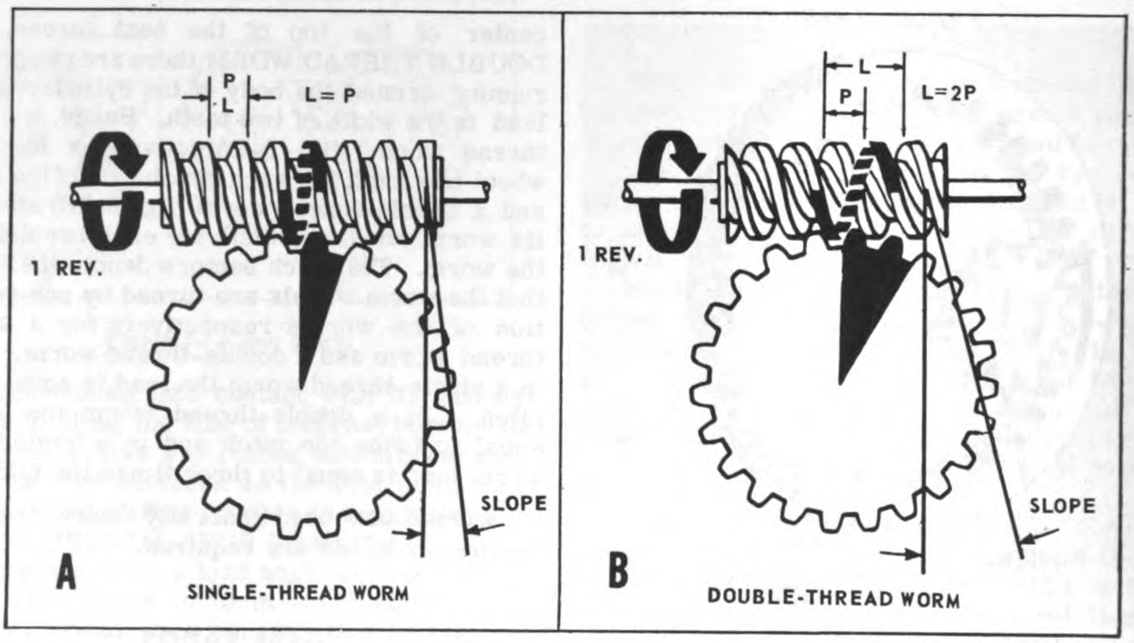



Figure 3-6.—Worm and worm wheel.

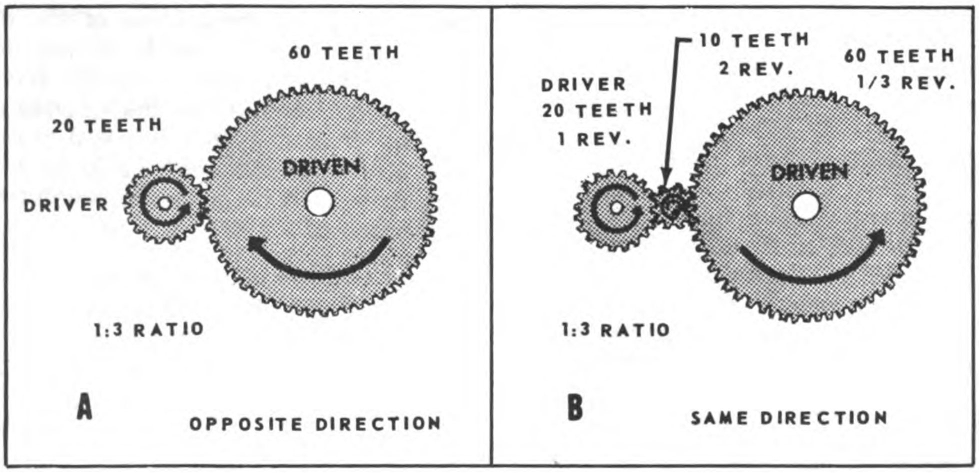



Figure 3-7.—Directions of rotation of spur gears.

the driven gear in the same direction as the driving gear.

An idler between two gears does not affect the gear ratio because each time the driving gear turns one tooth of the idler, the idler turns one tooth of the driven gear. If a 20-tooth pinion drives a 60-tooth gear through a 10-tooth idler (fig. 3-7B), for each revolution of the driving pinion the idler makes two revolutions because the idler has half as many teeth as the pinion. For each revolution of the idler the driven gear turns one-sixth revolution because the driven gear has six times as many teeth as the idler. Hence, for each revolution of the driving pinion the idler makes two revolutions and the driven gear makes 2 x 1/6, or one-third revolution. The gear ratio is 1 to 3—the same as if the pinion had driven the gear directly.

Gear ratios between worms and worm wheels are determined by dividing the number of threads n the worm by the number of teeth on the worm heel because each thread of the worm moves ne tooth of the worm wheel a distance equal to the lead–

$$\text{gear ratio} = \frac{\text{number of threads on worm}}{\text{number of teeth on worm wheel}}$$

If a single-thread worm drives a 100-tooth worm wheel, the gear ratio is 1 to 100. Thus, the worm makes 100 revolutions for 1 revolution of the worm wheel. If the worm is triple-threaded, the gear ratio is 3 to 100 and the worm makes 100 revolutions for three revolutions of the worm wheel.

The ratio of the speed of the driving gear to the speed of the driven gear is called the SPEED RATIO. Gear ratio and speed ratio are the inverse of each other; that is, if two mating gears have a gear ratio of 2 to 1, the speed ratio is 1 to 2.

Gear ratios are often used to change shaft values. Various electrical followup devices operate efficiently only at comparatively high speeds with low shaft values. When a signal is received by means of such a device, it is customary to reduce the speed and increase the shaft value of the signal received to match the values required by the associated mechanisms by means of gear ratios. Similarly, when a high-value signal is sent from the mechanism by means of a transmitter having a low shaft value, the shaft value is usually reduced by means of a gear ratio.

### GEAR TRAINS

When several gears are meshed together as shown in figure 3-8, they constitute a GEAR TRAIN. The ratio between the driving gear at one end and the driven gear at the other end of such a gear train is always the same as if the driving gear were meshed directly with the driven gear, because in such cases, the intermittent gears are idlers.

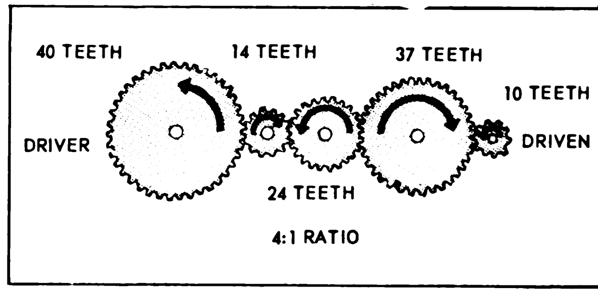



Figure 3-8.—Gear train.

When a large increase in the number of revolutions is required between two shafts, it may be better to obtain the increase in several steps rather than in a single step. Suppose a 12-to-1 ratio is needed between two shafts. A driving gear 12 times as large as the pinion would be required to obtain this increase in one step. Such a large driving gear may not be practical because it would be cumbersome and would waste valuable space.

This 12-to-1 ratio can be obtained in several steps using intermediate shafts, each of which carries two gears of different size, as shown in figure 3-9.

Gears A and B have a 2-to-1 gear ratio. For each turn of driver A, gear B makes two revolutions. Gear C also makes two revolutions for one revolution of driver A because gears B and C are on the same shaft. Gears C and D have a 3-to-1 gear ratio. Thus, gear D makes 3 revolutions for each turn of gear C, or 6 revolutions (3 x 2) for each turn of driver A. Because gears E and F have a 2-to-1 gear ratio, gear F makes two revolutions for each turn of gear E, or 12 revolutions (2x6) for each turn of driving gear A. The gear ratio between gears A and F is, therefore, 12 to 1. This ratio is obtained without the use of large gears. To determine the ratio of this train of gears, multiply together the gear ratios between each pair of gears.

## Differentials

A differential is a gear mechanism that performs addition or subtraction with the inputs from two shafts and translates the total or difference through a third shaft. It operates continuously and accurately, producing a continuous series of resultants from inputs of a fraction of a revolution to any number of shaft revolutions.

The types of differentials generally used in I. C. instruments are (1) bevel-gear differentials, (2) jewel-gear differentials, and (3) internal-gear differentials.

## BEVEL-GEAR DIFFERENTIAL

A bevel-gear differential is shown in figure 3-10. Four bevel gears are meshed together and grouped around the center of the mechanism. These four gears and the spider shaft are the heart of the differential. The left and right bevel gears are called END GEARS, and the top and bottom bevel gears are called SPIDER GEARS. The spider gears are meshed with the end gears.

The cross shaft and spider gears together are called the SPIDER and the long shaft is called the SPIDER SHAFT. All four of these bevel gears are free to rotate on precision bearings.

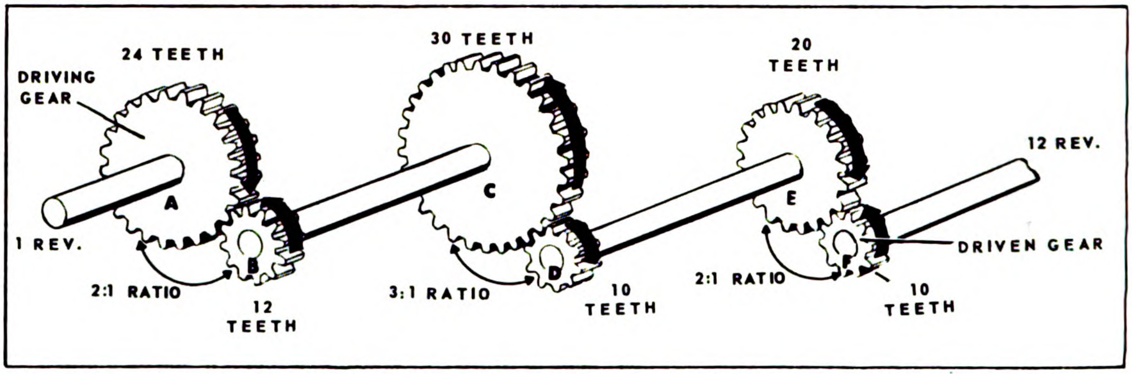



Figure 3-9.—Gear train with intermediate shafts.

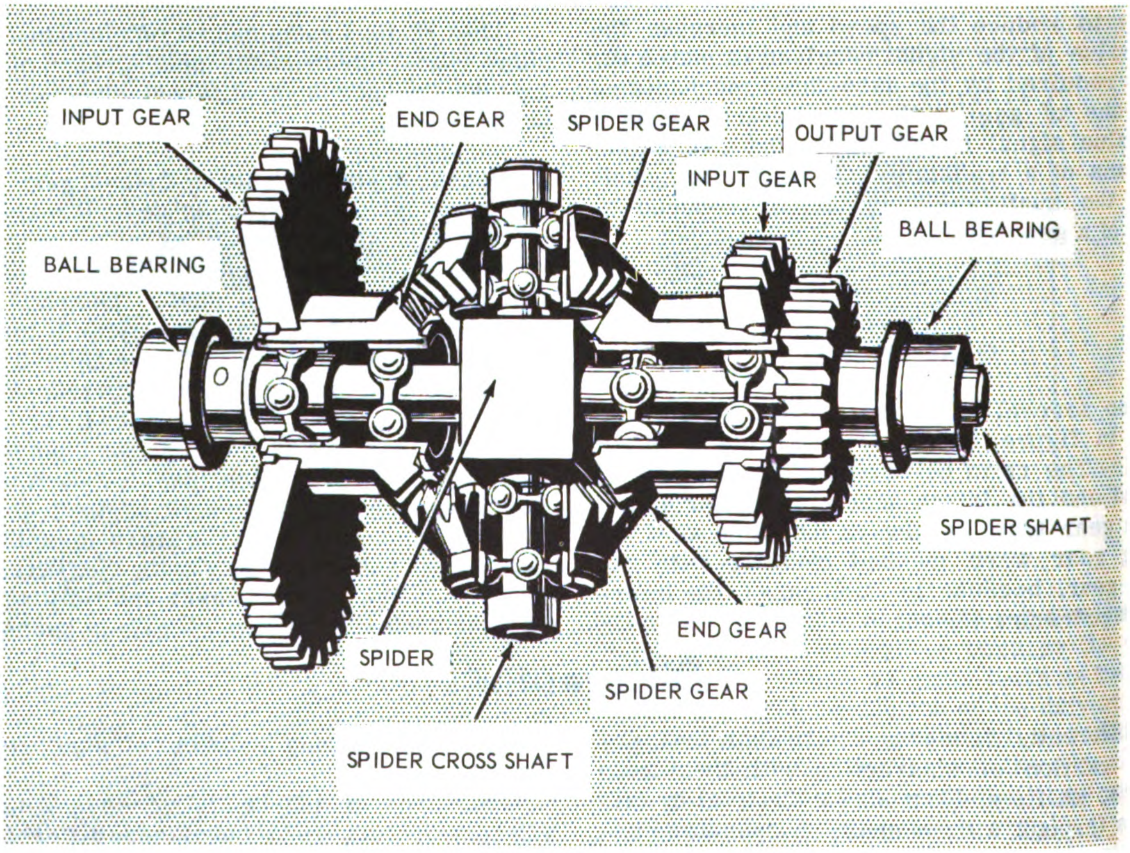



Figure 3-10.—Bevel-gear differential.

The three spur gears are used to connect two end gears and the spider shaft to other chanisms. Each of the two input gears is ached to an end gear. An input gear and an d gear together are called a SIDE of the dif-rential. The output gear is pinned to the spider aft and is the only gear in the mechanism that pinned directly to a shaft.

The two end gears in figure 3-10 are posi-ned by the input shafts, which represent quan-ies to be added or subtracted. The spider ars do the actual adding and subtracting. They low the rotation of the two end gears, turning spider the number of revolutions that is oportional to the sum of, or the difference be-een, the revolutions of the end gears.

If the left side of the differential is rotated ile the right side remains stationary, the ro-ing end gear turns and rolls the spider gears the stationary end gear. This motion rotates spider in the same direction as the input and ereby turns the output shaft with it. The out-t shaft turns the number of revolutions that is oportional to the input.

If the right side of the differential is now tated and the left side held stationary, the me action occurs. The spider gears again rn and roll on the stationary end gear, turning spider in the direction of the moving side. ie output shaft turns the number of revolu-ns that is proportional to the input.

Thus if both sides of the differential are rned in the same direction at the same time, spider will be turned by both sides at once. ie output will be proportional to the sum of e two inputs. However, the spider is not the iole sum of the two inputs. Because the spider ars are free to roll between the gears, the ider actually makes only half as many revo-tions as the sum of or the difference between e revolutions of the end gears.

This principle is easily demonstrated if a lindrical drinking glass turned on its side is lled along a table top by a ruler pushed across s upper side. The glass will roll only half as r as the ruler travels. The spider gears in e differential roll against the end gears in a milar manner. Hence, a differential produces ly half the answer in adding or subtracting e revolution of its input gears.

In order to produce the correct (whole) an-wer, 2-to-1 ratio gears are required between e spider shaft (differential output) and the in-t shaft of the next mechanism (fig. 3-11). his gear ratio doubles the output to give the whole answer. Actually the 2-to-1 ratio is seldom obtained in differential gearing in any computer for design reasons. However, for the sake of clarity it is assumed here that all differentials have 2-to-1 gearing and that the final output is complete and correct.

When both inputs of a differential rotate in the same direction, the differential ADDS (fig. 3-11). If both sides of the differential turn in the same direction for the same number of revolutions, the spider gears do not rotate on the cross shaft. Instead, they maintain a fixed position between the end gears and the cross shaft rotates end over end with them, carrying the spider around to a new position. The rotations of the spider and its shaft are equal to half the sum of the revolutions to the two inputs—that is, the spider shaft rotates exactly the same number of revolutions as each individual input when they

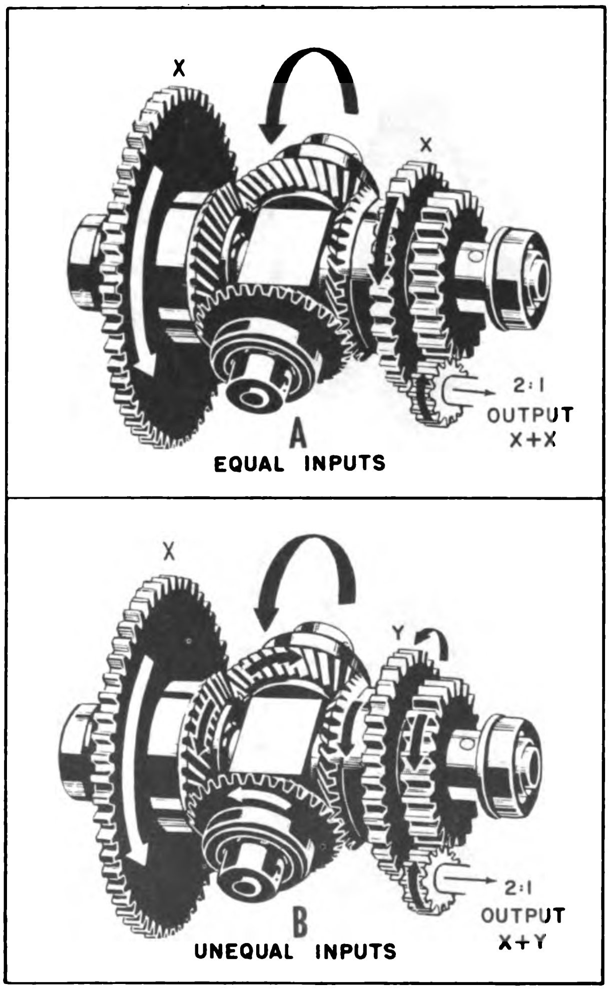



Figure 3-11.—Differential adding.

are equal and turn in the same direction (X + X in figure 3-11A).

If one side of the differential makes more revolutions than the other, the spider cross shaft and gears are carried around end over end by both end gears. At the same time, the spider gears roll on the end gear that is turning the fewer number of revolutions. The spider shaft turns half the sum of the revolutions of the two inputs when they turn in the same direction (X + Y in figure 3-11B).

The differential SUBTRACTS when the two inputs of a differential rotate in opposite directions (fig. 3-12). If the two inputs turn in opposite directions and have the same number of revolutions, the spider gears will roll between the end gears without moving the spider cross shaft. The output is zero (X - X = 0 in fig. 3-12A).

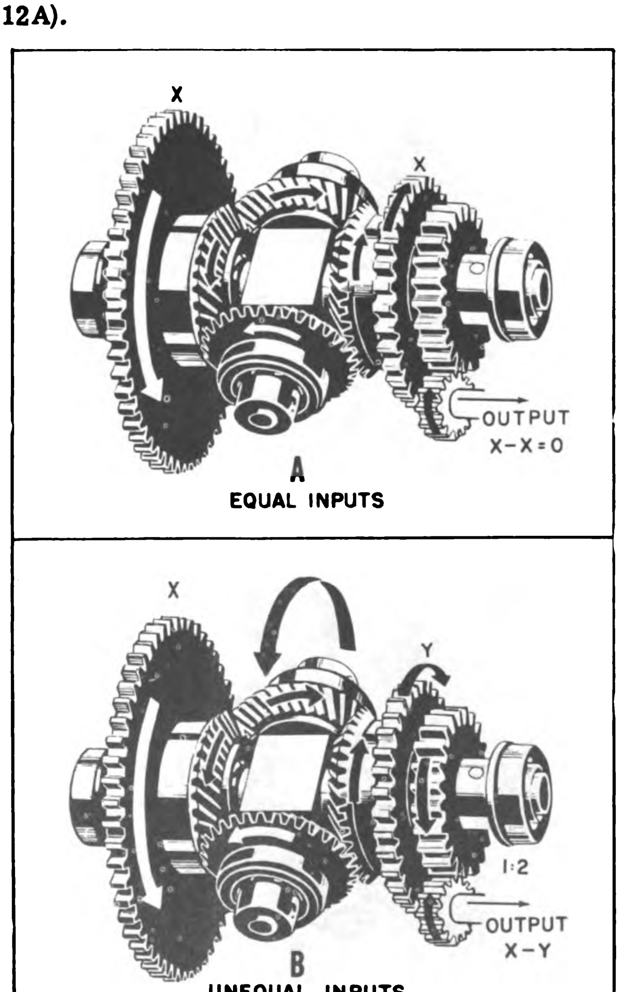



Figure 3-12.—Differential subtracting.

If the two inputs turn in opposite directions for an unequal number of revolutions, the spider gears roll on the end gear that turns the fewer revolutions, rotating the spider in the direction of the input that is turning the greater number of revolutions. The motion of the spider shaft in this case is equal to half the difference between the revolutions of the two inputs (X-Y in fig. 3-12B).

## SPUR-GEAR DIFFERENTIAL

The action of a spur-gear differential is identical to that of the bevel-gear differential. The spur-gear differential uses spur gears instead of bevel gears. The spider is a case that encloses the two end gears and the two spider gears. The two spider gears mesh together, and each meshes with one of the end gears. The shafts of the spider gears turn on bearings set into the spider so that the spider gears travel around with the spider just as in the bevel-gear differential. Each side of the spur-gear differential consists of a spur end gear and a side shaft.

The spur-gear differential may be made compact as in the jewel-gear differential (fig. 3-13). The designation, jewel-gear differential, is derived from the use of jewels as bearings.

The jewel-gear differential is designed to operate only small mechanisms with light loads, such as electrical contacts. Most of the shafts are mounted on jewel bearings so that the mechanism is sensitive to very small and very light inputs, and runs very smoothly. It is used in followup controls where the signals come from receiver rotors and where the exact amount of turning is very important.

## INTERNAL-GEAR DIFFERENTIAL

An internal-gear differential is shown in figure 3-14. The principle and use of this type of differential are the same as those of the bevel-gear and jewel-gear types. The internal-gear differential consists of an internal gear; a spur gear; two spider pinions; and a spider arm. The spur gear receives one input and the internal gear receives the other input. The output shaft of the differential is attached to the spider arm.

The INTERNAL GEAR, D, is a large ring with the teeth cut on its inside circumference.

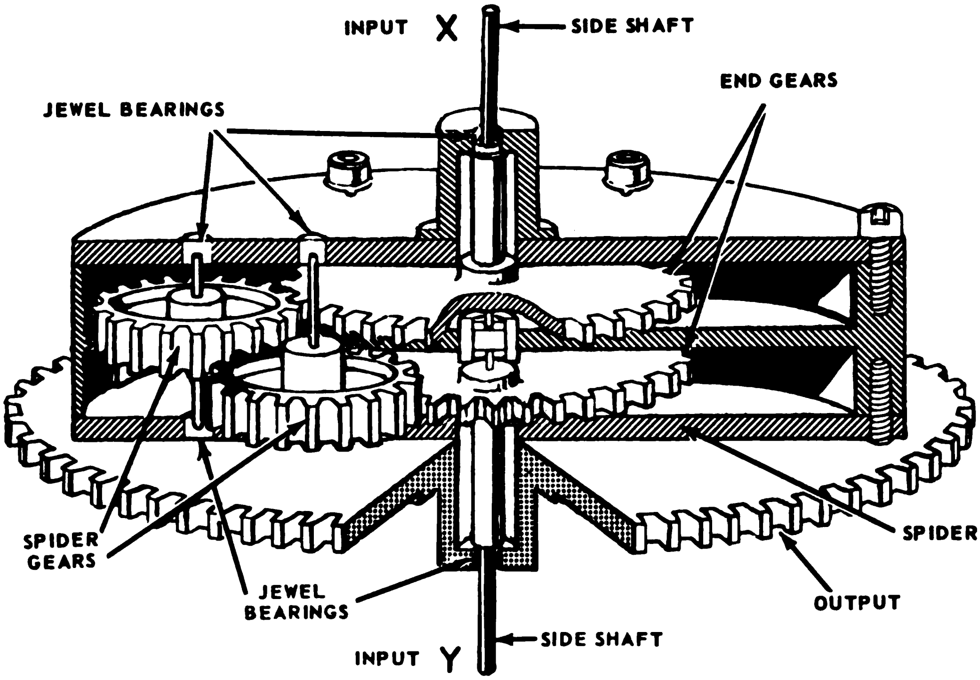



Figure 3-13.—Jewel-gear differential.

The SPUR GEAR, B, is mounted in the center of the internal gear and meshes with the two SPIDER PINIONS, C, which in turn mesh with the internal gear. The spider pinions, C, are connected together by the SPIDER ARM, A, which is pivoted to rotate about, but is not rigidly fixed to the axis of the spur gear, B. The OUTPUT SHAFT of the internal-gear differential is attached to the center of the spider arm, A.

In order to understand the operation of this differential consider the following example. Spider arm A is attached to the output shaft. Spur gear B has 48 teeth and receives one input. Spider pinions C each have 24 teeth and mesh with spur gear B and internal gear D. Internal gear D has 96 teeth. If spur gear B is turned clockwise one revolution while internal gear D is held stationary, spider arm A will follow clockwise through 1/3 revolution. This action may be explained by making certain assumptions.

First, assume that all gears are locked and spider arm A is rotated clockwise 1 complete turn. Because all gears are locked, each gear makes 1 complete turn clockwise as indicated in the table (fig. 3-14) by +1 for all members.

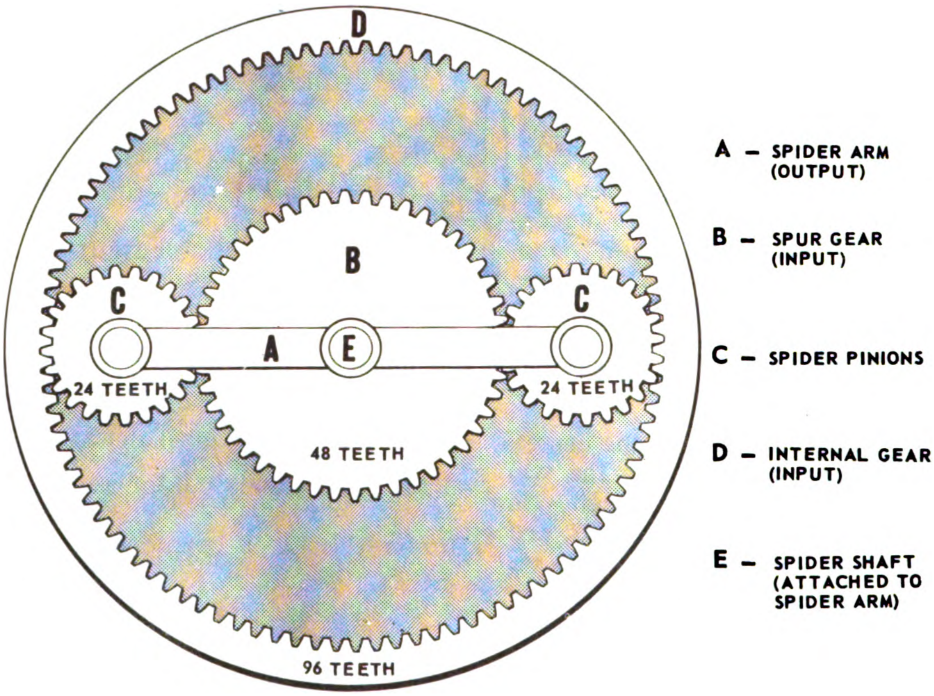
Next, assume that spider arm A is locked, and internal gear D is rotated 1 complete turn counterclockwise as indicated in the table by -1 for gear D and by 0 for arm A.

Pinion C rotates counterclockwise $-1 \times \frac{96}{24}$, or -4 revolutions. Spur gear B rotates clockwise $+1 \times \frac{96}{24} \times \frac{24}{48}$, or +2 revolutions.

The total number of revolutions of each member when internal gear D is stationary is determined by adding algebraically the two components of motion, as indicated in the table. In the first condition, internal gear D rotated one revolution clockwise; whereas in the second condition it rotated one revolution counterclockwise, resulting in a net total of zero. Hence, this action fulfills the requirement that D remain stationary. Spider pinion C rotates +1 -4, or -3 revolutions. Spur gear B rotates +1+2, or +3 revolutions and spider arm A rotates +1 +0, or +1 revolution. Thus, one clockwise revolution of spider arm A causes spur gear B to rotate 3 revolutions in the same direction. Conversely, 1 revolution of spur gear B causes arm A to turn in the same direction 1/3 revolution for the condition that internal gear D remains stationary.

If spider arm A is held stationary and internal gear D is rotated 1 revolution counterclockwise, spider pinion C rotates $\frac{96}{24}$ x 1, or 4 revolutions in the same direction. Spur gear B rotates in the opposite direction $\frac{24}{48}$ x 4, or 2 revolutions. Thus, the speed ratio of B to D is 2 to 1 when arm A is stationary. If this speed ratio is maintained, arm A will turn in the direct of the faster moving gear.

The laws that apply to the speed of the spi when there is a difference in speed of the driv motors, are not the same as for bevel-gear jewel-gear differentials; that is, the spider f lows the faster member but not at half the c ference in speed between the two.




| | A | B | C | D |
|---|---|---|---|---|
| GEARS LOCKED ARM ROTATED | + 1 | + 1 | + 1 | + 1 |
| ARM LOCKED GEARS ROTATED | 0 | 1 x 96/24 x 24/48 = +2 | −1 x 96/24 = −4 | − 1 |
| TOTAL | + 1 | + 3 | − 3 | 0 |

Figure 3-14.—Internal-gear differential.

# Servomotors

The outputs of many mechanisms in I.C. in-
·uments are not powerful enough to position
avily loaded shafts. Therefore, these outputs
e used to control the action of SERVOMOTORS,
FOLLOWUP MOTORS, that actually position
e loads.

Servomotors and followup motors are iden-
al, although they are often associated re-
ectively with F.C. and I.C. installations.
wever, these terms are used interchangeably
oughout this training course. These motors
e designed for operation on either d-c or a-c
rvice, depending upon the type of control in-
rporated in the particular servomechanism or
llowup system.

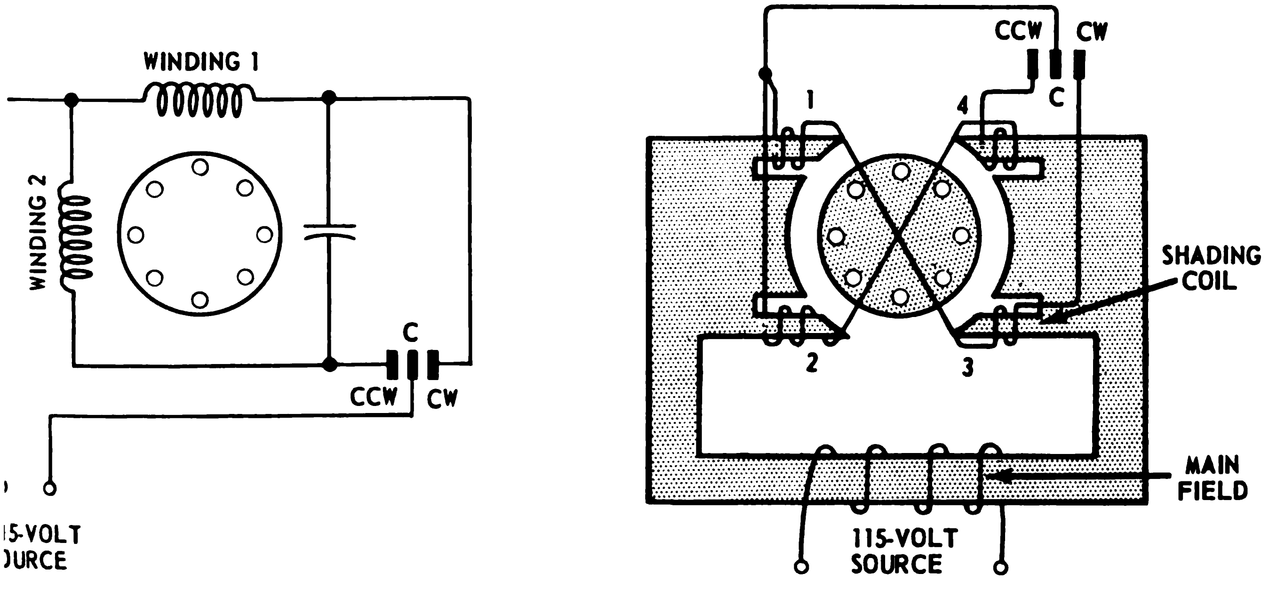
D-c servomotors are of the series and shunt
pes; whereas, a-c servomotors are of the
ngle-phase and two-phase induction types. The
ost common types employed in I.C. instruments
e the single-phase capacitor and shaded-pole
otors (fig. 3-15).

## CAPACITOR SERVOMOTOR

The capacitor servomotor is a split-phase motor, with a capacitor connected in series with either one or the other stator winding (fig. 3-15A), depending upon the position of center contact C. The capacitor action determines the direction of rotation by causing the current in the winding to which it is connected to lead the current in the other winding.

Stator windings 1 and 2 are connected respectively to outer contacts CW (clockwise) and CCW (counterclockwise) of the followup control. One side of the 115-volt, 60-cycle supply is connected to inner contact C of the followup control and the other side is connected to the other ends of windings 1 and 2. The followup control acts to bring the center contact, C, against either the CW or CCW contact and thus determines the direction of rotation of the capacitor type servomotor.

When the followup control completes the circuits through outer contact CW, the 115-volt




CAPACITOR MOTOR

A

SHADED - POLE MOTOR

B

Figure 3-15.—Servomotors.

supply is connected directly across winding 1 in parallel with series combination of winding 2 and the capacitor. The capacitor action causes the current in winding 2 to lead the current in winding 1, resulting in rotation of the rotor in a clockwise direction.

When the followup control completes the circuit through outer contact CCW, the 115-volt supply is connected directly across winding 2 in parallel with the series combination of winding 1 and the capacitor. Under this condition, current in winding 1 leads the current in winding 2, and the rotor turns in a counterclockwise direction.

If either the CW or the CCW contacts are closed, the motor will run until they are opened, at which time the motor stops. All servomotors are similar in two respects—(1) they are required to start and stop quickly and (2) they are electrically reversible.

### SHADED-POLE SERVOMOTOR

The shaded-pole servomotor consists of a squirrel-cage rotor and a stator having two salient poles. The salient poles have two split sections each of which is provided with shading coils (fig. 3-15B). A single-phase stator winding provides the primary component of magnetic flux for the motor.

The main field is normally energized even though the motor is stopped. During this time the action of the flux is similar to that in a transformer with the main field winding acting as the primary and the shading coils and rotor acting as the secondary.

However no torque is produced because the shading coil circuits are open and no current can flow through them. The motor remains idle without harmful effects because of the relatively high resistance of the cage rotor and the main field winding. The air gap restricts the magnetic coupling between the stator and rotor so as not to overload the main field winding.

When contact C is brought against contact CW a circuit is completed through shading coils 1 and 3. The motor then runs in a clockwise direction because the field now sweeps across the pole faces in the direction of shading poles 1 and 3 (clockwise). The action of the shaded pole motor is described in *Basic Electricity*, NavPers 10086.

Closing contacts C and CCW will cause the rotor to turn in the opposite direction.

A followup control may be used to position contact C.

## Cams

A cam is a machine element with a rotating or sliding surface or groove, shaped to transfer a desired motion to a second part called a FOLLOWER. The follower is usually returned to its normal position by a spring.

Cams have a variety of curved surfaces such as grooves, ridges, or contours. The curved surface is positioned by the input. Each point on the curved surface represents a different output value. As the follower rides on the curved surface it translates the output value of the cam to the desired motion.

As the input shaft turns at any given point of the cam, the follower is pushed by the curved surface into a position that registers the output value for that point of the cam. Some common types of cams are the constant-lead cam, reciprocal cam, secant cam, square cam, heart cam, and indented cam. The heart cam and the indented cam are the types most frequently used as components of followup systems in many I.C. instruments.

### HEART CAM

The heart cam is often used in synchro followup control systems to provide a flexible coupling between the outer and center contacts of an electric switch. This device (fig. 3-16) consists of a heart-shaped plate, two outer contacts, a center contact, a follower roller, and a follower spring.

The outer contacts CW and CCW are carried on an arm that is fixed to the heart cam. The heart cam is ballbearing mounted on the synchro-receiver rotor shaft so that the arm and cam turn freely as a unit. The center contact, C, is carried on a separate stationary arm. The two outer contacts and the center contact control

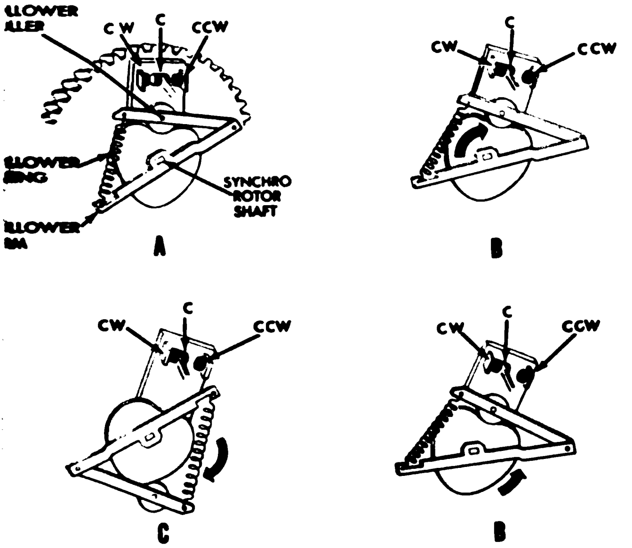



Figure 3-16.—Operation of a heart cam.

ne starting, stopping, and reversing of the ervomotor that drives the shaft load.

The follower arm, with the follower roller nd the follower spring, is keyed to the end of ne synchro-receiver rotor shaft. The follower pring keeps the follower roller seated firmly n the valley of the heart cam (fig. 3-16A).

Whenever an incoming signal from the synhro transmitter causes the synchro receiver otor to turn, the follower arm must turn because it is keyed to the rotor shaft. As the follower arm turns, the follower roller is pulled around. The follower roller, being firmly seated n the valley of the heart cam, pulls the cam round. When the heart cam is rotated, an outer contact is brought against the center contact, and the servomotor starts to drive (fig. 3-16B).

As the signal continues to come from the synchro transmitter faster than the servomotor can drive, the rotor of the synchro receiver continues to turn and to carry the follower arm around with it. The follower roller is now forced out of the valley and rides around the heart cam, pressed to its side by the action of the follower spring (fig. 3-16C).

Although an outer contact is held firmly against the center contact, the synchro-receiver rotor is still free to turn, without disturbing the contacts. If the followup fails to function, the follower continues to rotate around the heart cam until the response signal opens the contacts. This action provides a flexible coupling between the switch contacts which prevents damage to them in the event of power failure to the servomotor.

As the servomotor turns the load into correspondence with the input, the response shaft drives the bearing-mounted synchro-receiver stator backward (fig. 3-16D). This action turns the rotor backward without altering the input signal because it is locked magnetically with the stator. Thus the rotor transmits a backward torque to the heart cam that opens the electrical contacts and stops the servomotor. The bearing-mounted synchro receiver is described in detail later in this chapter.

## INDENTED CAM

The indented cam is also used to provide another type of followup control for the servomotor. This device (fig. 3-17) consists of an indented plate, a phenolic disk, a rocker contact assembly with roller, two outer contacts, and a center contact.

The phenolic disk holds the rocker assembly. The rocker is pivoted at its center. Two contact arms, supported by springs, are attached to the bottom of the rocker. The disk has two outer contacts located above the contact arms. When the rocker is tilted in one direction or the other, the contact arms can touch the outer contacts.

Three slip rings are mounted on the back of the disk. One slip ring is connected to the rocker assembly and the center contact, C. The other two slip rings are connected to the outer contacts, CW and CCW. Brushes on the slip rings connect the control for the servomotor to the rocker assembly.

The indented cam is mounted on a controlling shaft, which is in line with the shaft of the phenolic disk. The roller on the bottom of the rocker rides in the indent of the cam. When the roller on the rocker is in the center of the indent, all contacts are open and the servo-motor is stationary (fig. 3-17A). When the indented cam is turned clockwise, the rocker tilts, closing one

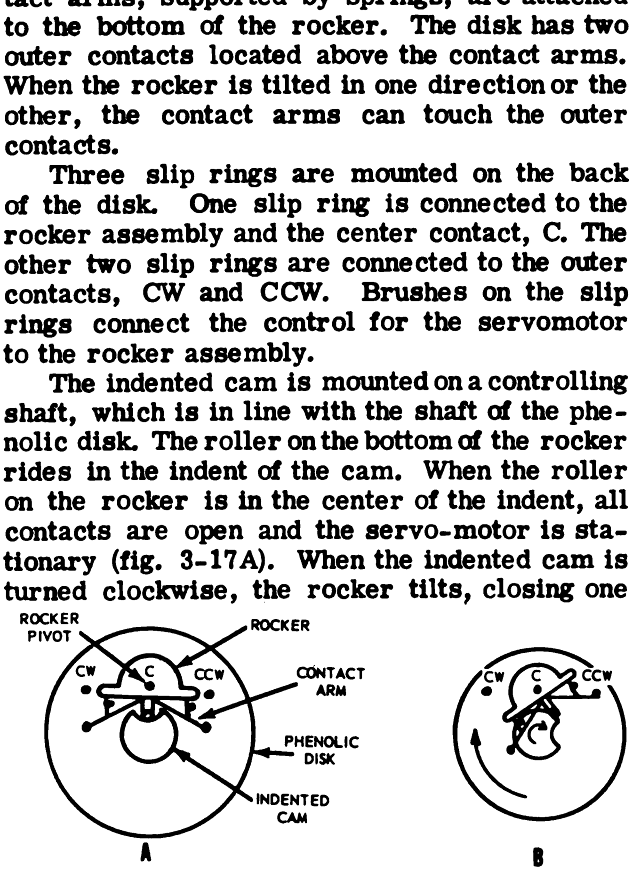



Figure 3-17.—Operation of an indented cam.

pair of contacts and causes the servomotor to drive the disk in the same direction (fig. 3-17B). Conversely, when the cam is turned counterclockwise, the rocker tilts in the opposite direction and closes the other pair of contacts and causes the servomotor to drive the disk in the same direction. In either case, the drive continues until the roller of the rocker drops back into the indent and the contacts open. If the indented cam is turned 30° clockwise, the servomotor drives the phenolic disk until it has followed through 30°. The roller of the rocker then drops back into the indent and opens the contacts, thus stopping the servomotor. The direction in which the rocker is tilted controls the direction of drive of the phenolic disk.

# Followup Controls

A SERVOMECHANISM is a combination of elements used to control a source of power. The output response of the system is fed back for comparison with the input. This feedback is the followup control of the servomechanism and the difference between these two quantities (input and feedback) is used to control the output power. When the difference between the output response and the input is zero, the output power of the servomechanism is zero. The followup control therefore regulates the action of the servomotor so that the position of the output shaft always represents the value of the quantity set into the control by the input shaft.

Suppose 1 revolution of the input shaft represents a range of 1,000 yards, and 1 revolution of the output shaft represents 100 yards. Then 10 revolutions of the output shaft is equivalent to 1 revolution of the input shaft.

## MECHANICAL FOLLOWUP CONTROL

The general principles of operation of all followup controls are illustrated by means of a simple mechanical followup control (fig. 3-18). This control consists essentially of a contact assembly and a differential. The principle of this type of control is represented schematically in figure 3-18A.

The CONTACT ASSEMBLY consists of a vertical contact arm and a horizontal base plate fastened at right angles to each other and pivoted on a pin, as shown in figure 3-18B. The control arm carries two outer contacts, CW and CCW. A stationary center contact, C, is mounted midway between the two outer contacts. A small crank arm is attached to the differential spider shaft beneath the contact assembly and carries a roller on one end.

In the normal position, the crank arm is horizontal and the base plate of the contact arm bears against the roller, by the action of a spring, to hold the contact arm in a vertical position. In this position the contacts are open and the servomotor is at a standstill.

If the crank arm turns clockwise, it rotates the outer contact arm clockwise, opposing the action of the spring. This action brings outer contact CW against center contact C and the motor drives in a clockwise direction.

Conversely, if the crank arm turns counterclockwise, the roller ceases to bear against the

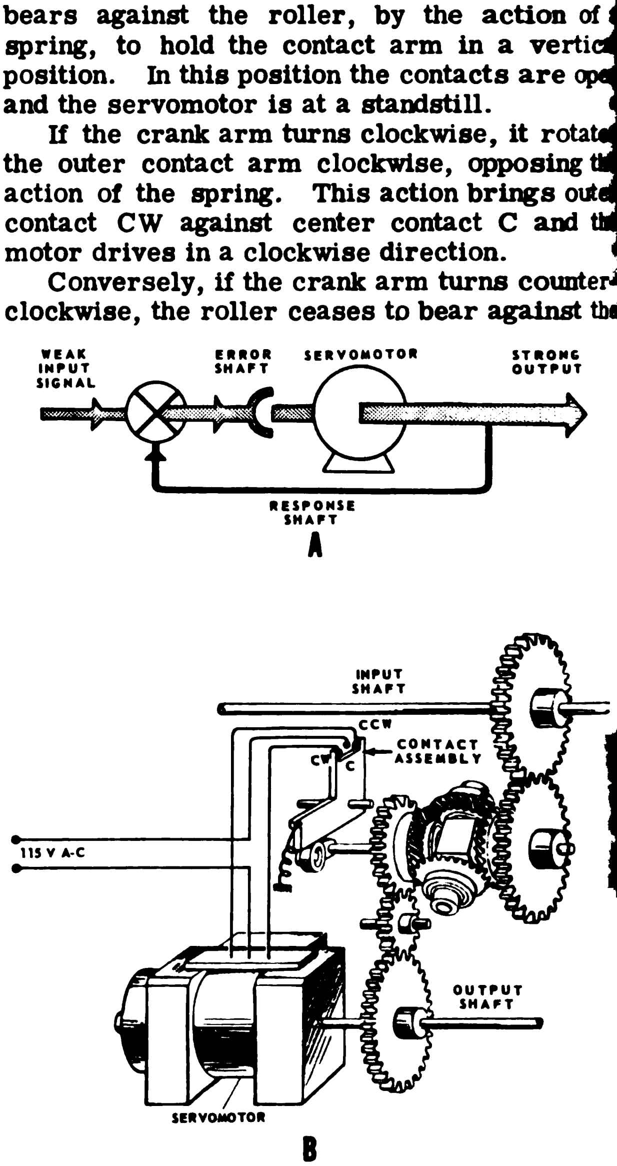



Figure 3-18.—Mechanical followup control.

se plate of the outer contact arm and this arm rotated counterclockwise by the action of the ring. This action brings outer contact CCW ainst center contact C and the servomotor ives in a counterclockwise direction.

The DIFFERENTIAL is used to measure the fference, or ERROR, in position between the put and output. The input is geared to one side the differential. The servo output is used to ) position the load and (2) drive the other side the differential. This action is called the rvo RESPONSE.

The spider of the differential turns when ere is a difference between the input and out- t. As the spider turns, the spider shaft op- ates the electrical contacts that control the eration of the servomotor so that the motor ives its side of the differential in a direction PPOSITE to that of the input. The servomotor ways drives in a direction to reduce the dif- rence between the input and output, or error, zero.

The OPERATION of the mechanical followup ntrol is illustrated in figure 3-19. For sim- icity, the followup control input shaft is geared the left side of a differential by a 1-to-1 ratio d the servomotor shaft is geared to the right de of the same differential by a 1-to-1 ratio. owever, this gear ratio is seldom found in ac- al practice. The gear ratios in the line can ry as long as the positions taken by the output aft represent the values of the quantities set to the followup control by the input shaft.

If the input turns counterclockwise 1/2 rev- ution, the left side of the differential is driven 2 turn (fig. 3-19A). The left side rotates the ider because the right side of the differential geared to the servomotor and is held station- ry. Because the input is 1/2 turn, the spider rns clockwise 1/4 turn and rotates the crank rm clockwise 1/4 turn. This action rotates the ter contact arm to bring contact CW against enter contact C.

When contact is made, the power source is onnected to the servomotor and the motor turns a direction opposite to that of the input (fig. -19B). As long as the contacts are closed the otor runs and turns the right side of the dif- rential. This action of the servomotor con- itutes the RESPONSE, which causes the spider rotate counterclockwise toward its original osition. Thus the crank arm is rotated counter- lockwise toward its original position, and the pring pulls the outer contact arm back to its vertical position to open the contacts and stop the motor.

The crank arm is now at its starting point. It has been rotated back 1/4 turn and the spider that drives it has also been rotated back 1/4 turn. As the spider has been driven back 1/4 turn, the right, or response, side of the differential has been driven back 1/2 turn. In other words, the servomotor shaft has also rotated 1/2 turn, which is the same amount that the input shaft rotated because the motor shaft is geared to the right side of the differential by a 1-to-1 ratio. Therefore, the number of revolutions, or fractions of a revolution, of the output shaft corresponds exactly with the number of revolutions, or fractions of a revolution, of the input shaft from the servomechanism.

If the input rotates continuously, the motor contacts remain closed and the servomotor drives continuously in a direction to open the contacts. Until the servomotor has driven sufficiently to make the output equal the input, the

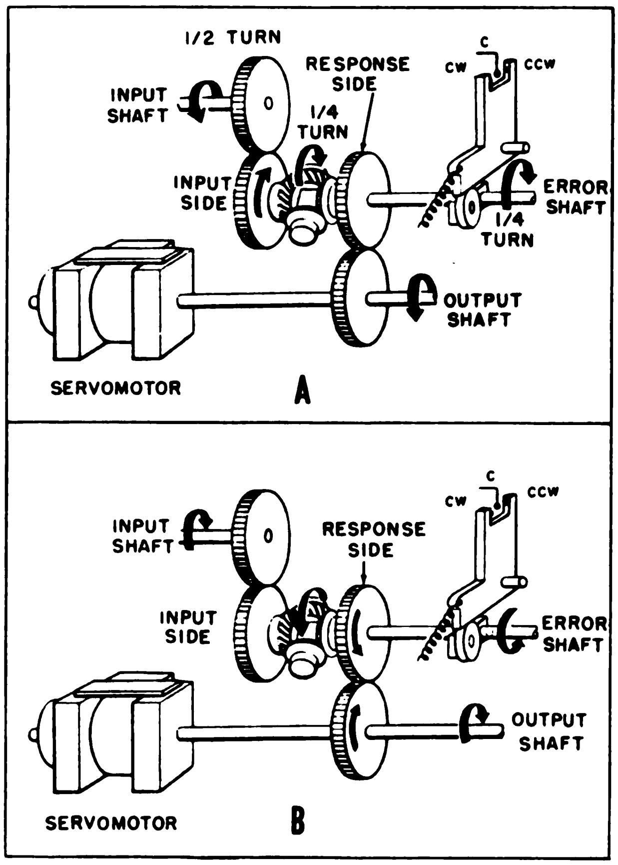



Figure 3-19.—Operation of a mechanical followup control.

input side of the differential is ahead of the response side. As long as the motor runs there is a difference, or error, between the input and output values. When both sides of the differential have been driven an equal amount, the output synchronizes with the input. This condition represents the point of correspondence, or zero error. At this point the switch contacts open and the motor stops.

### SYNCHRO FOLLOWUP CONTROL

In addition to mechanical followup controls, synchro receivers are commonly used as followup controls for servomotors in servomechanisms. The types of synchro followup controls are (1) single units operating at one speed and (2) two single units geared together operating at two different speeds. The two single units provide both fine and coarse control.

A single-speed synchro followup control consists essentially of a contact assembly and a bearing-mounted synchro receiver connected electrically to a synchro transmitter (fig. 3-20). The receiver controls the action of the servomotor that drives the shaft load. The principle of this type of control is represented schematically in figure 3-20A.

The contact ASSEMBLY that controls the action of the servo is similar to the contact assembly of the heart cam described previously. The two outer contacts are fixed on an arm that can be rotated as shown in figure 3-20B. For simplicity, the center contact arm has been considered as stationary. Actually, the center contact is mounted on an arm that can be rotated, within limits, by a MAGNETIC DRAG (fig. 3-20) geared to the servomotor. The purpose of the magnetic drag is to overcome the momentum of the servomotor and to bring the motor quickly to rest at the point of zero error.

When the rotor of the synchro receiver turns in response to a transmitted signal, contact is made between the center and one of the outer contacts (depending upon the direction of rotation of the rotor), causing the servomotor to drive in a direction to open the contacts. This action was described previously in connection with an application of the heart cam. The response shaft is geared to the stator of the bearing-mounted synchro receiver. As the servomotor turns the load in one direction, the response shaft drives the synchro-receiver stator in the opposite direction. The synchro stator and rotor are coupled together magnetically so that as the stator turns backward the rotor transmits a backward torque to the heart cam through the follower roller that finally opens the contacts and stops the motor.

A BEARING-MOUNTED SYNCHRO RECEIVER is used in this followup control to provide rotation of both the synchro stator and rotor. This type of synchro receiver with its stator bearings is mounted in hangers and is provided with a slip-ring and brush assembly for both the stator and rotor to transfer the electrical circuits from the stationary frame. The rotor is positioned by a signal from a synchro transmitter. The stator is turned by a worm wheel meshing with a worm that is driven by the response shaft.

The stator leads pass through one end cap and an insulating disk to three slip rings marked S1, S2, and S3. Three brushes marked S1, S2, and S3 bear against the respective stator slip rings.

The rotor leads are connected to two slip rings marked R1 and R2 and one end of the rotor shaft. Two brushes marked R1 and R2 bear against the respective rotor slip rings.

All five brushes are mounted on a terminal block and are connected so that signals can be transmitted to the receiver on the three stator leads while the stator is free to turn at all times. The terminal block and brush assembly are mounted on one of the stationary hangers. Single-phase 115-volt power is supplied to the rotor of the synchro-receiver in the usual way.

## Mechanical Counters

### SIX-PLACE ODOMETER

The six-place odometer is a six-figure counter that indicates the total revolutions of any rotating device to which it is geared. This counter consists of six drums, each containing figures from 1 through 9 to 0 on the outer surface.

The UNITS drum, or dial, is geared by a star wheel to the TENS dial; the tens dial is geared by a star wheel to the HUNDREDS dial; and so on. Thus, if a drum turns a complete revolution,

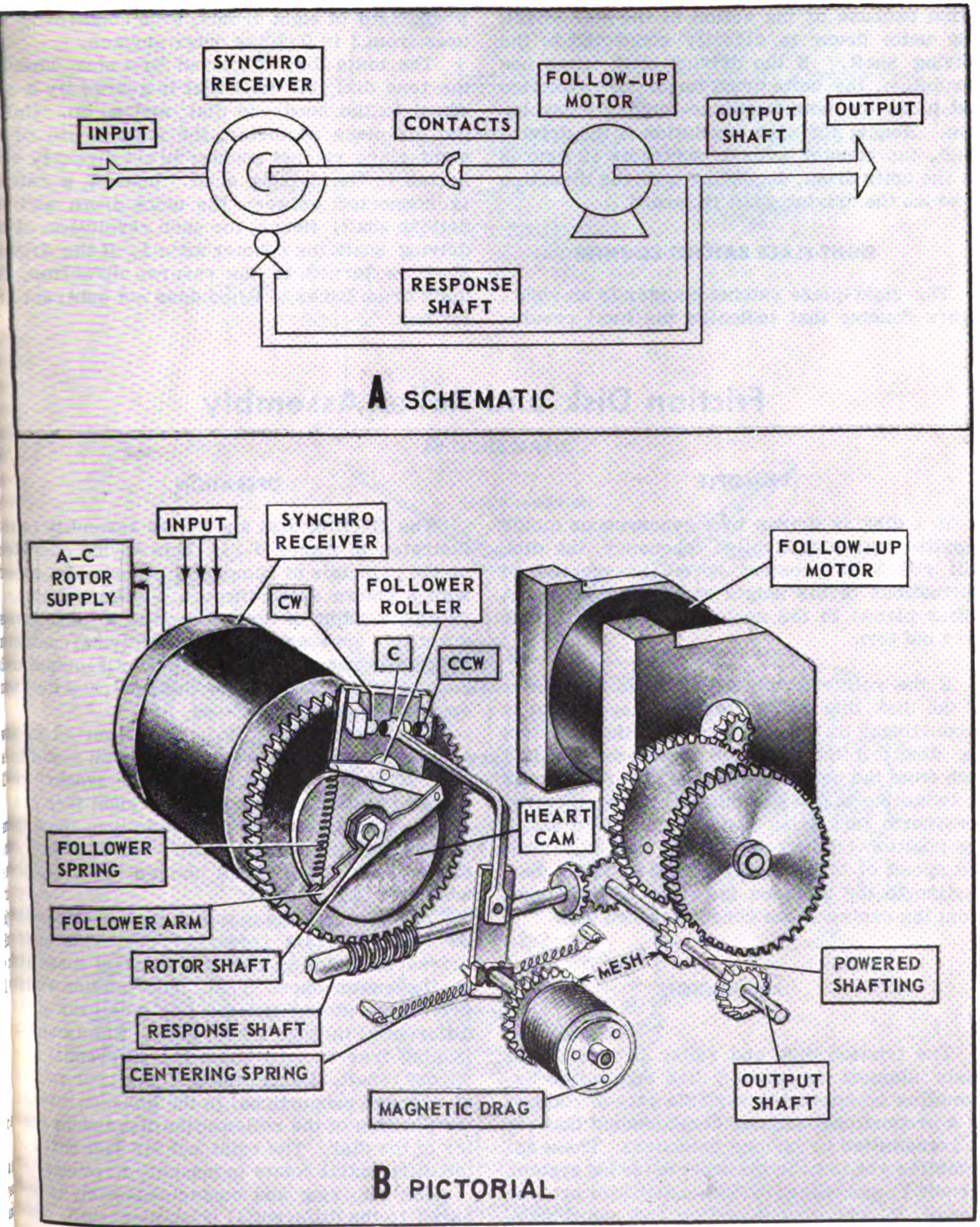



Figure 3-20.—Single-speed synchro followup control.

the next higher drum turns one-tenth of a revolution because of the action of the star wheel. The units drum is directly connected to the driving shaft. If the driving shaft turns one revolution, the units drum turns one revolution and turns the tens drum one-tenth of a revolution. Hence, for each revolution of the driving shaft, the counter adds or subtracts 10 figures on the units drum, depending upon the direction in which the driving shaft is turned.

### EIGHT-PLACE RATCHET COUNTER

The eight-place ratchet counter is an eight-figure counter that indicates the total revolutions of any rotating device to which it is geared. It consists of eight drums, each containing figures from 1 to 0 on the outer surface.

The units dial is geared by a star wheel to the tens dial; the tens dial is geared by a star wheel to the hundreds dial; and so on. Unlike the six-place odometer, the units drum of the eight-place ratchet counter is not directly connected to the driving shaft. Instead, a ratchet is connected between the units drum and the driving shaft. Hence, for each revolution of the driving shaft the counter adds 1. If the driving shaft is turned in the reverse direction, the units drum backs to 0 and does not subtract any further.

## Friction Disk and Roller Assembly

### PRINCIPLE

If a disk is driven by a synchronous motor supplied with a controlled frequency, the disk will run at a constant speed irrespective of fluctuations of the ship's supply frequency. A roller placed in the center of the rotating disk does not turn.

If the roller is moved out from the center of the disk, the roller turns at a speed that is proportional to the distance from the center of the disk. If the roller is moved out one-half inch from the center of the disk, the roller runs at twice the speed at which it ran when moved one-fourth inch from the center of the disk. If the position of the roller on the disk is varied, the speed of the roller is varied in direct proportion to the distance the roller is positioned from the center of the constant-speed disk.

### APPLICATION

The friction disk and roller is used as the basic element in friction disk and roller assemblies to convert a variable rate of rotation to a proportional angular displacement that can be transmitted to various indicators. These assemblies are used in the underwater log system, circuit Y; propeller revolution indicator system, circuit K, and wind direction and speed indicating system, circuit HD and HE.

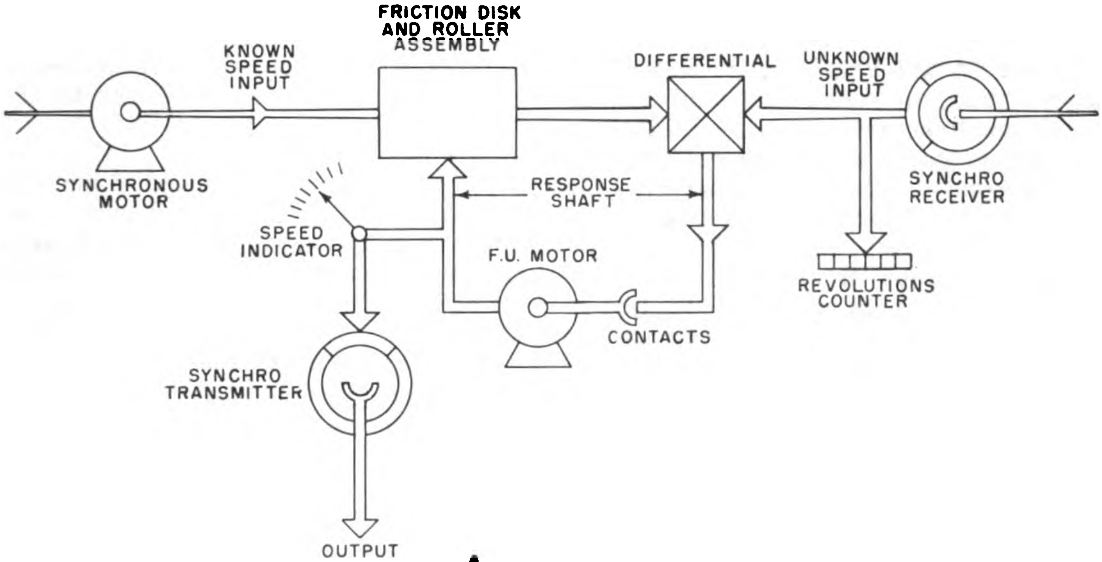
### OPERATION

The friction disk and roller assembly is illustrated in figure 3-21. This device operates on the principle of comparing an unknown speed with a known speed through a differential and using the output of the differential to make these quantities approach equality. Electrical contacts operate in response to the differential output and control a followup motor that matches the two speeds (fig. 3-20A).

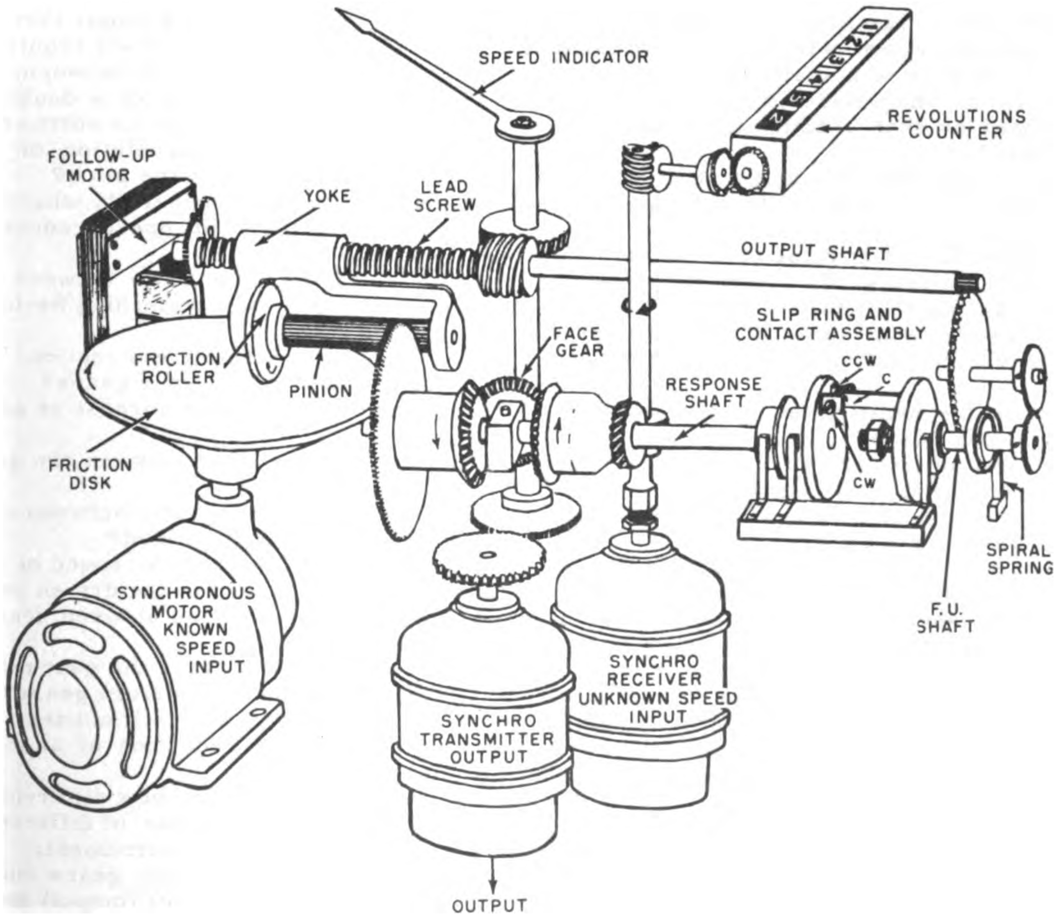
The rotation that is to be converted to an angular displacement is the unknown speed input. This input is received by the synchro receiver, which is geared to the right face gear of the differential and is free to turn about the differential (response) shaft. An extension of the synchro rotor shaft drives the six-place odometer (fig. 3-20B).

The synchronous motor is energized from the 60-cycle constant frequency bus. This motor drives the friction disk at a constant speed and is the known speed input. The friction roller drives the pinion and the left face gear of the differential through a spur gear. This assembly is also free to turn about the differential (response) shaft. Hence, the left face gear rotates at a speed proportional to the distance between the position of the roller on the disk and the center of the disk. The right and left face gears of the differential rotate in opposite directions.

The slip ring and contact assembly is secured to the differential (response) shaft. This assembly carries two outside contacts, CW and




A SCHEMATIC




B PICTORIAL

Figure 3-21.—Friction disk and roller assembly.

CCW, each connected to a slip ring. These contacts do not normally make contact with the center contact C, which is mounted on the followup shaft. Thus, the contact assembly can be turned in either direction so that one or the other of the outside contacts can make contact with the center contact. This action energizes the followup motor and determines its direction of rotation.

The followup motor drives the lead screw, which moves the yoke in or out (depending on the direction of rotation), thereby varying the revolutions per minute of the friction roller and the left-face gear of the differential. This action continues until the number of revolutions are the same as the right-face gear of the differential. When this equality is reached, the differential (response) shaft ceases to rotate and the contact assembly opens the circuit to the followup motor.

A pinion is cut on the end of the output shaft and engages a gear train that drives the followup shaft very slowly in the same direction as the differential (response) shaft whenever the followup motor is operating. This action restores the contacts to their normal (open) position slightly before the differential (response) shaft stops rotating to prevent hunting or overtravel of the lead screw.

## QUIZ

1. Name three quantities in connection with various I.C. systems that can be represented by the rotation of a shaft.
2. How is the magnitude of the quantity represented by shaft rotation increased or decreased?
3. What is the shaft value of a shaft that must be turned 10 revolutions to represent a 360° direction?
4. If a shaft has shaft value of 5° and the shaft counter indicates 20°, how many revolutions has the shaft made?
5. What is the total value of a shaft that has made 4.5 revolutions if the shaft value is 5°?
6. What is the name given to the smaller of two mating gears?
7. What kind of motion is transmitted when one gear positions another gear?
8. What kind of motion is transmitted when a gear positions a rack?
9. Gears used to transmit rotary motion between parallel shafts are called what?
10. What is the basic difference between a straight spur gear and a helical spur gear?
11. How does the meshing action of two helical gears differ from that of two spur gears?
12. Gears used to transmit rotary motion between two nonparallel shafts are called what?
13. How does a straight bevel gear differ from a spiral bevel gear?
14. What are miter gears?
15. How are the teeth arranged on an internal gear?
16. What is the relation between the axes of an external gear and an internal gear for the two gears to mesh?
17. What type of screw thread forms the groove around the body of a worm gear?
18. What is the lead of a single threaded worm if 16 turns of the worm are required to complete one revolution of the worm wheel?
19. (a) What is the lead of a double threaded worm if eight turns of the worm are required to complete one revolution of the worm wheel? (b) What is the pitch?
20. Worms are used generally where what relative magnitude of speed reduction is required?
21. What is the gear ratio between a 24-tooth driving gear and a meshing 84-tooth driven gear?
22. What are the relative directions of rotation of any two mating spur gears?
23. Where and for what purpose is an idler gear used?
24. How does an idler between two gears affect the gear ratio?
25. How is the gear ratio between a worm and worm wheel determined?
26. What is the ratio of the speed of the driving gear to the speed of the driven gear called?
27. What is the relation between gear ratio and speed ratio?
28. In figure 3-7, what is the gear ratio between the driving and the driven gears?
29. In gear trains, why is it not desirable to use a single gear reduction of as much as 12-to-1 ratio?
30. What is the function of a differential?
31. Name the three types of differentials generally used in I.C. instruments.
32. Why are 2-to-1 ratio gears required between the spider shaft (output) and the input shaft of the next (driven) mechanism in a bevel-gear differential?
33. What types of gears are used in the jewel-gear differential?

. Jewel-gear differentials are used with (a) what relative size of mechanism, (b) what relative amount of loading and (c) what relative requirement of load accuracy?

. Name the two types of a-c followup motors generally used in I.C. instruments.

. What are the requirements of a servomotor with regard to (a) quick starts and stops and (b) reversibility?

. What two types of cams are most frequently used as components of followup systems in many I.C. instruments?

. How is the heart cam mounted on the synchro receiver rotor shaft?

. What is the purpose of the follower spring?

. When an incoming signal from the synchro transmitter causes the synchro receiver to turn, how is this motion transmitted to the switch contacts?

. As the load comes into correspondence, the response shaft drives the bearing mounted synchro receiver stator in what relative direction with respect to that of the rotor?

42. In figure 3-17, what is the arithmetical relation between the signal that is used to control the output power and the input and feedback signals?

43. What is the function of the differential in figure 3-17?

44. In figure 3-18, if the input rotates continuously, what effect does this action have on the differential spider and the servomotor contacts?

45. Name the three essential elements of the single-speed synchro followup control shown in figure 3-19?

46. How is the units drum in a six-place odometer connected to the driving shaft?

47. How is the units drum in an eight-place ratchet counter connected to the driving shaft?

48. What is the function of the friction disk and roller assembly (fig. 3-21)?

## CHAPTER 4

# SWITCHES, PROTECTIVE DEVICES, AND CABLES

## Switches

Many devices are employed to control and to protect interior communication circuits and equipment. These devices consist principally of switches, fuses, and circuit breakers.

A switch is a device used for making, breaking, or changing the connections in an electric circuit under rated load conditions. An essential function of any switch is to maintain a good, low-resistance contact when in the closed position. Poor contacts have considerable resistance, which results in overheating the contact area. When heavy current is being carried by the switch, and the switch contacts are opened, an arc is produced. When the circuit is interrupted the arc is extinguished in the surrounding air between the contacts. In some switches when the circuit is interrupted the arc is extinguished in oil surrounding the contacts. Oil switches, however, are not used in naval ships because of the fire hazard. Most switches used in interior communication systems are of the rotary type.

### PUSHBUTTON

The simplest form of control is a pushbutton switch, which you have seen used to operate doorbells or similar devices. A pushbutton control may take one of several forms. They may vary from a single contact to several ganged springs and fixed contacts operated by one button. One weatherproof type is covered by a rubber or neoprene diaphragm, and operation is accomplished by pressing the center of the diaphragm.

Pushbutton contacts may be arranged so that the circuit is normally open and then closed when the button is pressed. Another contact arrangement is such that the circuit is normally closed, and opens when the button is pressed. Still another arrangement makes it possible to have one or more circuits normally closed by the button while other circuits connected to the same button are opened. Pressing the button opens one or more circuits and closes others.

Pushbutton controls are shown on equipment schematics. Figure 4-1 illustrates the symbols used to indicate several pushbutton arrangements.

Pushbutton control may be for either momentary contact or continous contact operations. In the latter case, a latching device holds the switch in the operated position until the latch has been released.

### KNIFE

The knife switch is the basic power switch from which most of our modern switches have been developed. A single-pole, single-throw knife switch consists of a single copper blade hinged at one end and designed to fit tightly between two copper jaws, or clips, at the other end. An insulated handle is fastened to the copper blade to open and close the switch. Terminals are provided for connecting the leads.

A two-pole, single-throw knife switch has two blades with one set of clips for each blade and an insulated handle that operates both blades simultaneously. Double-throw switches have two sets of clips (one set at each end) so that the blades can be thrown into either set of clips to shift from one circuit to another.

### ROTARY SNAP

The rotary snap switch (fig. 4-2) is a device that opens or closes a circuit with a quick motion. A type SR rotary snap switch consists of

| | |
|---|---|
| | momentary-contact push button normally open |
| | momentary-contact push button normally closed |
| | momentary-contact push button with two sets of contacts, one normally closed and one normally open |
| | maintaining-contact push button |
| | pilot switch (pressure, float, etc.) |
| | contactor, or relay coil (letter inside circle to suit) |

Figure 4-1.—Pushbutton symbols.

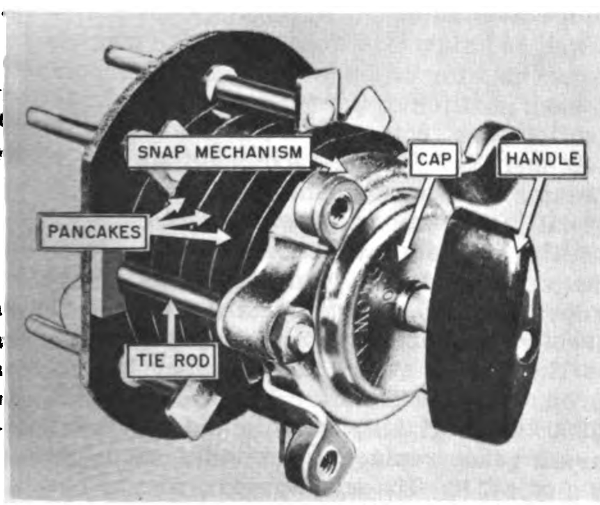



Figure 4-2.—Type SR rotary snap switch (10 ampere size, 1SR).

one or more sections, each of which has a rotor and a stationary member. Movable contacts are mounted on a bushing and stationary contacts are mounted on insulated discs, which are arranged one beneath the other in "pancake" style along the switch shaft. This type of construction has the advantages of shockproofness, compactness, flexibility of circuit arrangements, and protection to the operator. The operator, by rotating the switch handle, triggers a spring and cam arrangement, which, in turn, operates the switch contacts. If the spring should break, further rotation of the handle will eventually cause a projection on the handle's shaft to contact a projection on the operating shaft to operate the switch. However, the switch-driving shaft and handle will be misaligned from its normal position, and the characteristic snap action will not be apparent.

Snap switches are available in a wide variety of amperage ratings (from 10 to 200), poles, and mountings (bulkhead or panel mounting).

The switch type designation indicates its current rating (1SR is 10 amp, 3SR is 30 amp, and so on); number of poles (3SR3 is 30 amp, 3 pole); switching action (1SR3A is single throw, for example, on off, on off); mounting style (1SR3A1 is front mounted, back connected); and enclosure for type switches (3SR4B1-3 is watertight). An exploded view of a type 6SR snap switch is illustrated in figure 4-3.

Most snap switches are suitable for 450-volt, 60-cycle, a-c and 250-volt d-c operation. Present 10-ampere switches are suitable for 120-volt operation only, although the switches are sometimes used at higher voltages where the currents are very small. Care must be exercised in the application of multithrow (double-throw and triple-throw) switches. The movable blade, in some cases, is so wide that in moving from one stationary contact to a second, the two stationary contacts will be momentarily bridged by the arc and movable blade, causing a short circuit. Therefore, each time a multithrow switch is to be installed, a careful check should be made on both the switch and the intended circuit to make sure that a switch of the proper current and voltage ratings is used.

One of the most frequent causes of switch failure has been the use of excessive amounts of grease on switch contacts. Arcing causes carbonizing of the grease resulting in a high-resistance film of carbon on the contacts. Without any lubricant, excessive wear of contacts will result. Microscopic examination of the surfaces reveals that both movable and stationary contacts are rough and actually touch each other at relatively few points. At these points there is excessive pressure, which results in rapid wear. The presence of a small amount of petrolatum fills the "valleys" and distributes the pressure throughout the entire contact surface, thereby eliminating excessive wear.

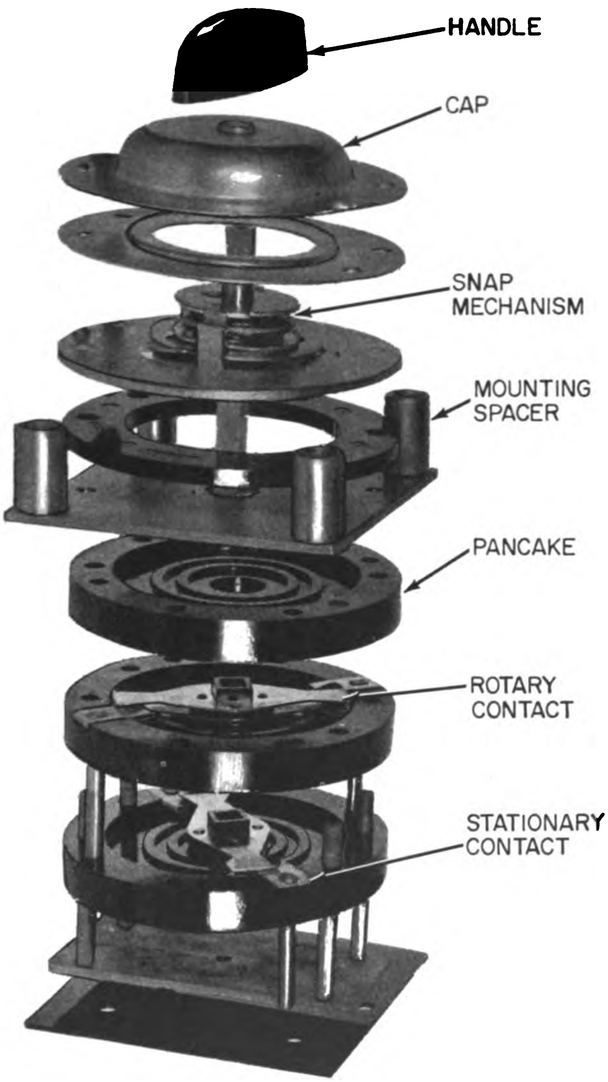



Figure 4-3.—Type SR snap switch—exploded view (60 ampere size 6SR).

### MULTIPOLE ROTARY

#### TYPE J

The type J multiple rotary switch (fig. 4-4) consists of an equal number of rotors and pancake sections. The number of sections required in the switch is determined by the individual application. A shaft with an operating handle extends through the center of the rotors. The movable contacts are mounted on the rotors, and the stationary contacts are mounted on the

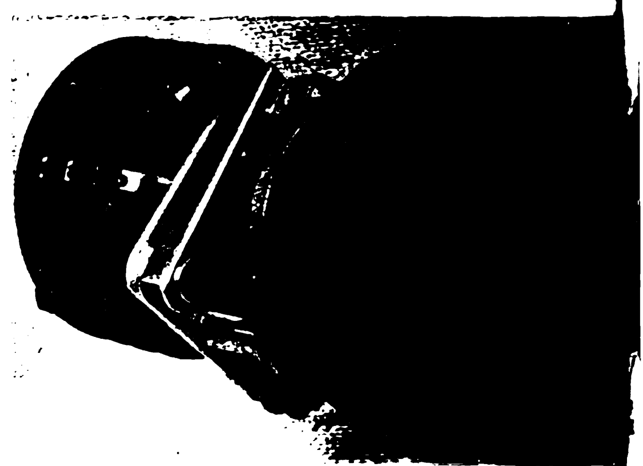


Figure 4-4.—Type J switch.

pancake sections. Each section consists of eight contacts, designated A to H, and a rotor with two insulated movable contacts spaced 180° apart. Each movable contact is arranged to bridge two adjacent stationary contacts. The switch has eight positions. A detent mechanism is provided for proper alignment of the contacts in each position of the operating handle. In one position, the rotor contacts bridge segments A-B and E-F; in the next position, the rotor contacts bridge segments B-C and F-G. Diagonally opposite pairs of contacts are subsequently bridged for the remaining positions. The various circuit leads are connected to the proper pancake terminals, and the transfer of circuits is effected by operating the handle.

The type J switch is no longer being procured. Bureau Standard Plan No. 9000-S6202-73350 is available, showing adaptor parts to permit ready replacement of a damaged J switch by a type-JR. The adaptor parts may be readily fabricated onboard ship or obtained from the activity furnishing the JR switch.

#### TYPE JR

The type-JR switch (fig. 4-5) is installed on recent I.C. switchboards. This switch is smaller in size and more rapidly disassembled than the J switch. These features result in a saving in switchboard space, and facilitate repairs. The JR switch is of the 1JR, 2JR, 3JR, or 4JR type.

The 1JR switch has only one movable contact per section. This movable contact bridges two adjacent stationary contacts.

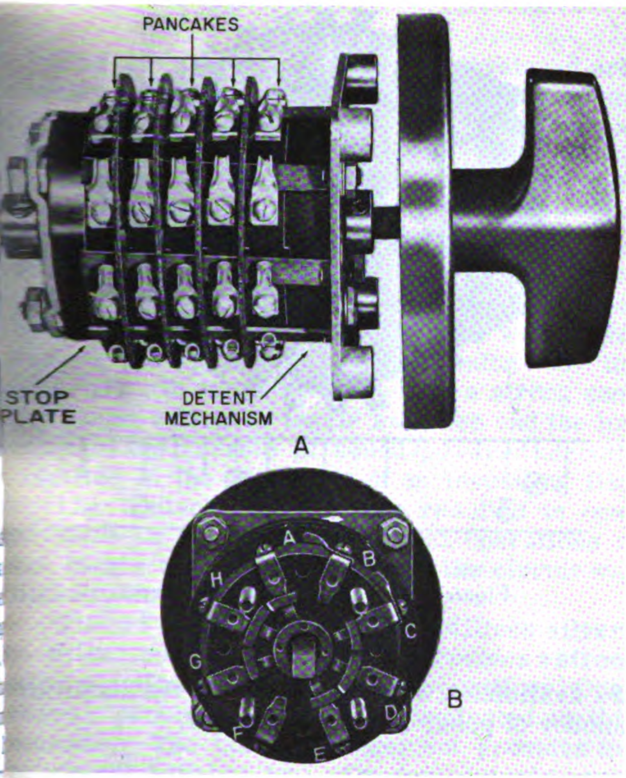



Figure 4-5.—Type 4JR switch.

The 2JR switch has two movable contacts per section, 180° apart. Each movable contact bridges two adjacent stationary contacts.

The 3JR switch utilizes one of the stationary contacts as a common terminal. This stationary contact is connected, in turn, to each of the other stationary contacts of the section by a single-wiper contact. The 3JR-type is used for selecting one of several (up to seven) inputs.

The 4JR switch is designed as an "either or both switch" with two movable contacts per section. Each movable contact bridges three adjacent stationary contacts (fig. 4-5B). This switch is used to select either or both of two indicators or synchros. The positions for energizing two indicators are:

90° right—both indicators energized.
45° right—indicator 1 energized only.
0° off.
45° left—indicator 2 energized only.

When the 4JR switch is in the OFF position, both indicators are connected together, but are disconnected from the power supply.

The designations of JR switches are determined by the type of section (rotary and stationary contacts) followed by the number of sections in the switch. For example, a 2JR10 switch denotes a JR switch with 10 type-2JR sections.

The JR switch is stocked in multiples of 5 sections (up to 25 sections). In some cases, a switch with a number of sections (not a multiple of five) has been installed. If this switch must be replaced, a switch with the next largest number of sections that is a multiple of five should be installed if space permits. It is preferred to have all sections of a switch the same, but, if absolutely necessary, a switch with some sections of one type and some sections of another type can be provided.

Type-JR switches are rated at 120 volts, 60 cycles, and 10 amperes. The switch should not be used on d-c circuits because of the possibility of severely burned contacts when operated slowly (teased). The switch is of the nonshorting type. Although the blade bridges two adjacent contacts simultaneously (for example, contacts 1 and 2 when the switch is operated), the blade breaks contact 1 before making the next alternate contact 3. For example, in the 2JR switch alternate terminals may be connected to an independent source of a-c power without danger of short circuit during movement of the switch blade.

Barriers are also provided between sections to prevent terminals from turning and shorting to adjacent terminals.

If the sections are not uniform the switch will be designated by JRSP followed by the number of sections.

The JR switch has a stop deck, which permits setting the switch to the number of positions desired. By inserting pins or screws in the stop deck immediately after the desired last position, the switch movement will be limited to the positions between these points.

## TYPE JL

The JL switch is identical to the JR, except in size, mounting facility, and electrical rating. The diameter of the JL deck is approximately 1 3/4 inches; whereas the diameter of the JR deck is approximately 2 1/4 inches. The rating of the JL switch is 120 volts, 60-cycles, 5 amperes. Standard types are available in 3, 5, and 10 sections. The JL switch has a threaded bushing for single-hole mounting.

### TYPE JA

The JA switch (fig. 4-6) was developed primarily for circuit selection in sound-powered telephone applications. It provides a greater number of selections and a smaller switch than is possible with the JR switch. The JA switch is (at present) furnished only with common rotor sections as shown in figure 4-7. Sixteen position and 30 position JA switches, which permit selection of 16 and 30 circuits respectively,

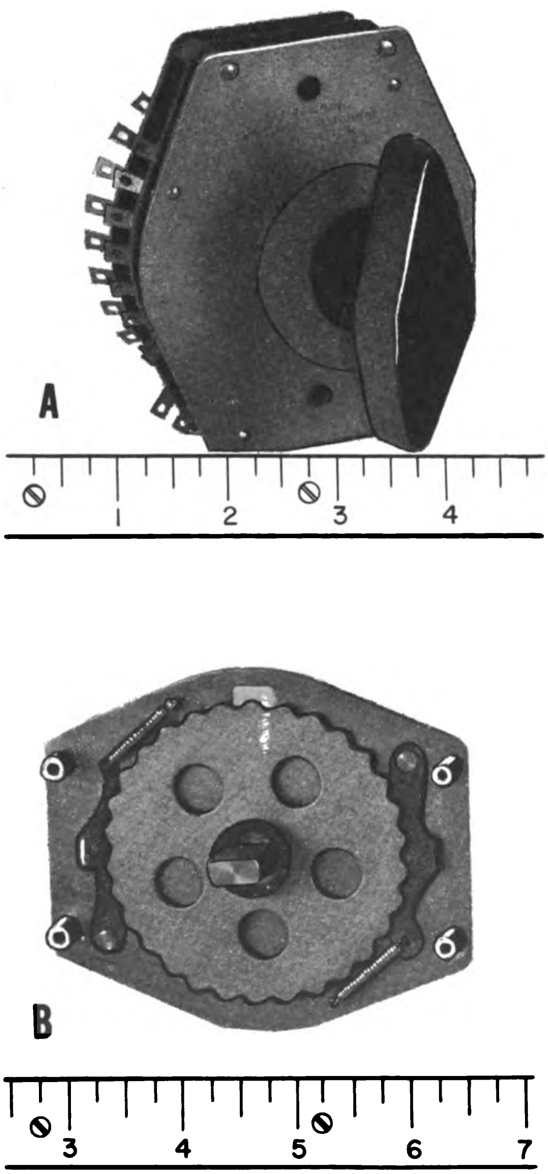



Figure 4-6.—Type JA switch and detent mechanism.

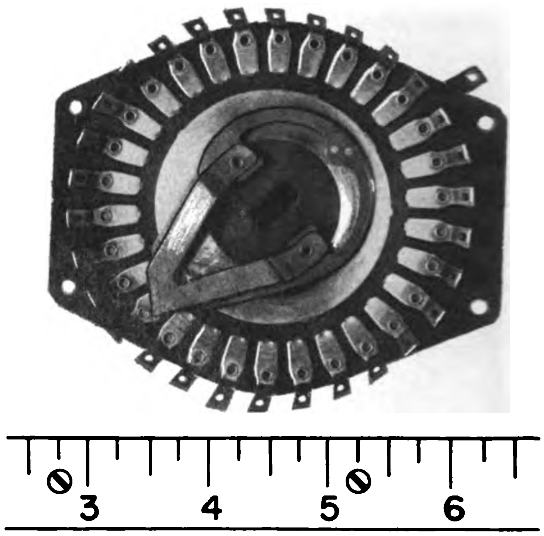



Figure 4-7.—Type JA switch contacts.

are available. With the JR switch the maximum number of possible selections is 7.

The JA switch also provides lower contact resistance by using either silver or silver-overlay contacts. With brass or copper, an insulating film forms over the contacts which is only broken down if appreciable voltage and power are available in the circuit. However, in sound-powered telephone circuits, there is insufficient power to break down the film, and relatively high resistance results. The silver-to-silver contacts of the JA switch consist of pure silver welded to beryllium copper (laminated metals process). The tarnish that forms on pure silver is a sulfide, which does not adversely affect conductivity. However the wiping action of the making contacts removes this film. Silver or silver-coated contacts are now being utilized for latest type JR switches and other low-current switches. In larger switches, silver (unless alloyed with other metals) is unsatisfactory because it vaporizes too readily due to arcing.

The JA switch is available in 2, 6, and 10 sections. An example of the switch designation is JA6C (16) for a 6-section, 16-position switch: here the first number designates the number of sections, the C indicates common rotor, and the number in parentheses indicates the number of positions.

### TYPE JF

The JF switch (fig. 4-8) was developed priıarily to replace toggle switches in the 10 and 0 switch boxes for sound-powered telephone pplications.

Because of the problems in making toggle witches watertight, it was necessary to provide gasketed cover for the 10 and 20 switch boxes, hich contained the toggle switches. The cover ad to be open when the switches were operated. herefore, the switch box was not watertight, eading to possible malfunctioning of the witches. In addition, the lack of a strong conıct wipe action in toggle switches and the low oltage and current of sound-powered circuits esulted in the formation of an insulating film n the contacts. This film resulted in open ircuits or it required several operations of ıe toggle switch handle before the circuit was ıitially made.

The JF switch replacement utilizes silvero-silver contact surfaces and provides a strong iping action in moving between positions. Open ircuit problems have been eliminated in this nanner. The blade arrangement provides for . circuit between two adjacent contacts, such s in the 2JR switch previously discussed. The ype 2JF has two such blade arrangements per witch deck. The standard switches have 1, 3, ınd 5 switching decks, which are indicated in he type designation by the number following JF.

The original production of the switches had ı detent to limit the switching action to two ositions. The present design has a 12-position letent arrangement with adjustable stops. The stops can be adjusted by removing the four screws on the back plate and arranging the stop arms mounted on the switch shaft to give the number of positions desired.

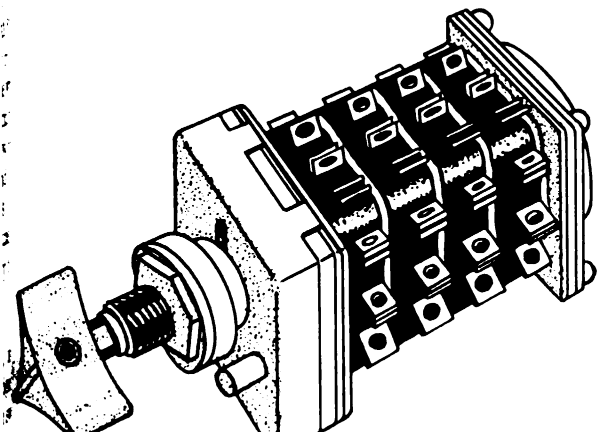


Figure 4-8.—Type JF switch.

An O ring on the switch shaft within the mounting bushing prevents water from entering the switch. An O ring is also provided on the outside of the mounting bushing to give a watertight seal against the panel in which the switch is mounted. These features have eliminated the need for a watertight cover over the switch.

The JF switch is satisfactory for 120 volt, a-c applications up to 1 ampere. In addition to sound-powered telephone usage, it is being used in such applications as loudspeakers, microphone stations, and similar low-current applications. CAUTION: The switch decks are of molded nylon material. Therefore, care must be observed in soldering the leads to the switch contacts to prevent too much heat from being passed back to the switch deck. Excessive heat will destroy the switch deck or damage the insulation between adjacent contacts.

### WATERTIGHT CASE

All switches that are not incorporated with a switchboard, panel, or other assembly are usually mounted in a watertight case. In the interests of standardization, only the watertight case, or enclosure type switches most frequently used are carried in stock. For example, the JR switch in the enclosure is carried only in 5, 10, 15, and 25 sections in both bulkhead- and panel-mounted cases. The JA switch is carried only in two sections (16 and 30 positions) bulkhead-mounted cases. In addition, there is a 6-section JA enclosed switch used primarily for radiophone units. Snap switches are available in enclosures up to 200 amperes, and the available varieties of poles and positions are limited, particularly in the higher-ampere ratings.

In the obsolete J switch (fig. 4-4), the type of switch used in the case was necessarily different from the switchboard type because the switchboard type has no mounting plate. When the J switch is being replaced, notice (looking at the switch from the front) that the terminals in each section are lettered successively A to H clockwise. In the JR switch, the same switch is used (because a mounting plate is provided) both for switchboards and enclosures. When used on a switchboard, the mounting plate is secured to the panel close to the switch handle.

When used in an enclosure, the switch section is turned over, end for end, and the mounting plate is secured to the end opposite the handle. Thus, it will be noted that the terminal lettering (fig. 4-5B), which is clockwise when viewed from the end opposite the handle in the switchboard installation, is counterclockwise when viewed from the end opposite the handle in the watertight case. This fact should be borne in mind when it is necessary to replace a J switch by a JR switch, using adaptor parts as previously explained.

Until the development of the JA switch, the 16-position, sound-powered telephone selector switch was the NA-16, which was an enclosed special type J switch with 8 sections. The same function can be accomplished by the JA switch with 2 sections. A Bureau of Ships standard plan is available that illustrates how a JA switch unit may be readily substituted for the J switch unit in the NA-16 assembly. This should be done when the J switch unit requires replacement or develops excessive contact resistance in the sound-powered telephone line. To avoid replacement of cables, retain the existing case wherever practicable.

## LEVER OPERATED (CONTACT MAKERS)

Manually operated switches are used in alarm and warning systems to complete an electric circuit to various types of audible and visual alarm signals. There are many types of lever-operated switches used in the Navy. The type depends upon the circuit in which it is installed.

Most manually operated switches utilize JR interiors (fig. 4-9) (formerly type J interiors). These switches are operated by a lever with suitable locking plate. In the interests of standardization, two types of interiors are available, each containing three 2JR sections. One type is the JRM-300, which has a spring return mechanism; and the other type is the JR-304, which has a positive detent mechanism. By using slightly different arrangements of pins, lever, and locking plate, five types of switches can be obtained:

| | |
|---|---|
| S2JRM3-22 | 2-position, spring return to left position. |
| S2JRM3-22L | Same except with locking plate, can be arranged to lock in either or both positions. |
| S2JR3-22 | 2-position, positive detent in both positions. |
| S2JRM3-23 | 3-position, spring return to center position. |
| S2JR3-23 | 3-position, positive detent in all positions. |

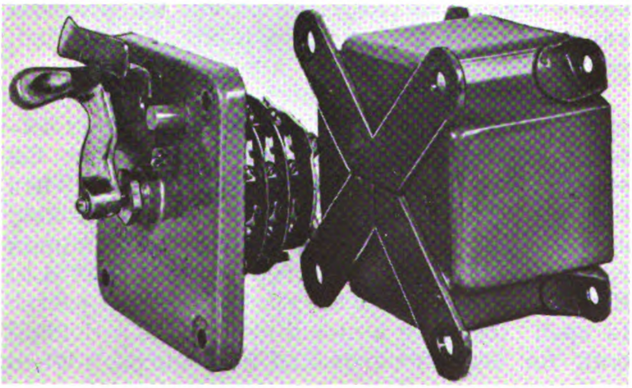


Figure 4-9.—Lever-operated switch (manual contact maker).

Special switches are in use where the standard switches cannot be used. For example, the diving alarm switch on the submarine bridge must be pressureproof. For submarine service, a distinctive shape is used for the operating lever knob or heads of alarm switches in conning tower and control room (where illumination is low) to avoid the possibility of confusion in operating the proper switch. A square-shaped knob is used for the diving alarm switch, a star-shaped head for the collision alarm switch, and a standard rounded head for general alarm.

Manually operated switches are available in single and 2- and 3-ganged types. These switches are used in such systems as the fireroom emergency signal, general alarm, chemical-attack alarm, steering emergency signal, whistle operation, lifebouy-release, and flight-crash signal.

## RELAYS AND CONTACTORS

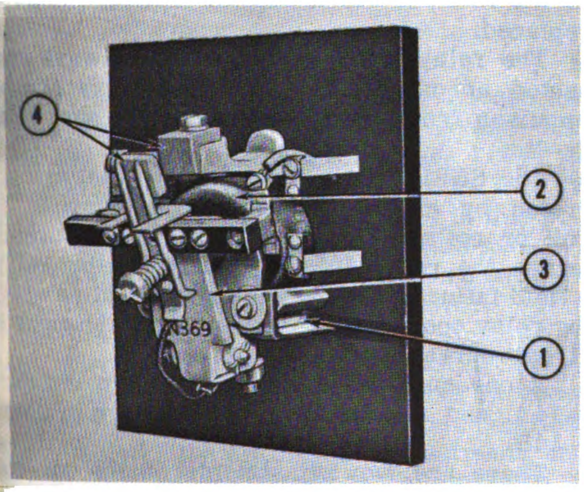
### D-C

A relay is a magnetically operated switch. The operating coil can be connected in series with a supply line to the load or shunted across the line. A contactor, like the relay, is a magnetically operated switch, except that the main contacts are designed to carry the heavier current of the load device.

The coil design is influenced by the manner in which the relay is used. When the relay is designed for series connection, the coil is ıally wound with a fairly small number of ·ns of large wire because the load current ll be flowing through the winding. When the lay is designed for shunt connection, the coil wound with a large number of turns of small re, which will increase the resistance and ıs lower the current through the coil.

The contacts of relays and contactors may en or close when energized. This means that lays can be used as protective devices, as ntrol devices, or to perform both functions multaneously. Because of this flexibility, re- ys and contactors are used in many shipboard ıplications.

The SHUNT type contactor (connected across e line) operates when line voltage is applied its operating coil 2 (fig. 4-10). The contacts, are arranged to complete or interrupt an ectric circuit. In this arrangement the con- cts are connected in series with the voltage ıpply to the controlled circuit. When voltage applied to the coil, a magnetic pull attracts ıe armature, 3, which closes the main contacts, . When the voltage supply to the coil is in- rrupted, the magnetic pull on the armature removed, and the armature spring pulls it way from the magnet. This action opens the ontacts and deenergizes the controlled circuit.



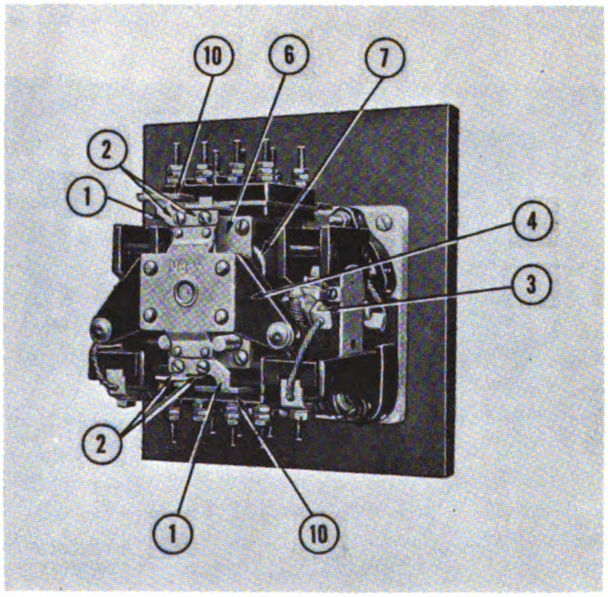

1. Magnet frame.
2. Operating coil.
3. Armature.
4. Main contacts.

Figure 4-10.—Shunt type d-c contactor.

The double-pole, shunt-type contactor (fig. 4-11) may be used for miscellaneous power control functions so long as the current rating of the contacts is not exceeded. The construction of this contactor is such that it can withstand severe mechanical shocks. This feature is obtained by using two armatures of equal mass that are connected by levers so that they move simultaneously in opposite directions. When this construction is used, any mechanical shock (regardless of direction or intensity) will tend to move both armatures in the same direction. The resulting forces will neutralize each other through the lever mechanism and prevent false operation.

Figure 4-12 shows two parts of the assembly of the double-pole, shunt-type contactor. Numbers of these parts correspond to numbers shown in figure 4-11 for identification.

To disassemble the unit, first remove the interlock operating arms, 1, by taking out the four screws, 2. Then take out the connector screws, 3, and lift off the front armature, 4.




1. Interlock operating arm.
2. Interlock arm screws.
3. Connector screws.
4. Front armature.
6. Coil clamp.
7. Operating coil.
10. Interlock operating bar.

Figure 4-11.—Double-pole, shunt-type contactor.

In figure 4-12A, the four screws, 5, holding the coil clamp, 6, are removed to expose the coil, 7. Disconnect the coil leads and lift the coil out of the magnet frame.

The interlock contacts may be inspected by removing the two screws, 8, and lifting the interlock assembly (fig. 4-12B) off the magnetic frame. This exposes the two cover screws, 9, which, when removed, allow access to the interlock contacts. When the interlock mechanism is replaced, make sure the interlock operating arms, 1 (fig. 4-11) properly engage the bakelite operating bars, 10 (fig. 4-12B). The interlock assembly looks as though it could be mounted in either of two positions. However, there is a slight difference in the length of the operating bars, and therefore the interlock mechanism can be mounted in one position only.

The interlock contacts should never be filed or lubricated. When they become excessively worn, they should be replaced with new contacts.

A detailed view of the main contacts is shown in figure 4-13. These contacts should be removed when the dimension, A, becomes 1 9/16 inches for copper contacts or 1 11/16 inches for carbon contacts. These contacts should never be lubricated. Grease, dust, or copper oxide act as insulators, which increase contact resistance and cause unnecessary heating. Accumulations of dust and grease should be wiped off while the circuit is deenergized. Copper oxide can be removed with a burnishing tool. The formation of copper oxide on contacts is often an indication of excessive contact temperature. If excessive heating occurs, check the remaining wear allowance and the current being carried by the contacts. If both are satisfactory, weak contact spring pressure may be the fault, in which case the spring should be replaced.

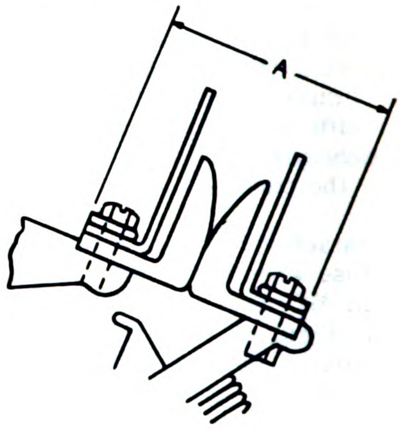
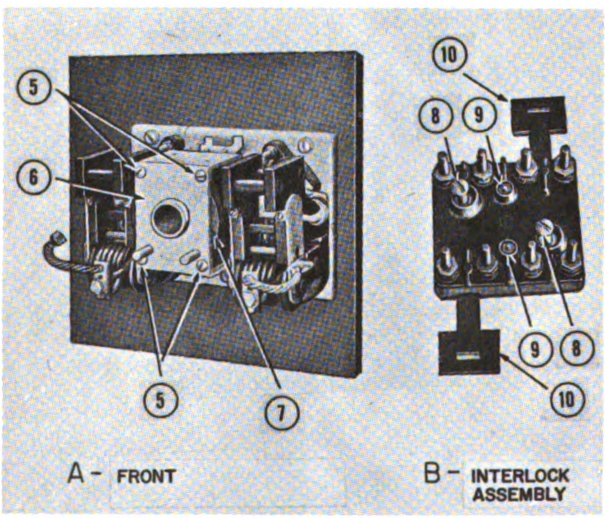



Figure 4-13.—Detailed view of contacts.




5. Coil clamp screws.
6. Coil clamp.
7. Operating coil.
8. Interlock mounting screws.
9. Interlock cover screws.
10. Interlock operating bar.

Figure 4-12.—Double-pole, shunt-type contactor components.

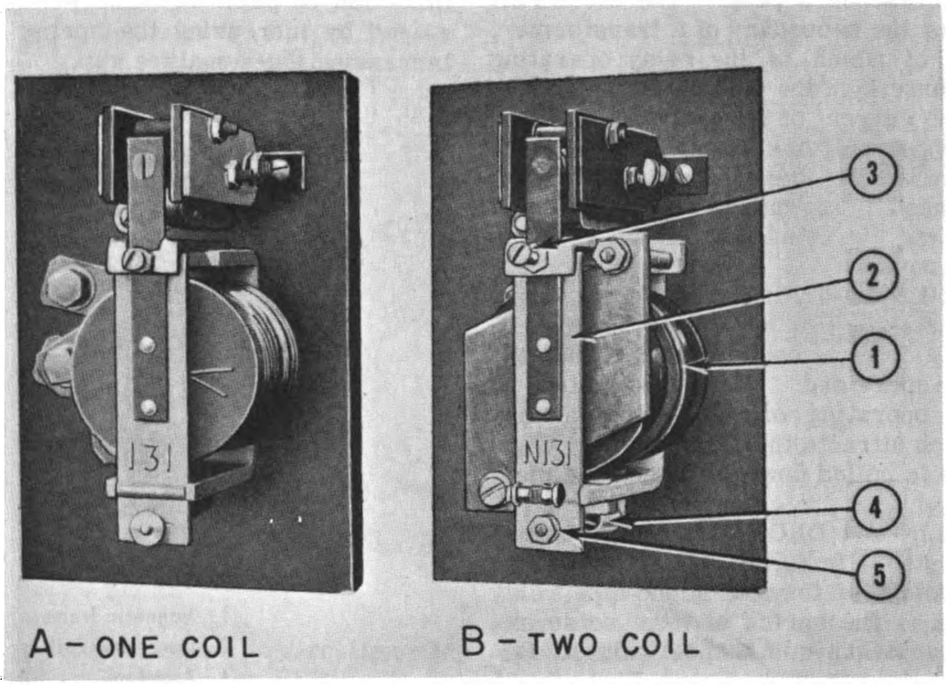
The relay types described are always connected across the line, and the relay control impulses from the pilot device are sent along the line.

The SERIES type relays (fig. 4-14) are operated by circuit current flowing through the coil or coils. This feature makes it possible to use the relay as a field decelerating relay, a field failure relay, or for any application where the relay operation is in response to changes in circuit current flow.

A one-coil series relay is shown in figure 4-14A, and a two-coil relay is shown in figure 4-14B.

There are two adjustments on the one-coil relay. The differential adjustment sets the difference between the opening and closing current values. The second adjustment sets the range of operating values. Usually, the operating adjustment is the only one required.

To adjust the differential, push the armature lever, 2 (fig. 4-14B) by hand until the contacts




1. Operating coil (one or two coils).
2. Armature lever.
3. Differential adjusting screw.
4. Tension spring.
5. Range adjusting nut.

Figure 4-14.—Series type relays.

close. (Be sure the power is off). Loosen the locknut that holds the stationary contact and adjust the contact position to provide 1/4 of an inch spacing between lever 2 and the face of the magnet core. Lock the contact in this position. When the contact is set in this manner, there is approximately 1/32 of an inch between the pin in the magnet core and the lever.

Release lever 2 and allow the contacts to open. Then turn the differential adjusting screw, 3, until the gap between the contacts is about 1/8 of an inch. Lock the screw in this position. This completes the differential adjustment, and the operating values should be within 20 to 25 percent of each other.

The range adjustment for operating values is made after the differential adjustment. To increase the range, increase the tension of spring 4 by turning nut 5 clockwise (fig. 4-14B). To decrease the range, turn the nut counterclockwise.

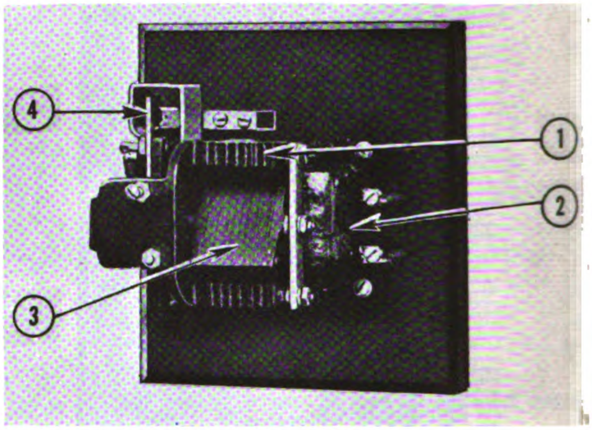
### A-C

All complete electrical systems whether a-c or d-c, use relays for control and protection purposes. The basic difference in relays designed for use on a-c and those designed for d-c is in the armature and magnet core construction.

The armature and magnet cores of an a-c relay are made up of laminations, and those of a d-c relay are of solid material. The use of laminations in an a-c relay reduces the heating due to eddy currents. In addition, a copper strap or ring (called shorted turn) is placed near the end of the pole piece of an a-c relay to reduce "chatter" during operation. Because the alternating current is going through a peak, dropping to zero, and going through a peak in the opposite direction and then dropping to zero again during each complete cycle, the coil tends to release the armature each time the current drops to zero and attracts the armature each time it reaches a peak. The SHORTED TURN acts as the secondary of a transformer, the primary of which is the relay operating coil. The current in the shorted turn is out of phase with the current of the operating coil because the copper ring has low-inductive reactance. Thus, when the operating coil flux is zero, the flux produced by the shorted coil is different from zero, and the tendency of the relay to "chatter" is reduced.

An a-c SHUNT relay is illustrated in figure 4-15. The basic function of the relay is to make or break an electrical control circuit when the relay coil is energized. To do this, voltage is applied to the operating coil, 2 (connected across the line), which attracts the armature, 3. When the armature is pulled down, it closes the main contacts, 4.

The PULLIN and DROPOUT current values may be adjusted. In figure 4-16 the various adjustment points of the a-c shunt-type relay are indicated. The spring and the setscrew, E, control the pickup and dropout values. Before the relay is adjusted, screw F should be set to clear the armature when the armature is in the closed position. Point B should be six threads from the extreme adjustment in the direction of point C. The pullin value can be raised by increasing the spring tension or by increasing the armature gap.




1. Magnetic frame.
2. Operating coil.
3. Armature.
4. Main contacts.

Figure 4-15.—A-c shunt relay.

# Fuses

A fuse is a safety device used to open an electric circuit when the current flow exceeds a safe value. Fuses are made in many styles and sizes for different voltages and currents, but they all operate on the same general principle. Each fuse contains a soft metal link that melts and opens the circuit when overheated by excessive currents.

## PLUG FUSE

A plug fuse has a piece of zinc-alloy wire mounted in a porcelain cup with a metal cover. A threaded contact base similar to a lamp socket is provided so that the fuse can be screwed into a socket in the fuse block. Plug fuses are used on small-capacity circuits ranging from 3 through 30 amperes at not more than 250 volts. Some plug fuses have small mica windows so that the fusible link can be observed. The plug fuse is seldom used in naval vessels but is extensively used in commercial applications.

## CARTRIDGE FUSE

### RENEWABLE AND NONRENEWABLE

A cartridge fuse consists of a zinc-alloy link enclosed in a fiber, plastic, ceramic, or glass cylinder. Some fiber and plastic fuse cylinders are filled with nonconducting powder. The fuse may be either of the renewable or nonrenewable type. In the renewable type, the fuse link is held securely by brass screw caps on each end of the fuse. This type fuse is no longer authorized by the Navy because more than one fuse link or a link of higher capacity can be inserted into a cartridge. This procedure would increase the fuse capacity and would not provide adequate circuit protection. In the nonrenewable type, the end caps are attached permanently to the fiber tube, and the fuse link is soldered to these caps.

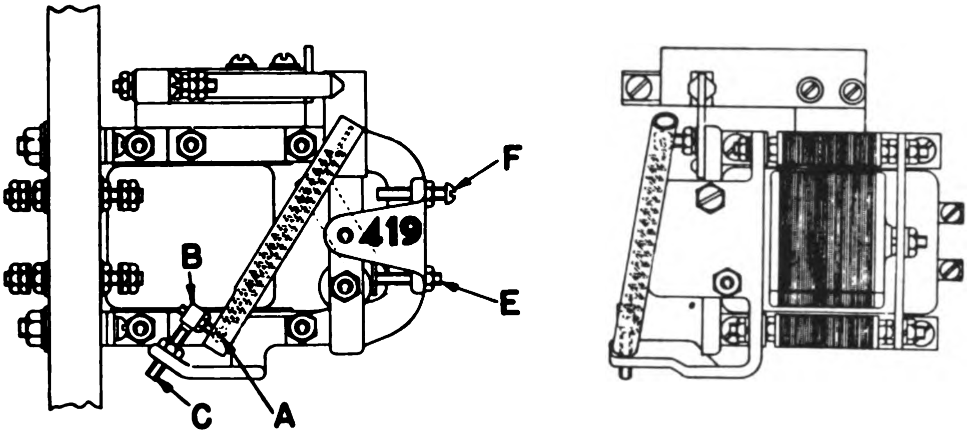



Figure 4-16.—Adjustment of a-c shunt relay.

SIZES

The smaller fuses are used in circuits up to 60 amperes and are made in the FERRULE, or round-end-cap type. Large sizes with short flat blades attached to the end caps are rated from 65 through 600 amperes. These blades fit tightly into clips on the fuse block similar to knife-switch clips.

Cartridge fuses are made in capacities of 1 through 1000 amperes for voltages of 125, 250, 600, and 1000 volts. Fuses intended for 600- and 1000-volt service are longer and do not fit the same fuse receptacles as fuses intended for 250-volt service. Fuses of different ampere capacity are also designed for different sizes of receptacles. For example, fuses of 1 through 30 amperes fit one size of receptacle, and fuses with capacities of 35 through 60 amperes fit a different size receptacle.

Cartridge fuses used with I.C. equipment are of various sizes, such as the miniature style FO2 and FO3 1 1/4" x 1/4" fuse rated from 1 through 30 amperes at 120 volts and the midget style FO9 1 1/2" x 3/8" fuse rated from 1 through 30 amperes at 120 volts. The standard 2" x 9/16" fuse is rated from 1 through 30 amperes at 450 volts for a-c service and 250 volts for d-c service. Fuses above 60-ampere capacity have knife-blade contacts and increase in diameter and length as the capacity increases.

A special type silver-sand fuse has been developed in physical sizes identical to the standard fuses and rated at 500 volts, a-c or d-c. These fuses have the same current range as the standard fuses for the same size. However they have a short circuit current interrupting capability of 68,000 amperes. This characteristic permits their use in ship service power systems.

Before fuses are pulled, the switch for the circuit should be opened. Approved fuse pullers must be used for removing fuses from block-type fuseholders. Fuses should never be short circuited or replaced with fuses of larger current capacity.

The fuses used in interior communication switchboards and equipment are listed in table 4-1.

The application of fuses in I.C. circuits is based on the fuse characteristic. The characteristic A fuse is used where no appreciable inrush current is expected in the circuit. In addition, several types of fuses similar to miniature styles but of varying lengths are used in some units. Also, special fuses are used in some specialized equipment such as telephone indicating type fuses in the ship's service telephone equipment.

Note that the miniature style fuses FO2 and FO3 are electrically equivalent to the much larger style M fuse. It is expected that the miniature fuse will eventually supersede the style FO9.

**TIME DELAY**

The characteristic "B" (time delay) fuse is used for fusing loads such as motor supply circuits in which overloads and motor-starting

Table 4-1.—Fuses for I.C. Switchboard and Equipment.

| Style [1] | Current range (amperes) | Maximum d-c or rms volts | Characteristic | Fuseholder type [2] |
|---|---|---|---|---|
| F03 | 0 - 30 | 125 | A | FHL10G; FHL11G |
| | 0 - 15 | 250 | A | |
| | 0 - 15 | 125 | B | |
| F09 | 0 - 30 | 250 | A | FHL12G |
| | 0 - 30 | 125 | B | |
| | 0 - 10 | 250 | B | |
| F15 | 0 - 30 | 250 | A or B | FHL13G |
| | 0 - 30 | 450 | A | |
| F16 | 31 - 60 | 250 | A or B | FHL14G |
| | 31 - 60 | 450 | A | |
| F19 | 61 - 100 | 250 | A or B | FHL15G |
| | 61 - 100 | 450 | A | |
| F20 | 101 - 200 | 250 | A or B | FHL16G |
| | 101 - 200 | 450 | A | |
| F60 | 0 - 30 | 500 | C | FHL12G |
| F62 | 31 - 60 | 500 | C | FHL14G |
| F63 | 61 - 100 | 500 | C | FHL15G |
| F64 | 101 - 200 | 500 | C | FHL16G |

[1] Fuse type in accordance with Specification MIL-F-15160

[2] Fuseholder type in accordance with Specification MIL-F-19207

surges of short duration may be encountered. Common trade names for such fuses are Fusetron and Slo Blo. A conventional fuse of much higher rating would be required to prevent blowing of the fuse during surges. Then this rating would be too high to provide necessary protection for the normal steady state current of the circuit.

The characteristic B fuse is rated as to its time lag characteristic with a minimum blowing time at some overload current. A typical rating for this type fuse would specify "12 seconds minimum blowing time at 200 percent rated current." The short circuit capacity of this type fuse is appreciably below that for the characteristic A fuse. The characteristic C fuse (silver-sand) is used where extremely high, short-circuit currents are available. These fuses have the same blowing time characteristic as the characteristic A fuse. However the short circuit capacity is 68,000 amperes, and the voltage rating is 500 volts a-c or d-c.

## SELECTION OF PROPER FUSES

Individual fuses are provided on the I.C. switchboards for each associated circuit. A separate fuse is used in each line of each circuit. This has the effect of considerably increasing the maximum short circuit current that the fuses can safely interrupt. It also provides greater protection to the remaining circuits energized from the same bus in case of a possible defect in one fuse.

In general, fuse ratings should be approximately 10 percent above the maximum continuous connected load. In circuits such as call bell systems and alarm systems where only a mall portion of the circuit is likely to be op-rated at any one time, the fuse rating should e 10 percent greater than the load of one as-ociated group of signals operated or 15 percent f the total connected load, whichever is greater. Vhere the circuit incorporates branch fuses, uch as those associated with the fire-control witchboards, the rating of the fuses on the I.C. witchboard should be 20 percent above the naximum connected load to provide sufficient nargin so that branch fuses will always blow efore the main fuses.

Sometimes, the fuses provided by the manu-acturer of the I.C. switchboard are of inade-uate rating because the load data on some ircuits were incomplete. In that case, the hip's force may have to increase the fuse rating o prevent too frequent blowing. The circuit hould first be carefully checked to ensure that ll equipment is operating properly. The neces-sity for increased fuse capacity should be rought to the attention of the Bureau of Ships. n no case should the fuse rating be greater han two and one-half times the rated capacity of the smallest cable in the circuit, which is not otherwise fused. If too large a fuse were used, a fire hazard would exist. Fires have been reported that were caused by using fuses which were of such high ratings that they did not blow when a short circuit occurred. Note that when the fuse is used in an extractor post type holder, a derating of 10 percent or more results because the reduced rate of heat radiation causes the fuse to open sooner than normal. Considerable irregularity has been found in dimensions of many makes of fuses, which may result in less positive contact in the holder, thus causing more heating and consequently greater derating of the fuse. Fuses now being procured must meet more rigid dimensional tolerances; also, the fuse holders are being improved. I.C. Electricians should make sure that all fuses used on I.C. switchboards and panels are of makes that will fit properly in the holders.

## FUSE HOLDERS

### TYPES

The extractor post combination fuse holder and blown-fuse indicators, FHL13G, FHL14G, FHL15G, and FHL16G were developed in order to make it practicable to mount fuses on a dead front metal panel and have the fuses readily available for replacement.

The type FHL13 to 16G fuse holder consists of a base and a plug, as shown in figure 4-17. The base extends behind the panel, and into it is screwed the plug containing the fuse. Behind a hole in the plug cap is a small neon lamp used as a blown-fuse indicator, which lights when

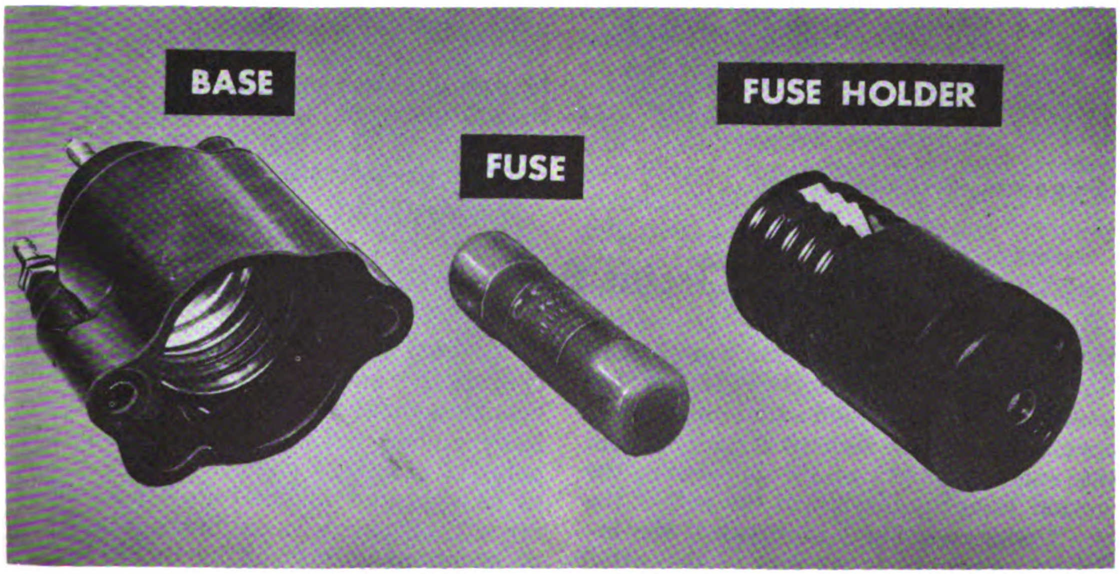



Figure 4-17.—Fuse-holder assembly.

the energized circuit through the holder is interrupted by the blowing of a fuse. Series resistors of different values are used with the lamp on 125- and 250-volt circuits, except for the MIDGET holder, which is rated for 125 volts only.

### SIZES

Two basic fuseholder designs are represented by those listed in table 4-1. The types, FHL10G, FHL11G, and FHL12G (fig. 4-18) consist of fuseholder body and a fuse carrier. The body is mounted on the panel, and the carrier with the fuse placed in the clips is inserted into the body in a manner similar to inserting a bayonet-type lamp into a socket. Removal of the fuse is accomplished by pusing and turning the fuse carrier in a counterclockwise direction, again similar to the removal of a bayonet base lamp. The types, FHL10G and FHL11G, accommodate 1 1/4" x 1/4" diameter fuses. The type, FHL10G, will hold two fuses and can therefore be used to fuse both sides of the line, or, in conjunction with a type FHL11G, will fuse a three phase line. FHL12G will accommodate 1 1/2" x 13/32" diameter fuses. When these fuseholders are mounted in a dripproof enclosure they maintain the dripproof integrity. They also possess the ruggedness, vibration, and high-impact shock resistance necessary for shipboard use.

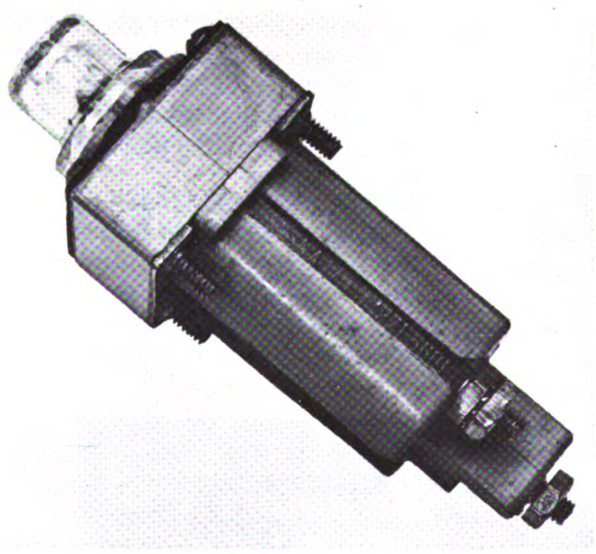


Figure 4-18.—Fuse holder type EL-1.

The extensive use of low-voltage power supplies has required the use of incandescent lamps in place of neon glow lamps in some indicator light circuits. A modification of the type FHL-10G fuseholder has recently been designed, which provides a third terminal connected to a 28-volt incandescent lamp in the cap. By insertion of a suitable resistor between the load terminal and the added terminal, the lamp will be energized by a sufficient voltage to become visible when the fuse has blown. In some low-voltage fuse holders the resistor and lamp are included within the clear plastic cap. Low-voltage fuseholders should not be used in sensitive, low-current equipment. Where overload condition occurs and the fuse blows, the low resistance indicator circuit may pass sufficient current to damage the equipment.

Due to the design of certain fuses and in cases where space does not permit use of indicator type fuseholders, separate indicator light circuits are mounted on a panel and connected in parallel with separately mounted fuses and fuse clips. In some cases an alarm circuit in the form of a bell or buzzer will be used in place of the indicator light.

## Circuit Breakers

A circuit breaker is an electric switch used to open or interrupt a circuit between separable contacts under normal or abnormal conditions. Under normal conditions with the circuit current within the rated capacity of the breakers, the switch action is accomplished at the will of the operator. Under abnormal conditions, the interruption of currents in excess of the rated continuous current, such as short circuits, is accomplished automatically.

Ordinarily, circuit breakers are required to operate infrequently, although some classes of breakers are suitable for frequent operation. Navy circuit breakers (either double or triple pole) of different current ratings are designed to be operated manually or electrically. Many circuit breakers open automatically (in case of short circuits), and by the addition of suitable relays can be arranged to provide protection against undervoltage, reverse current, and verse power. The general classes are (1) air rcuit breakers and (2) oil circuit breakers. l circuit breakers, however, are not used in ıvy ships.

## AIR CIRCUIT BREAKERS

Air circuit breakers are furnished in either e open type for switchboard mounting or the ıclosed type for dead-front panel mounting. 3-pole, type ACB circuit breaker is shown figure 4-19. The contact assembly consists the main bridging and arcing contacts. The oving elements of these contacts are attached a contact support, which is pivoted when ac- ıated by the operating mechanism. All current- ırrying contacts are arc-resisting silver or lver-alloy inserts.

When the contacts are closed by the operating ıechanism, the arcing contacts close before the ıain contacts. Proper pressure on the main nd arcing contacts is maintained by means of prings.

When the breaker opens, the main contacts pen first, shunting the current through the arcing contacts to prevent burning of the main contacts. When the arcing contacts open and the movable arcing contact passes under the front of the arc runner, a magnetic field is set up. This magnetic field blows the arc up into the arc quencher to open the circuit quickly.

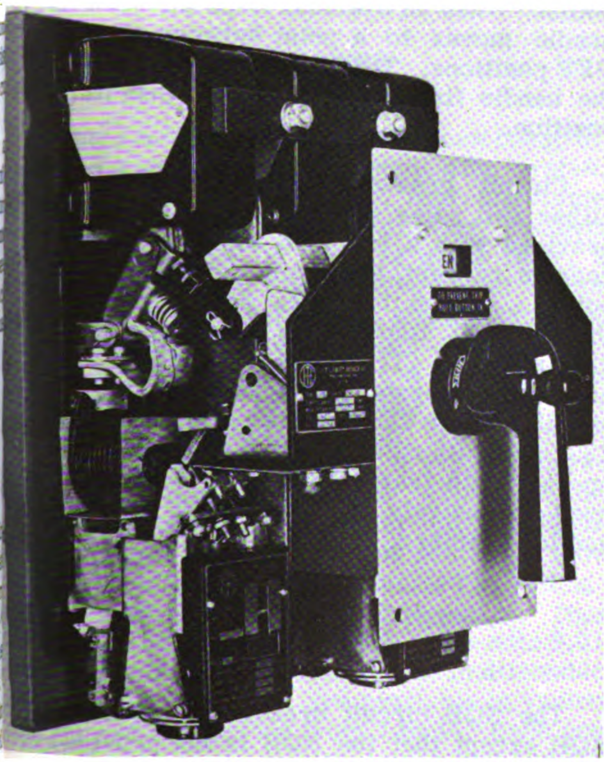


Figure 4-19.—Type ACB circuit breaker.

## TRIP MECHANISM

The trip mechanism is actuated by a release, or relay, to provide automatic operation under a wide variety of conditions. Releases and relays may be classified as (1) instantaneous, (2) definite time, and (3) inverse time, according to the period that elapses before the opening of the circuit. Instantaneous tripping means that no delay is introduced in the action of the device. Definite time means that a fixed delay action is introduced, which is independent of the actuating quantity. Inverse time means that a delayed action is purposely introduced, which varies inversely with the actuating quantity.

Release devices may be of the thermal or magnetic type or a combination of the two—a thermal device for overload protection and a magnetic device for short-circuit protection. Thermal release devices are used only for overload protection and depend upon the deflection of a bimetallic element that is heated by the circuit current. Magnetic release devices employ an electromagnet, or solenoid, which acts directly on the trip mechanism of the circuit breaker.

A magnetic release consists of a solenoid that acts on an iron plunger. For overload circuit protection, the solenoid coil, a few turns of heavy wire, is connected in series with the load circuit, and may act directly to operate the trip mechanism or may actuate a relay in a control circuit to trip the circuit breaker. In addition, circuit breakers of this type can be tripped manually by a small lever or button. The principal types of air circuit breakers used in naval ships are the ACB, AQB, and NQB.

## TYPE ACB

The ACB circuit breaker is adaptable to various protective features. In d-c applications these features include overload and short-circuit protection, and, by the addition of a suitable relay, reverse-current protection. In a-c applications these features are overload and short-circuit protection, and, by the addition of a suitable relay, reverse-power protection. The overload protection may be instantaneous, inverse-time delay, or a combination of these. Circuit breakers may be provided with auxiliary switches and mechanical linkages that operate lights and colored disks to indicate the closed or open positions of the breaker.

The primary purpose of the ACB breaker is the high-speed clearing of faults such as short circuits and overloads. Navy-type ACB circuit breakers have frame sizes of 225, 600, 1600, and 3200 amperes. The ACB breaker provides overload protection for the generators, main power and lighting distribution system, bus ties, and supplies for turrets and winches. It provides control features in small-capacity generating plants, emergency generators, and battery switchboards. This breaker is equipped with a hold-in button, which allows the operator to keep the breaker closed under conditions that would normally cause it to open automatically. Electromagnets are used in the tripping mechanism to operate mechanical linkages, allowing heavy springs to open the breaker. A time delay is provided so that momentary current surges and short-time operation under overload conditions will not cause the circuit breaker to open automatically.

## TYPE AQB

The AQB circuit breaker (fig. 4-20) is housed in an insulated enclosure. The enclosure is secured to the panel frame by screws, and the removable cover is secured to the breaker housing by screws. Some circuit breakers have terminals at the front and some have terminals at the rear. The rear terminals are arranged to form a plug-and-socket connection to the bus assembly so that the whole circuit breaker can be removed for repairs. The trip device is a combined thermal and magnetic type of unit in which the thermal part operates on overloads and the magnetic part operates on short circuits. The tripping action allows momentary surges of current, such as those produced

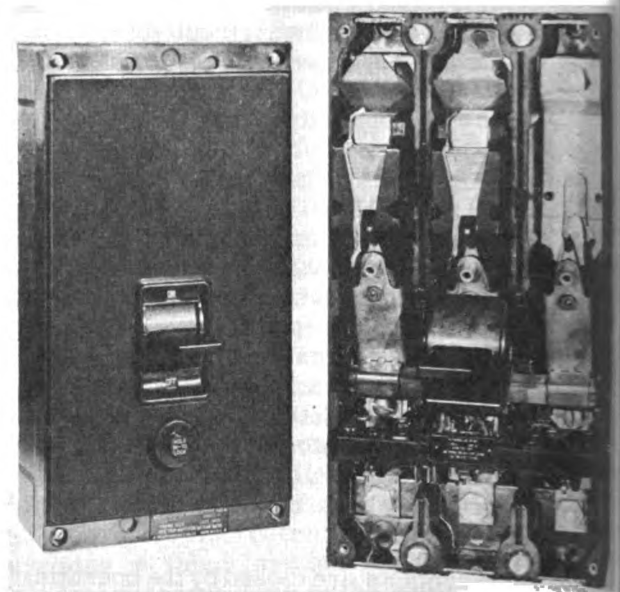


Figure 4-20.– Type AQB circuit breaker.

when induction motors are started. It protects apparatus from sustained overloads, and it acts instantaneously on short circuits. The tripping unit can be made inoperative by a hold-in button. When an overload trips the breaker, the handle moves to a point between the ON and OFF positions. The breaker is reset by moving the handle first to the OFF, and then to the ON position.

Circuit breakers of this type may have either two poles or three poles. Each pole is provided with a trip unit, which, in case of excessive current, simultaneously trips all of the poles. These breakers are rated from 15 through 600 amperes in frame sizes of 100, 225, and 600. Trip units rated at 100 amperes and below operate with frame 100; units rated at 125 through 225 amperes operate with frame 225; and units rated at 250 through 600 amperes operate with frame 600. The AQB breaker is used extensively in distribution switchboards and load centers.

## TYPE NQB

The NQB circuit breaker is similar to the AQB except that the NQB is not provided with protective or automatic tripping. This type of breaker is used to isolate circuits.

# Cables

## INSTALLATION CONDITIONS

The reliability of electric distribution systems in naval vessels depends largely upon the adequacy of the cable installation. This adequacy concerns not only current-carrying capacity, voltage drop, and insulation, but also the ability of cables to withstand various conditions of service and exposure, such as bending, twisting, vibration, shock, heat, cold, oil, and dampness. Nearly all cables are exposed to moisture and rough usage. Some circuits require only a few conductors having a high current-carrying capacity; others require many conductors having a low current-carrying capacity. Most cables are protected externally by an armor basket weave of steel, bronze, or aluminum. Furthermore, most cables are highly resistant to heat and flame, and are nearly impervious to moisture when properly sealed at their ends. Hence, it is obvious that shipboard electric installations require a wide variety of cables to meet the various conditions of service and exposure.

## NONFLEXING

Cables most frequently used in new construction ships on interior communication systems are of the reduced diameter, heat, and flame-resistant armored types, utilizing synthetic silicone insulation, a wall of glass fiber, an impervious sheath, and braided metal armor. These cables are available in single, two, three, four and multiconductor types—SSGA, DSGA, TSGA, FSGA, and MSCA designations, respectively—also in telephone twisted pair (TTHFWA). The SSGA, DSGA, TSGA, FSGA, and MSCA types are available in various current ratings, ranging in conductor cross sections from 2,828 to 800,000 circular mils for FSGA. The approximate copper cross section in thousands of circular mils is indicated by adding a number suffix to the cable designation. Thus, DSGA-9 denotes a 2-conductor cable with 9,016 circular mils per conductor. The multiconductor cables, type MSCA, are available in various numbers of conductors from 7 to 44. Each conductor has a cross sectional area of 1,779 circular mils; the number of conductors is indicated by adding a number to the cable designation. Thus, MSCA-37 denotes a 37-conductor cable. The telephone cables are available in 1 1/2 to 60 pairs, the number of pairs being indicated by a suffix at the end of the cable designation. The conductor cross section is approximately 700 circular mils. The reason for use of a 1 1/2 pair (3-conductor cable) is to avoid replacement of a complete cable due to breakage of one conductor.

## FLEXING

Cables for repeated-flexing service are of the single conductor (SCOP), double-conductor (DCOP), triple-conductor (TCOP), and four-conductor (FCOP) types. They are designated like the corresponding HFA types. The construction of these cables utilizes essentially a wall of synthetic insulation, a thermosetting or thermoplastic impervious sheath, and necessary fillers. The thermoplastic impervious sheath is specifically required for DCOP-4, DCOP-23, and TCOP-23 cables and may be specified for other sizes (where necessary) to pierce the pressure hull of submarines; the thermoplastic sheath permits vulcanizing a doughnut to the cable insulation to prevent the water pressure from forcing the cable through the pressure-proof stuffing box.

The ASO or ST commercial-type, 3-conductor flexible cable is used for single-phase or d-c portable equipment in lieu of 3-conductor Navy cable so that its green conductor may be used for the ground in conformance with commercial practice for grounding portable equipment. Three-conductor Navy cable does not have a green conductor at the present time.

## COLOR CODES

The following color code applies to all multiple conductor (except twisted-pair or 3-conductor commercial for portable tools and equipment) cables having from 2 to 44 individually insulated conductors within a common protective sheath. For example, all single-conductor cables are 1 black; all 2-conductor cables consist of 1 black and 1 white; all 3-conductor cables consist of 1 black, 1 white, and 1 red, etc., up to a 44-conductor cable, where all the color combinations listed in table 4-2 would be included. In cables with more than one layer of conductors, the numbering shown in the table is from the innermost to the outermost. For example the No. 1 conductor will be the center conductor (or one of the center conductors where two or more are used as a center) of the concentric lay. The color coding of 3-conductor flexible cable for single-phase d-c portable equipment and tools is black, white, and green.

Individual conductors and pairs in twisted-pair telephone cables are color coded by pairing the solid colors in sequence—that is, first 1 (black) with 2 to 12 inclusive in the order listed in the table, then 2 (white) with 3 to 12 inclusive in the order listed, then 3 (red) with 4 to 12 inclusive in the order listed, and so forth.

Table 4-2.—Color Coding of Multiple Conductor Cables.

| Conductor No. | Base color | Tracer color | Tracer color |
|---|---|---|---|
| 1 | Black | | |
| 2 | White | | |
| 3 | Red | | |
| 4 | Green | | |
| 5 | Orange | | |
| 6 | Blue | | |
| 7 | White | Black | |
| 8 | Red | " | |
| 9 | Green | " | |
| 10 | Orange | " | |
| 11 | Blue | " | |
| 12 | Black | White | |
| 13 | Red | " | |
| 14 | Green | " | |
| 15 | Blue | " | |
| 16 | Black | Red | |
| 17 | White | " | |
| 18 | Orange | " | |
| 19 | Blue | " | |
| 20 | Red | Green | |
| 21 | Orange | " | |
| 22 | Black | White | Red |
| 23 | White | Black | " |
| 24 | Red | " | White |
| 25 | Green | " | " |
| 26 | Orange | " | " |
| 27 | Blue | " | " |
| 28 | Black | Red | Green |
| 29 | White | " | " |
| 30 | Red | Black | " |
| 31 | Green | " | Orange |
| 32 | Orange | " | Green |
| 33 | Blue | White | Orange |
| 34 | Black | " | " |
| 35 | White | Red | " |
| 36 | Orange | White | Blue |
| 37 | White | Red | " |
| 38 | Brown | | |
| 39 | " | Black | |
| 40 | " | White | |
| 41 | " | Red | |
| 42 | " | Green | |
| 43 | " | Orange | |
| 44 | " | Blue | |

# Installation Marking

## CLASSIFICATION OF CIRCUITS

I.C. circuits are classified according to importance and to readiness.

### IMPORTANCE

Each I.C. circuit is classified into one of the following three groups according to its importance.

VITAL CIRCUITS are those circuits that are essential to the fighting effectiveness of the ship. The loss of a vital circuit such as the gyrocompass system, would seriously impair fighting effectiveness.

SEMIVITAL CIRCUITS are those circuits that are very important but not essential to fighting effectiveness. The loss of a semivital circuit, such as the auxiliary battle telephone system would impair fighting effectiveness less than the loss of a vital circuit.

NONVITAL CIRCUITS are those circuits that are not essential to fighting effectiveness. The loss of a nonvital circuit, such as the boiler-feed signal system, would not impair fighting effectiveness.

Repairs to these groups of I.C. circuits are performed in sequence of their importance.

### READINESS

Each I.C. circuit is classified into one of the following four groups according to its readiness.

CLASS 1 CIRCUITS are those that are essential to the safety of the ship. These circuits are energized at all times.

CLASS 2 CIRCUITS are those that (along with class 1 circuits) are essential to satisfactory ship control. These circuits are energized during the preparation period for getting underway, while standing by, while underway, and until the ship is secured after coming to anchor.

CLASS 3 CIRCUITS, or BATTLE CIRCUITS, are those that (along with class 1 and class 2 circuits) are essential to complete interior control. These circuits are energized during condition watches.

CLASS 4 CIRCUITS are the convenience circuits that are energized only when required.

Supply switches on I.C. switchboards are colored as shown to identify readily the class of circuit.

Class 1 . . . Yellow--continuously energized
Class 2 . . . . . . . Black--underway circuits
Class 3 . . . . . . . . . . . Red--battle circuits
Class 4 . . . . . . White--convenience circuits

In Appendix II is the table from the 1958 *General Specifications for Ships of the U. S. Navy.* The table has five columns. The first, Circuit Designation, refers to the letter or letters assigned to a circuit (for instance, L). The second column tells us that this circuit is the Rudder Order System. The third column, Importance, indicates that this circuit is a vital circuit with the letter, V. The fourth column, Readiness Class, tells us that the system is used for ship control with the number 2. The last column refers to section (S65-5) of the Bureau of Ships *General Specifications for Ships of the U. S. Navy.* This section contains the functions, tests, and specifications for the Rudder Order System.

## CABLE MARKING

### LETTER DESIGNATION

Ready identification for maintenance and repairs of I.C. circuits is provided by cable designations embossed on the cable tags (fig. 4-21). These cable designations include (1) service letter, (2) circuit letter(s), and (3) cable number. The SERVICE is denoted by the letter, C, which is the designation for all cables and circuits that comprise the I.C. system in naval ships. Each circuit is distinguished by a single letter or double letters. These letters identify the cable as a part of one of the numerous I.C. circuits. If two or more circuits of the same system are contained in a single cable, the number preceding the circuit letter or letters, is omitted. The cable number is the number of the cable of the particular circuit.

A typical cable designation is C-MB144. The letter, C, denotes the service (the I.C. system). The letters, MB, denote the circuit, engine-order system, which may actually include wires of circuits 1MB, 2MB, 3MB, and so forth. The number 144 denotes cable number 144 of circuit MB.

Auxiliary cable designations have the circuit letter, or letters, preceded by the letter X as C-XLC14. The letter, C, denotes the I.C. system; the letters, XLC, denote the auxiliary gyrocompass system; and the number, 14, denotes cable number 14 of circuit XLC.

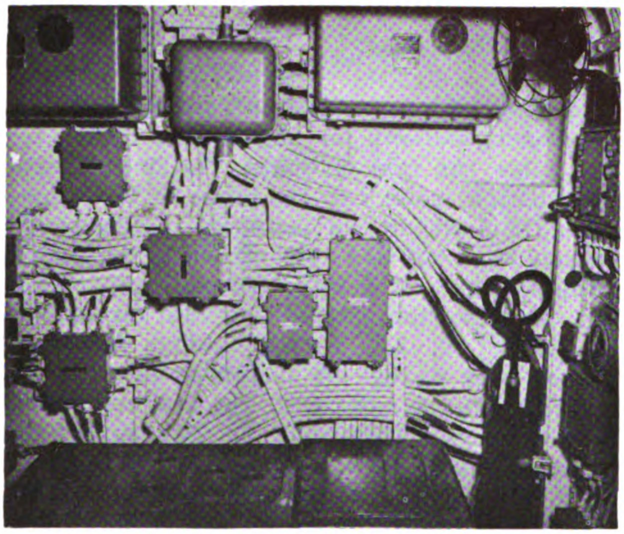


Figure 4-21.—I.C. cable and box markings.

## COLOR

Metal cable tags, colored as shown in table 4-3 were used to identify vital, semivital, and nonvital circuits prior to 1956. Current new construction uses gray tags only.

Table 4-3.—I.C. Cable Identification Tags.

| Class of circuits | Ships constructed prior to 1950 | Ships constructed 1950 to 1956 |
|---|---|---|
| Vital | Light blue | Red |
| Semivital | Green | Yellow |
| Nonvital | Gray | Gray |

## TERMINAL MARKING

### SOURCE

In single-letter circuits and all d-c supply circuits the positive terminal is designated by a single letter, as M. Similarly, an arbitrary polarity of single phase, a-c circuits is designated by a single letter, as M (assumed instantaneous positive). The other side (representing the opposite polarity) of both d-c and a-c circuits is designated by the double letter, as MM.

Double-letter circuits have supply lead markings assigned as for single-letter circuits, except that the second letter of the negative is doubled, (for example, positive MB, negative MBB).

All I.C. terminals are stamped with the circuit marking and additional numbers that are necessary to identify each wire and its function in the circuit (fig. 4-22).

The wire terminals, 3EP and 3EPP respectively are the positive and negative supply terminals from cable CE52, which emanates from the I.C. switchboard and leaves from cable CE53. The wire terminals, 3EP3, 3EP5,

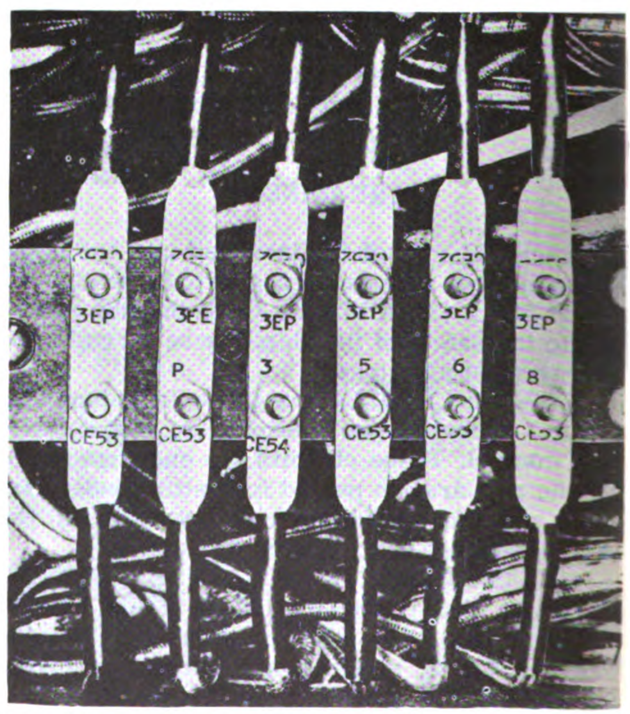



Figure 4-22.—Wire-terminal markings.

3EP6, and 3EP8, from cable CE52 are the positive terminals of pushbutton stations 3,5,6, and 8, respectively. The functions of these wires are found on the elementary and isometric drawings of the 3EP (protected E call) circuit for your ship. Where terminals are too small to permit stamping, tags or sleeving resistant to fire, grease, and continued handling are used. The following system is used.

Numbers following the circuit letter indicate a serial number assigned for the station, followed by the section wire number designating the function of the circuit. On systems containing synchros, the numerals, 1, 2, and 3, are used for the connections to secondary windings. Where more than one synchro is employed in a single instrument, the numerals, 4, 5, and 6, apply to the second synchro, and 7, 8, and 9 to the third synchro. For example, 1-MB14 should be interpreted as follows:

1–starboard circuit
MB–engine-order system
1–station number, such as pilot house
4–connection to secondary windings of the No. 2 synchro receiver in the instrument

If corresponding portions of a circuit are energized from the forward and aft I.C. switchboards, the suffix letters, F and A, are added to the ends of wire markings to indicate the switchboard from which the wire originated.

All terminals in a circuit that may be connected without a break (in the electrical sense) shall be assigned the same wire marking. A fuse, switch, or instrument is considered a break in the circuit and requires a change in the wire marking.

Signal contacts should be connected to the positive (single-letter connection) in the instruments. The section-wire markings for bell or visual signal circuits should be assigned the next higher number after assignment of numbers to secondary windings of all synchro receivers in the instruments. For example, in an instrument containing two synchro receivers the signal circuits should be assigned section wires Nos. 7, 8, etc.

## CONNECTION BOXES

All connection boxes, branch boxes, and other wiring appliances installed on interior communication and fire-control circuits should contain an information plate giving the circuit letter and serial number of the appliance. The serial numbers begin with the circuit letter and numeral 1 for each circuit, and are assigned consecutively beginning in the hold (forward) and proceeding to the hold (aft) and progressing upward deck by deck.

## MULTIPOLE ROTARY SWITCH AND TERMINAL BOARD

Multipole rotary switches and terminal blocks for I.C. and F.C. switchboards are provided with standard wire markings for identification. For multipole rotary switches associated with terminal boards the markings, A, B, C, and so forth are engraved on each barrier of the switch.

Terminal board markings comprise the wire designation, switch terminal designation, switch barrier marking, and the section in which the terminal is located. A typical terminal board marking is B-3-1Y77. The combination, B3, is the corresponding switch terminal designation. The letter, B, is the switch-barrier marking, the numeral, 3, is the number of the switch section in which the terminal is located (the sections are numbered consecutively from the handle end of the switch); and the combination, 1Y77, is the ship's wire designation.

# QUIZ

1. What are the three principal classes of devices used to control and protect I.C. equipment?
2. Most switches used in I.C. systems are of what general types?
3. Pushbutton control may be for either of what two operations with respect to the condition of the contacts?
4. What are the (a) maximum and (b) minimum current (except special purpose switches) ratings of snap switches?
5. What is the current rating of a type 3SR3 snap switch?
6. What are the voltage ratings of most snap switches?

7. What difficulty may be encountered in attempting to use a double-throw snap switch for selection of a single load between two independent power sources?
8. What is apt to be the effect of excessive amounts of grease on the switch contacts?
9. What is the effect of a small amount of lubricant on switch contacts?
10. What is the rating of type JR switches?
11. Is the JR switch of the shorting or non-shorting type?
12. Why should the JR switch not be used on d-c circuits?
13. What bad feature is common to all multipole rotary switches due to the inherent design of the detent mechanism?
14. For what application aboard ship was the JA switch designed primarily?
15. The JA switch provides lower contact resistance than types using brass or copper contacts. How?
16. In how many section combinations is the JA switch available?
17. What is the complete designation for a JA switch having a common rotor, 6 sections, and 16 positions?
18. How does the JF switch overcome the open circuit problems of the toggle switches it was designed to replace?
19. The JF switch is satisfactory for 120-volt applications of what current rating?
20. From what material is the JF switch deck molded?
21. Why must precautions be observed while soldering the leads to the JF switch contacts?
22. What type switch unit should be substituted for a J switch unit in the NA-16 assembly when the J switch unit requires replacement or develops excessive contact resistance in the sound-powered telephone line?
23. What is an essential difference between a relay and a contactor?
24. What feature in the contactor (fig. 4-11) makes it possible for the contactor to withstand severe mechanical shock and prevent false operation?
25. (a) How many adjustments are provided on the one-coil relay shown in figure 4-14,A? (b) What are these adjustments called? (c) Which adjustment is made first?
26. What is the function of the copper strap or ring placed near the end of the pole piece of an a-c relay?
27. In what two ways may the pullin value of the a-c shunt relay (fig. 4-16) be increased?
28. Plug fuses are intended for use on circuits of what range of currents and at not more than what voltage rating?
29. Only fuses of what rating or under should be removed from an energized circuit?
30. What Navy type fuse is used for motor supply circuits in which motor-starting surges of short duration may be encountered?
31. In general, fuse ratings should be approximately how much percent above the maximum continuous connected load?
32. How much greater may the fuse rating be than the rated capacity of the smallest cable in the circuit?
33. How is the blown fuse indication usually obtained on I.C. and A.C.O. switchboards and panels?
34. In circuits in which the operating voltage is too low to energize a glow lamp for blown-fuse indication, what type indicators are used?
35. What is the primary purpose of the type ACB circuit breaker?
36. The energy used to open the ACB breaker comes from what components?
37. What is the function of the time delay provided in the ACB circuit breaker?
38. The type AQB breaker is used extensively in what two general applications?
39. What type of insulation is used in the reduced diameter cables most frequently used in newly constructed ships' I.C. systems?
40. What are the three groups in which I.C. circuits are classified according to importance?
41. (a) What letter is used to designate the positive side of d-c circuits and the instantaneous positive side of single letter a-c circuits? (b) What letter designation represents the other (opposite polarity) side of the circuit?

# CHAPTER 5

# I.C. AND A.C.O. SWITCHBOARDS

## I.C. Switchboards

The I.C. switchboard is the nerve center of the interior communications system. Its function is to energize all interior communication and fire control circuits, including fire control electronic systems, and in small ships to supply power to other electronic equipment.

The I.C. switchboard is installed behind the armor belt and below the waterline to obtain maximum protection. It is energized from a normal, an alternate, and an emergency power supply to ensure continuous service.

In large combatant ships two main I.C. switchboards are provided. One switchboard is located in the forward I.C. room, and the other switchboard is located in the after I.C. and gyro room. Thus, each system or equipment receives its normal supply from the nearer I.C. switchboard. The after main I.C. switchboard is usually arranged similarly to the forward main board, except that in the after board some of the special buses such as the controlled-frequency bus may be omitted.

On the older ships separate I.C. and action cut-out (A.C.O.) switchboards are installed. In new construction ships, I.C. switchboards are composed of power control distribution, and A.C.O. sections.

I.C. switchboards installed in naval ships are of the (1) live-front, (2) semidead-front, (3) dead-front, and (4) dead-front front-service types.

### LIVE-FRONT

The live-front I.C. switchboard (fig. 5-1) is the oldest type of board and is found only in older ships. All switches are of the live-front, knife blade lever type with fuses in exposed clips, which are mounted on insulating panels. Blown-fuse indicators are installed over the fuses. The ship's cables are connected to the switch and fuse terminals in the rear of the switchboard.

### SEMIDEAD-FRONT

The semidead-front I.C. switchboard is seldom used but may be encountered on some ships. All switches are of the dead-front type, either snap switches or enclosed switches, and are mounted on metal panels. The fuses associated with the snap switches are mounted in open clips on slightly recessed insulating strips beneath the associated switches. A hinged metal door with peep holes is mounted in front of each fuse strip to permit viewing the blown-fuse indicators. Fuses are replaced by removing the metal panel and pulling the fuses from their clips with a fuse puller. The ship's cables are connected to the switches and fuses from the rear of the switchboard.

### DEAD-FRONT

The dead-front I.C. switchboard (fig. 5-2) utilizes dead-front-type switches. The fuses, except those mounted in enclosed switches, are mounted in plug-type combination fuse holders and blown-fuse indicators. This type of switchboard is the most commonly used as it has many advantages over the other types. The principal advantages are: (1) all switches and fuses are mounted behind the panel, affording complete protection to operating personnel against electric shock; (2) fuses are placed in plug-type holders and mounted perpendicular to the panel, resulting in a more compact and efficient board; and (3) meters, circuit breakers, and bus-tie switches are behind hinged panels, simplifying the maintenance of the board.

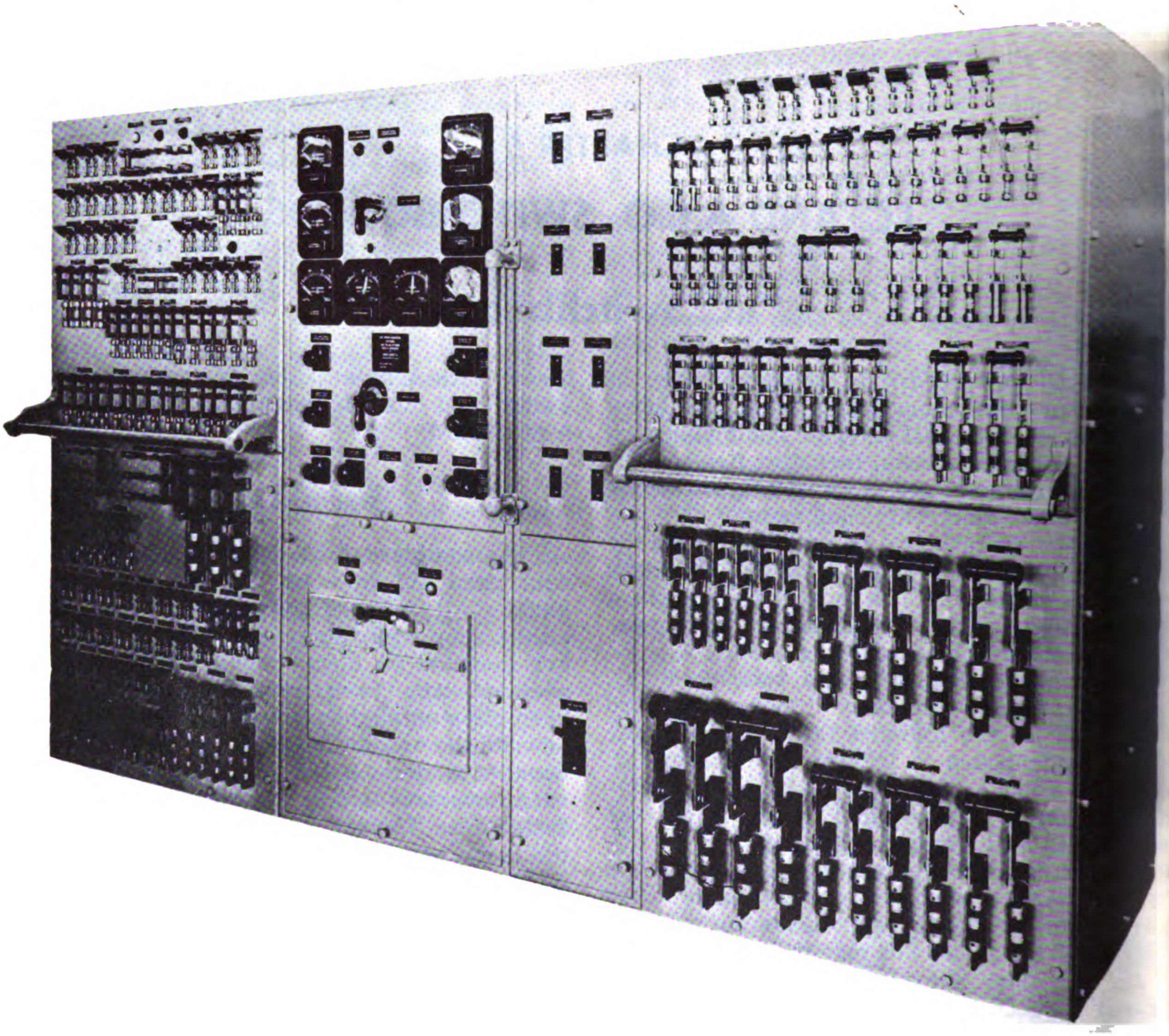


Figure 5-1.—Live-front I.C. switchboard.

## DEAD-FRONT FRONT-SERVICE

The latest type of I.C. switchboard is the dead-front front-service I.C. board (fig. 5-3). This board is constructed similiarly to the dead-front type except that it is designed so that installation, operation, and maintenance can be accomplished entirely from the front of the switchboard. The front-service design utilizes a box-type construction with hinged front panels. Switches and fuse holders up to 60-ampere capacity and other relatively light items are mounted on the hinged panels while heavier items are mounted behind removable panels.

Terminal boards are provided within the switchboard enclosure for termination of all ship's cables except for a few of the larger cables, which run directly to their associated switches and fuse holders. All wiring between the terminal boards and the equipment mounted on the hinged and stationary panels is installed by the switchboard manufacturer to permit free swinging of the panels without interference from, or damage to, the wiring.

In order to reduce the rigidity of the switchboard, and to permit separate movement of panels during shock, cables are used instead of horizontal buses for connection between or among switchboard sections. Some vertical buses may be used, however, to supply sections of the individual panel.

The principal advantage of this type of switchboard is that it can be mounted against a bulkhead because no access space is required in the rear of the board. This feature results in a saving of space, which is most important aboard ship.

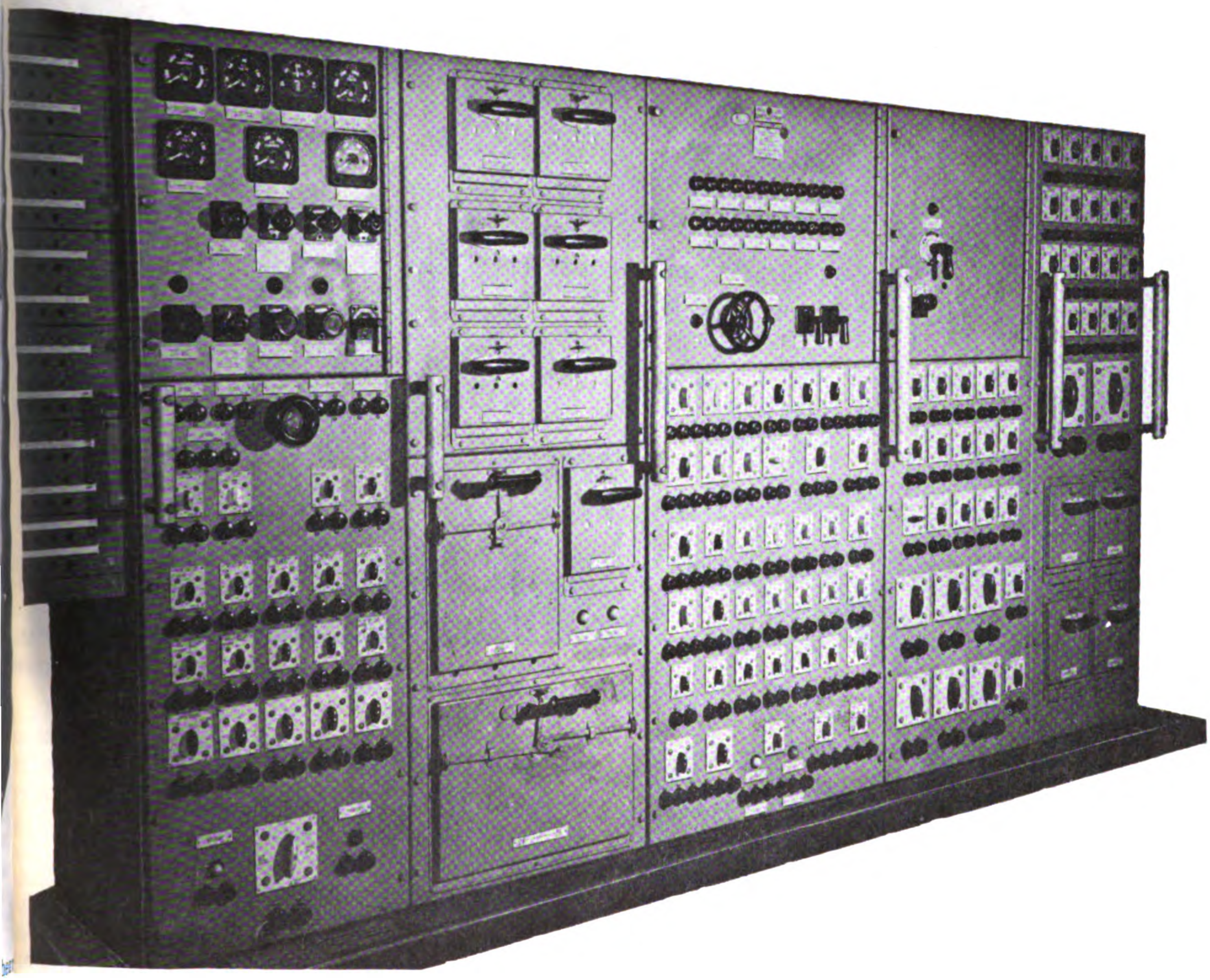


Figure 5-2.—Dead-front I.C. switchboard.

## A.C.O. Switchboards and Sections

The function of the action cutout (A.C.O.) section is to permit isolation of various portions of I.C. systems and to transfer control of certain systems from one station to another. Separate switchboards are usually provided for specialized systems such as the sound-powered telephone system.

In older combatant vessels the A.C.O. switchboard (one or more sections) is located in the central station, which also functions as damage

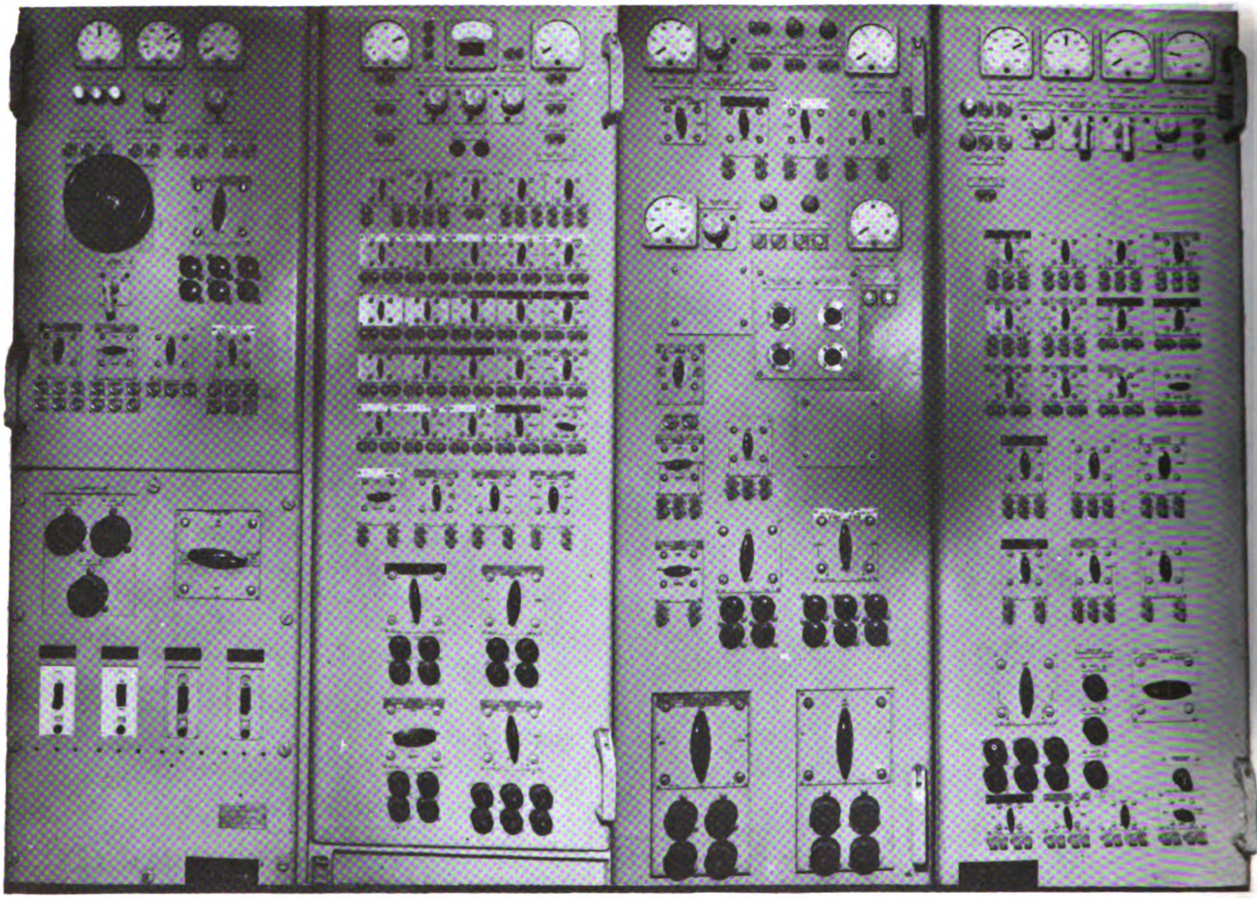


Figure 5-3.—Dead-front front-service switchboard.

control central. In recent vessels damage control central is combined with engineering central and is located nearer to the engineering plant and farther from the I.C. room. The A.C.O. therefore, is located in the I.C. room and is part of the I.C. switchboard.

## LIVE-FRONT A.C.O. SWITCHBOARD

A.C.O. switchboards installed in naval ships are similar in construction to the several types of I.C. switchboards.

The live-front A.C.O. switchboard is found only in the older ships. This switchboard utilizes (1) type-J switches mounted on insulating panels to control synchro circuits and (2) open-type knife blade switches, with fuses in open clips to disconnect contact makers and audible signals.

## DEAD-FRONT A.C.O. SWITCHBOARD

The dead-front A.C.O. switchboard (fig. 5-4) utilizes dead-front steel panels. On these panels are mounted type-J or type-JR rotary switches, snap switches, and fuse holders.

## DEAD-FRONT FRONT SERVICE A.C.O. SECTIONS

The dead-front front-service A.C.O. sections are shown in figure 5-5A, B, and C. All self-synchronous circuits are controlled by type-JR multiple rotary switches and have individual fuses for synchro primary excitation wires, and overload indicators are provided in some synchro secondaries. Draw-out switch units are utilized, each unit incorporating the associated fuse holders and overload indicators. Multiple rotary selector switches are always

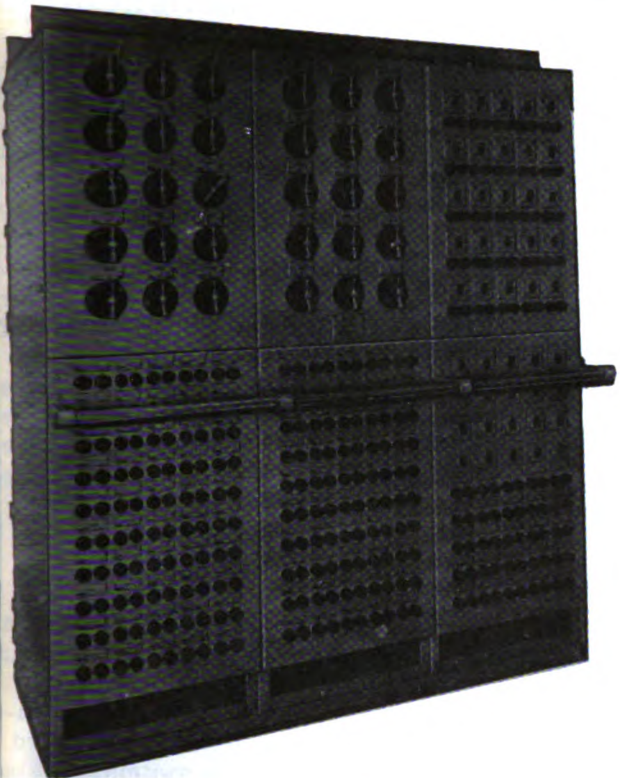


Figure 5-4.—Dead-front A.C.O. switchboard.

used on the A.C.O. section to permit the selection of several different stations or supplies.

The inherent design of the equipment on most I.C. synchro circuits is such that if all receivers and indicators are in parallel, a casualty to any station on the circuit or to corresponding cables would incapacitate the entire circuit. The only means of overcoming this condition is to provide action cutout switching; individual fuses; and, in some cases, automatic disconnect relays in one or more central points to disconnect damaged instruments and cables. The use of action cutout switching is limited to the most important circuits, the loss of which might endanger the ship.

In order to reduce the number of switches on A.C.O. sections, two synchro indicators are usually grouped on each multipole rotary switch. These switches are of the 4JR-type and usually provide "either or both" selection. By "either or both" is meant that the synchro signal as connected to the switch can be connected to either of two instruments singly or to both instruments simultaneously. Such a switching

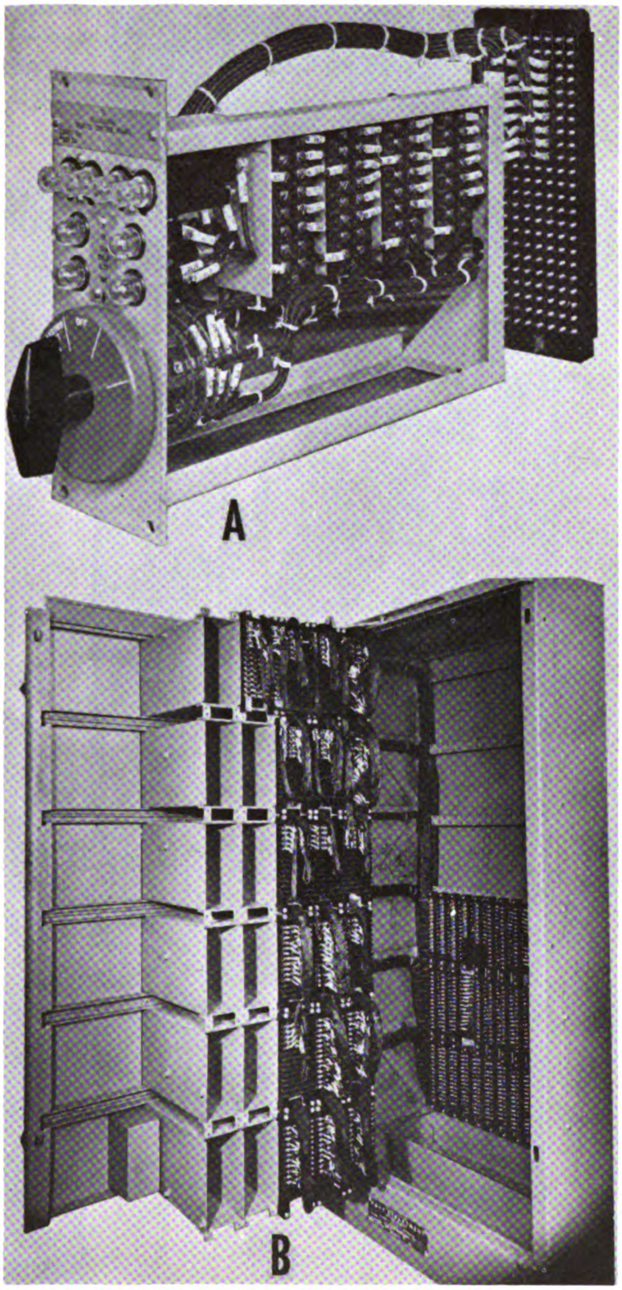
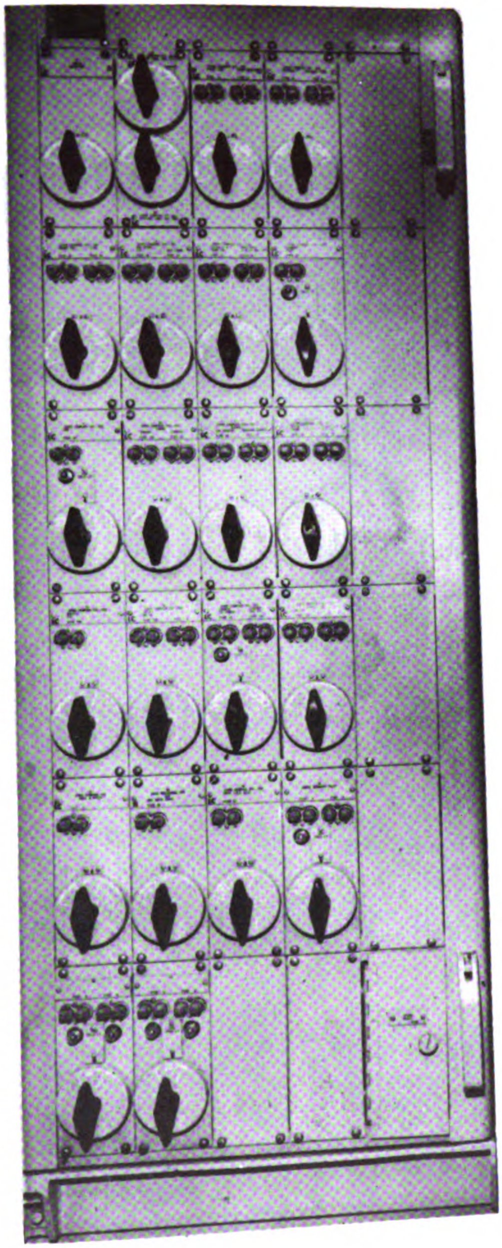



Figure 5-5.—Dead-front front-service section. (A) Action cutout unit; (B) Rear view, door open.

arrangement might be used to connect the underwater log transmitter to the pilot house or to the open bridge, or to both the pilot house and the open bridge.

If several switches receive parallel inputs from the same transmitter, separate connections may be provided from the terminal boards



C

Figure 5-5.—(C) Front view of dead-front front-service section.

to the input terminals of the first and last switches of a series. Jumper connections are then provided from these switches to the switches between. Thus, any switch can be removed without disrupting the input connections to any other switches. If practicable, all switches of the same circuit are grouped together, and all switches that control instruments in the same station or for related functions are located on the same vertical line.

Another switch arrangement on the A.C.O. section may provide for selecting a transmitter at one of several stations. For example, the engine-order system may be controlled from the pilot house, the open bridge, or the secondary conning station. The A.C.O. section may also provide for isolating damaged circuits. For example, the output from the general-announcing amplifier may be connected to, or disconnected from, the various subgroups of speakers.

Many instruments on important circuits have individual disconnect switches on the A.C.O. section so that the instruments can be energized as needed or disconnected from the circuit in the event of trouble.

## LOCAL I.C. SWITCHBOARDS

An I.C. switchboard is usually provided in each engineroom (motor or maneuvering room in electric-drive ships) to energize local I.C. circuits. The normal supply for each switchboard is from the nearer main I.C. switchboard. The emergency supply for each switchboard is from a local emergency lighting circuit. This arrangement provides the switchboard with the same power backup as that of the main I.C. switchboard. However, in case of loss of power at the main I.C. switchboard or damage to the connecting cable, the local switchboards can still be energized from a local source. Automatic bus transfer switches are provided on the I.C. switchboards in the engineroom and steering gear room on later ships to minimize interruptions if the normal power source is lost. Action cutout switches are provided to disconnect instruments connected to local transmitters.

A local I.C. switchboard (fig. 5-6), is usually installed in each steering gear room to energize all circuits associated with steering such as the steering-order and rudder-angle indicator systems. The normal supply for this switchboard is from the steering-power transfer switchboard through a local transformer. An alternate supply is taken from a local emergency lighting circuit to provide power if the normal supply is lost, because manual or emergency steering gear is provided in case of power failure to the steering power switchboard.

A local I.C. switchboard (fig. 5-7) is also installed in each turret. This switchboard is energized via a local 450/120-volt transformer and a triple-pole, double-throw switch from the normal and alternate 450-volt power feeders to the turret. A supply from the I.C. switchboard is not provided because with modern high-speed turrets, the turret is relatively useless if the power to it fails. Local I.C. switchboards may be installed for Weapons Control, and Electronic Counter Measures systems.

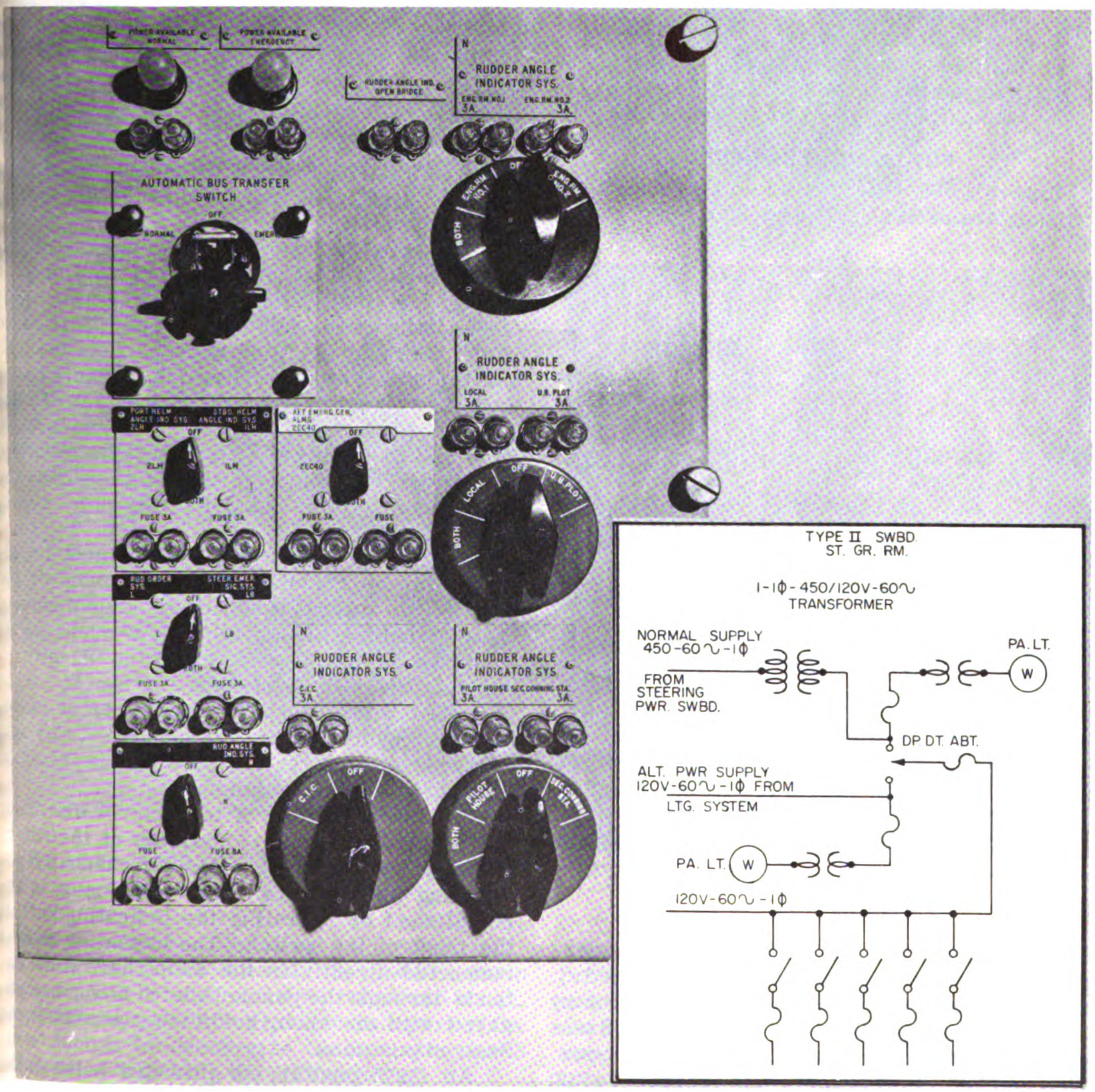



Figure 5-6.—Local I.C. switchboard, steering gear room.

# Switchboard Devices and Components

The following devices and components are used on I.C. switchboards:

1. Meters and meter transformers
2. Meter switches
3. Indicator lamps
4. Snap switches
5. Multipole rotary switches
6. Disconnect switches
7. Automatic bus-transfer switches
8. Fuses
9. Fuse holders
10. Blown-fuse indicators
11. Overload indicators
12. Indicator lights
13. Relays and control switches

The rheostats and start-stop push switches for the associated motor generator sets are usually mounted on the I.C. switchboard.

## BUS-TRANSFER SWITCHES

Type-K, 3-position, manually operated switches are used on I.C. switchboards of older design to transfer between the normal and emergency sources of power. More modern I.C. switchboards are provided with automatic rotary bus-transfer switches (fig. 5-8A), which are simpler and more compact than other types. This design of the automatic bus-transfer switch utilizes a pancake construction similar to that used in the manual rotary snap switch although the contact structure is different (fig. 5-8B). The switch is operated by a solenoid (fig. 5-8C) which is energized from the normal power supply through a voltage-sensitive relay (fig. 5-8D). This relay is mounted in the back part of the switch, but when the space behind the panel is limited, it can be mounted separately from the switch.

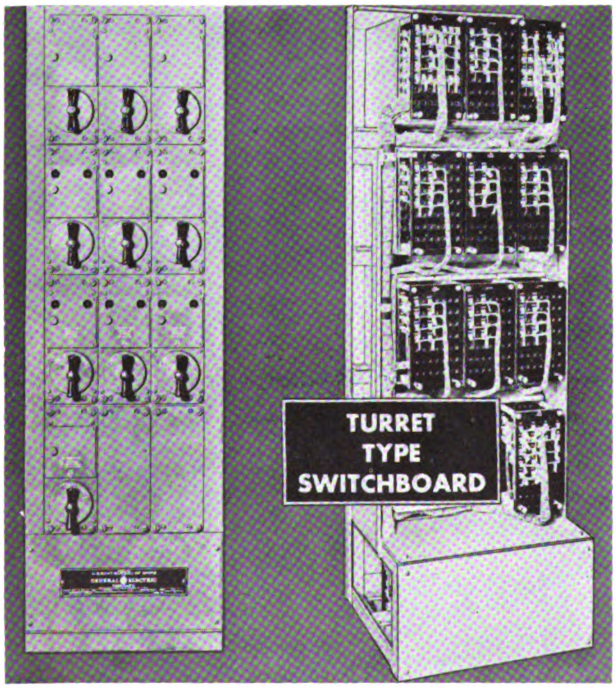



Figure 5-7.—Turret-type combined I.C. and A.C.O. switchboard.

The solenoid operates the switch contacts to the normal position against the action of a spring. If the voltage on the normal supply feeder falls below 60 to 70 percent of its rated value, the relay operates to deenergize the coil, and the spring moves the switch contacts to the emergency-power-supply position. When the voltage on the normal supply feeder rises above 85 to 90 percent of its rated value, the sensitive relay energizes the coil and thus restores the switch contacts to the normal power supply position.

The rotary bus-transfer equipment is adjusted by the manufacturer to transfer at the percentage values specified. Adjustments of these transfer values must not be made unless absolutely necessary because the sensitive relay is a precision device and should not be tampered with. Such adjustments can be made, however, by removing the sensitive relay and following the instruction contained in the plans furnished with the equipment.

In case of failure of the control circuit or the spring, emergency operation of the rotary transfer equipment provides for manually positioning the contacts. This positioning is accomplished by operating the indicating knob at the front of the switch. The indicating knob is connected directly to the main shaft which extends through the panel. A latch key, when engaged with the knob, holds the contacts in the desired positions.

An OFF position is provided between the normal and emergency positions.

The automatic bus-transfer switch previously described is being replaced by a similar switch, which corrects some of the difficulties encountered in the original type. The new switch is constructed so that when the blades

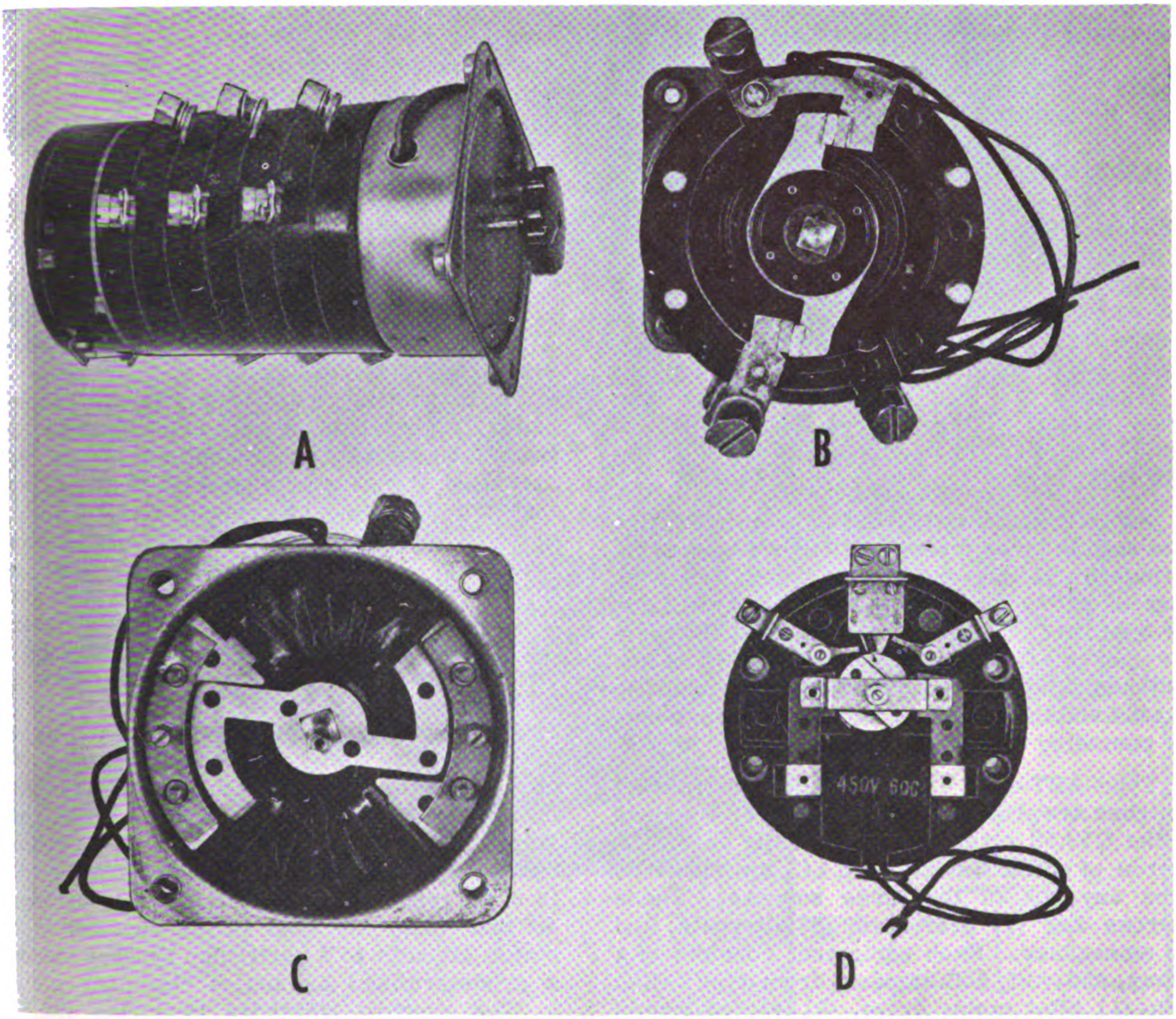



Figure 5-8.—Automatic rotary bus-transfer switch. (A) External view; (B) Rotary contact; (C) Magnetic coil; (D) Voltage-sensitive relay.

of the switch are closed, they will remain closed under conditions of vibration and shock. An auxiliary switch is provided as a part of the new design to deenergize the operating coils when the switch is in the OFF position.

The switch has three-positions—(1) service, (2) off, and (3) emergency. It may be operated either electrically or manually. When necessary, the switch can be locked in any one of the three positions.

Whenever the switch is in the locked position, it automatically disconnects the circuits to protect the electrical components. Because the two contacting positions are located on the same shaft, no mechanical interlocking linkage is necessary as in the case of separate contactor mechanisms.

Twin dual action plunger-type solenoids are employed with two parallel coils to initiate motion in either contact position. The movable cores of the solenoids are positioned one on each side of the shaft and are in static balance when deenergized. The neutral OFF position lies between the two energized positions. From the neutral off position either of the two sources (service or emergency) may energize its respective solenoid as conditions demand.

If both systems are energized, the service supply predominates and immediately neutralizes the EMERGENCY connections. With the switch in the SERVICE position, transfer to the EMERGENCY position takes place automatically at a preselected percentage of full voltage, or a failure takes place either in phase A or phase B of the service supply. The preselected percentage of full voltage is obtained by adjusting the voltage sensitive relay. When low voltage occurs across the service supply, the automatic bus-transfer switch instantly responds to transfer the load to the emergency line. When normal voltage is restored, the switch again functions to transfer the load to the SERVICE supply.

Automatic rotary bus-transfer switches are available in three frame sizes based on current ratings of 25, 50, and 100 amperes. For each current rating, separate switches are available for operation on 120-volt and 450-volt, 60-cycle a-c service. The principal difference in the switches is in the design of the operating coils and the voltage-sensitive relays for the particular operating voltages.

Type-ABT-A3 automatic bus-transfer switches are provided in attack aircraft carriers of the CVA59 class to automatically select the source of power for the main I.C. switchboards from any one of the three sources. These sources are (1) preferred, (2) alternate, and (3) emergency. Each equipment consists of a 3-way, 450-volt, 600-ampere, drum-type switch with (1) pilot motor drive, (2) leading-supply selector switch, (3) test switch, and (4) automatic-manual selector switch, together with relays and control circuits.

In manual operation the drum-switch hand wheel is turned to place the load in contact with any one of the three selected sources of supply.

In automatic operation the switch will select any one of the three supplies, depending on the position of the leading selector switch and the magnitude of the supply voltage. For example, if the leading selector switch is in the PREFERRED position and the magnitude of the preferred supply voltage is within the proper limits, the switch will connect the load to the preferred supply.

If the preferred supply voltage falls below the proper limits, the switch will automatically connect the load to the alternate supply and restore it to the preferred supply when the voltage returns to normal. If the load is connected to the alternate supply and low voltage occurs on both of these sources, the switch will automatically transfer the lead to the emergency supply and restore it to the proper supply (depending upon the position of the leading selector switch) when voltage is restored to normal.

## OVERLOAD INDICATORS

Recent designs of A.C.O. sections are provided with synchro overload transformers. These transformers are in series with the secondary connections of selected synchro torque indicator to provide immediate information to operating personnel regarding a casualty so that the damaged instruments can be disconnected quickly by operating the associated switches. It is also necessary in each case to fuse the primary wires. Otherwise, a short in one indicator might blow the main fuses of the circuit, and no power would be available to operate the overload indicators to show the faulty circuit.

The overload transformer (fig. 5-9) consists of two primary windings, each in series with one leg of the synchro stator wires. The secondary winding is connected to a small neon lamp mounted on the face of the I.C. switchboard (fig. 5-9A). The overload transformer is a current-sensitive device. It is arranged so that when the sum of the currents in the stator circuits to a particular synchro exceeds a predetermined amount, a neon lamp glows.

The synchro stator is in series with the primary coils of the transformer. An increase of current in the primary winding of the transformer will increase the voltage between the secondary terminals of the transformer.

The secondary of the transformer has numerous taps to provide a wide range of voltages for a given current.

The transformer may be used under different load currents. However, the tap used is dependent on the breakdown voltage of the neon lamp.

The principal difference between the operation for I.C. synchro circuits and for F.C. circuits is that for I.C. synchro circuits the overload transformers are usually set to provide a much greater relative displacement between transmitter and indicator before the overload

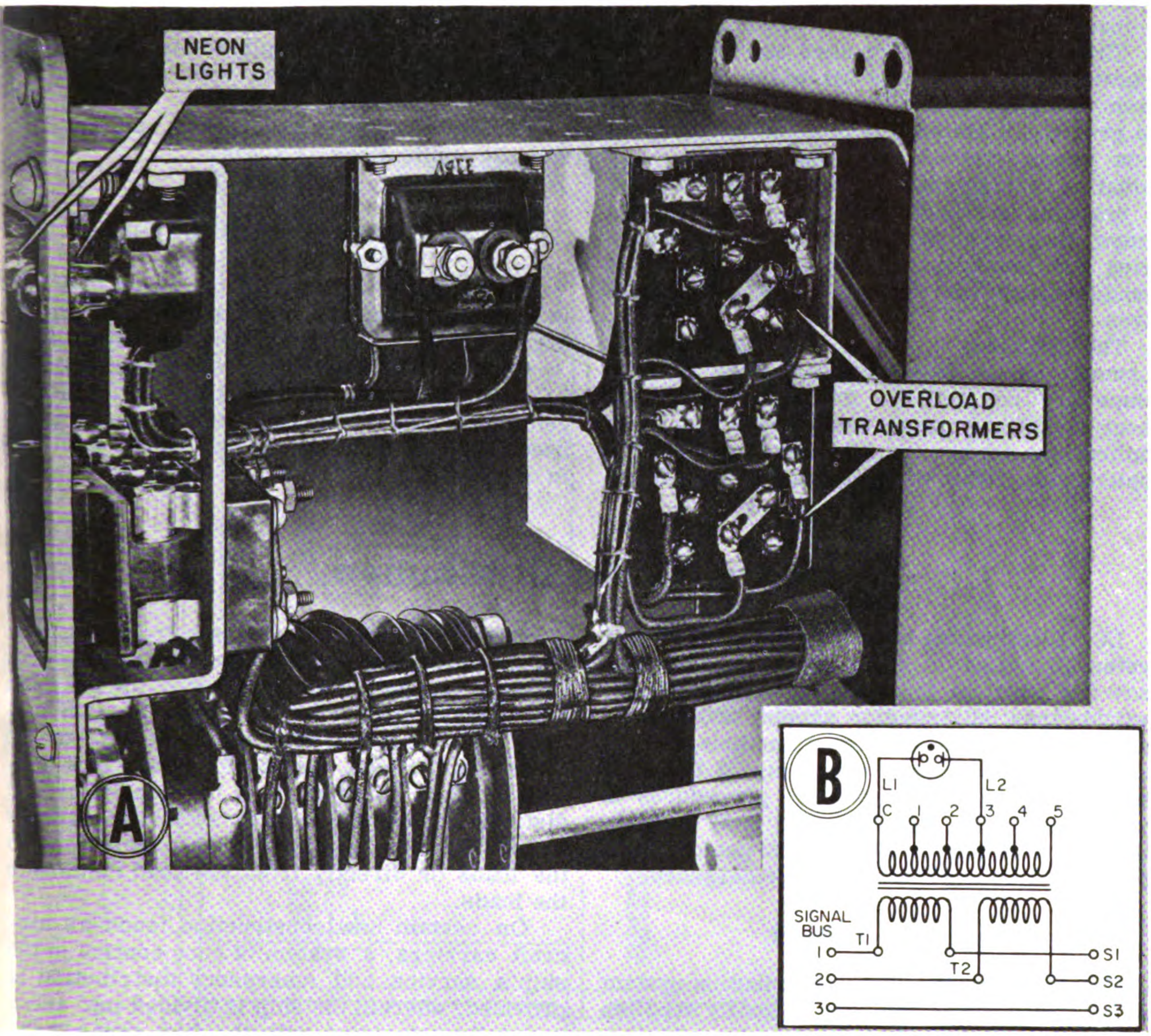



Figure 5-9.—Overload transformer. (A) External view; (B) schematic diagram.

lamp lights. F.C. synchro circuits are usually precision systems in which a relatively slight displacement between a transmitter and indicator may involve a serious error. Most I.C. circuits are generally used for the transmission of a relatively small number of orders, and a displacement between transmitter and indicator is not serious until sufficiently great to cause an incorrect order to appear at the indicator.

Operating personnel of I.C. switchboards should be very cautious when operating switches to disconnect indicators, particularly on vital circuits such as the engine order system. When practicable, operating personnel should investigate before operating the switch, as the overload indication may be a result of too low a setting on the overload transformer.

Energizing a circuit by means of a transfer switch generally results in a flash on the associated overload light, which is caused by the momentary displacement between the transmitter and receiver. Such indications are normal and show that the system is operating properly. Continual flashing, however, should be investigated.

The overload transformers are designed to operate with neon lamps for which the breakdown voltage is 52.5 volts a-c and 74 volts d-c. As previously stated, the breakdown voltage of neon lamps varies over a wide range. Any variation in this breakdown voltage is equivalent to changing a transformer tap. Replacement lamps, therefore, should be selected by measuring the breakdown voltages until a lamp is found that conforms approximately to the values given.

The indicator lights on I.C. switchboards normally use two 6-volt lamps because 120-volt lamps are not suitable for the vibration and shock conditions encountered aboard ship. A-c applications require transformers, whereas d-c applications require resistors to furnish the necessary voltage. The a-c indicator lights are provided with integral transformers for either 120-volt or 450-volt applications. D-c indicator lights are provided with separate resistors.

Globes of various colors are required for specific applications.

### RELAYS AND CONTROL SWITCHES

Undervoltage and auxiliary relays are used in automatic transfer switches and alarms associated with I.C. switchboards and panels.

Control switches are used principally on I.C. switchboards for starting I.C. motor-generator sets. Starting push switches are used in some installations and rotary switches in others.

# Electric Power Distribution

I.C. Electricians should study the electrical system installed in their ships so that they know the physical locations of the generators, switchboards, distribution panels, and cables, and thoroughly understand the functions and relations of the various components of the system. They must observe the procedures of system operation so that they may help to maintain maximum reliability and performance of the electric installation in an emergency.

### SHIP SERVICE POWER

The ship service power distribution system is the electrical system that normally supplies power to the ship's equipment and machinery. The switchboards and associated generators are located in separate engineering spaces to minimize the possibility that a single hit will damage more than one switchboard.

The ship service generator and distribution switchboards are interconnected by switches and cables, designated bus ties, because they tie together the buses of different switchboards. Thus, any ship service switchboard can be connected to feed power from its generators to one or more of the other switchboards. The bus ties may also be used to connect two or more switchboards so that the generators can be operated in parallel (or the switchboards can be isolated for split plant operation).

Power distribution is direct from the ship service generator and distribution switchboards to large and important loads, such as the main I.C. switchboard, steering gear, the gun turrets, and to loads near the switchboard. In large installations (fig. 5-10), power distribution to other loads is from the generator and distribution switchboards or switchgear groups to load centers, to distribution panels, and to the loads or directly from the load centers to the loads.

On certain new construction, such as aircraft carriers, a system of zone control of the ship's service and emergency distribution is provided, wherein the ship is divided into areas generally coinciding with the fire zones of the damage control system. The system establishes a number of vertical zones, each of which contains one or more load center switchboards supplied through bus feeders from the ship's service switchgear group. A load center switchboard supplies power to the electrical loads within the electrical zone in which it is located. Thus, zone control is provided for all power within the electrical zone. The emergency switchboards may supply more than one zone, the number of zones depends on the number of emergency generators installed.

In smaller installations (fig. 5-11), the distribution panels are fed directly from the generator control and distribution switchboards.

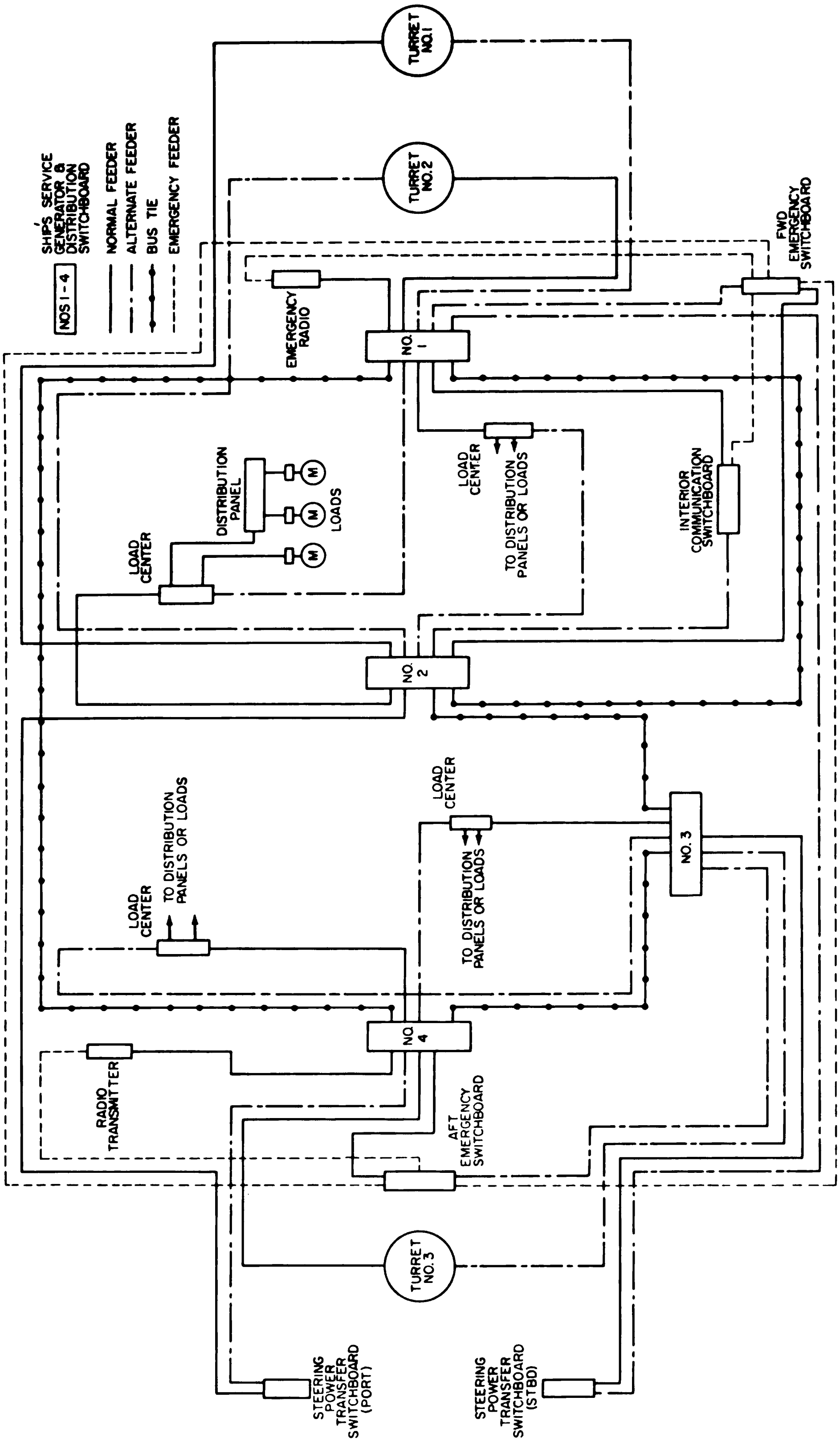



Figure 5-10.—Power distribution in a large combatant ship.

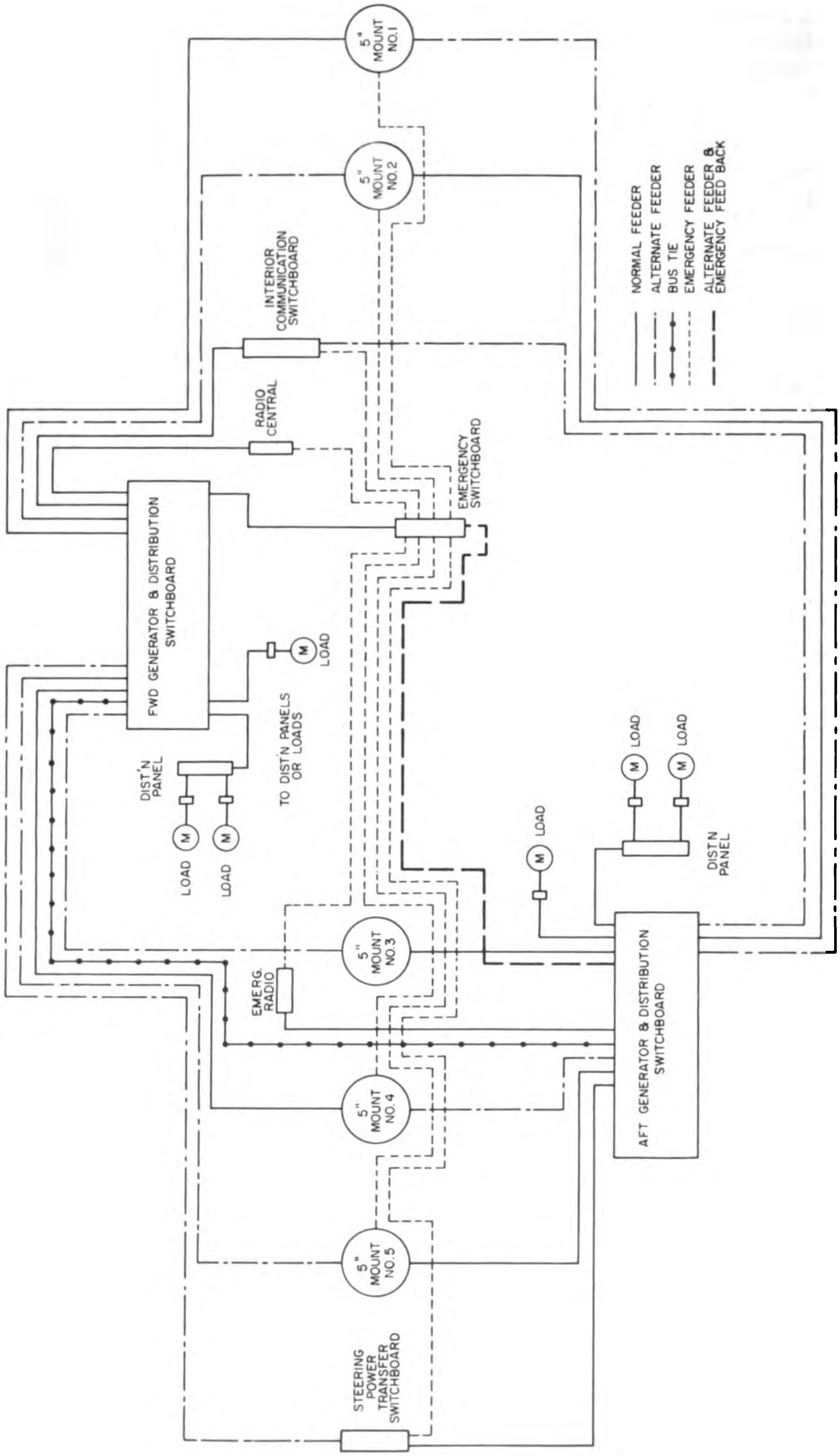



Figure 5-11.—Power distribution in a destroyer.

The distribution panels and load centers (if any) are located centrally with respect to the loads that they feed. This arrangement simplifies the installation and requires less weight, space, and equipment than if each load were connected to a switchboard.

## GENERAL AND BATTLE POWER CIRCUITS

The power circuits that supply motors and appliances that are not essential during battle and are therefore nonvital are called General Power Circuits. The battle power circuits comprise all other circuits and are energized under battle conditions.

At least two independent sources of power are provided for selected vital loads. The distribution of this dual supply is accomplished in several ways: by a NORMAL and an ALTERNATE ship service feeder; NORMAL ship service feeder, and an EMERGENCY feeder (figs. 5-10 and 5-11).

The normal and alternate feeders to a common load run from different ship service switchboards and are located below the waterline, on opposite sides of the ship, to minimize the possibility that both will be damaged by a single hit.

## BUS-TRANSFER EQUIPMENT

Bus-transfer equipment is installed at load centers, distribution panels, or loads that are fed by both normal and alternate and/or emergency feeders. This equipment is used to select either the normal or alternate source of the ship's service power, or to obtain power from the emergency distribution system if an emergency distribution system feeder is also provided.

Automatic bus-transfer equipment is used for loads that require two power supplies, except for auxiliaries that are used when lighting off the engineering plant and fire pumps, which have manual bus-transfer equipment. On the steering power switchboard, which is provided with a normal, alternate, and emergency power supply, manual bus-transfer equipment is used to select between the normal and alternate supplies, and automatic bus-transfer equipment is used to select between the ship service and emergency supplies.

The lighting circuits are supplied from the 120-volt secondaries of 450/120-volt transformer banks connected to the ship service power system. In large ships the transformer banks are installed in the vicinity of the lighting distribution panels located at some distance from the generator and distribution switchboards. In small ships the transformer banks are located near the generator control and distribution switchboards and energize the switchboard buses that supply the lighting circuits.

The lighting distribution system feeders, mains, and submains are 3-phase circuits; the branches are single-phase circuits. The single-phase circuits are connected so that under operating conditions the single-phase loads on the 3-phase circuits are as nearly balanced as possible.

## PHASE SEQUENCE

Phase identification is denoted by the letters, A, B, and C, in a 3-phase system. Switchboard and distribution panel bus bars and terminals on the back of switchboards are marked to identify the phase with the appropriate letters, A, B, or C.

The phase sequence in naval vessels is ABC; that is, the maximum positive voltages on the three phases are reached in the order: A, B, and then C. Phase sequence determines the direction of rotation of 3-phase motors. Reversal of the phase sequence reverses the direction of rotations of electric motors. The phase sequence of the power supply throughout a ship is always ABC, irrespective of whether power is supplied from any of the switchboards or from the shore power connection. This condition ensures that 3-phase, a-c motors will always run in the correct direction.

## SHORE POWER CONNECTION

A shore power connection is provided at, or near a suitable weather deck location to which portable cables from the shore or from a vessel alongside can be connected to supply power for the ship's distribution system when the ship service generators are not in operation. This connection also can be used to supply power from the ship's service generators to a ship alongside. The shore power circuit breaker is located on the after switchboard on most destroyers. The breaker connects the shore power to the bus tie system.

## MULTIPURPOSE POWER OUTLETS

Multipurpose power outlets are provided to supply 450-volts, 3-phase power for portable hoists; portable tools that require 450-volt power, portable welding units for repair, maintenance, and damage repair purposes, including underwater welding and cutting; and portable submersible bilge pumps. The multipurpose power outlets are of the grounded type and are used with grounded plugs and cables having a ground wire that grounds the metallic case and exposed metal parts of the tool or equipment when the plug is inserted in the receptacle. The ground wire provides a conducting path of low resistance between the metal housing of the tool and the ship's structure. In the event of a casualty to the insulation of the tool, the ground wire will shunt the operator, thereby protecting him from electrical shock.

These outlets are located so that two portable pumps can be operated in any compartment by using 75 feet of cable for each pump. The outlets are fed from battle power distribution panels. A minimum number of outlets are fed from any one panel to provide as great a diversity of supply as possible. An adapter is provided with the 75-foot extension cables for making connections to the casualty power system if power is lost from the outlets.

## D-C POWER

D-c power in ships with a-c power systems is furnished either by oversize exciters for the ship's service generators or by separate motor-generator sets or by rectifiers. The principal d-c loads are carbon-arc searchlights, degaussing installations, battery charging stations, and the interior communications and fire control system. The use of the 24-inch, carbon-arc searchlight has been discontinued aboard most ships with a consequent reduction in the d-c power requirements. Rectifier power supplies are used as d-c power sources in the latest ships provided with a-c power systems.

## EMERGENCY POWER

The emergency power distribution system is provided to supply an immediate and automatic source of electric power to a limited number of selected vital loads in the event of failure of the ship service power distribution system. The system, which is separate and distinct from the ship service power distribution system, includes one or more emergency distribution switchboards. Each emergency switchboard is supplied by its associated emergency generator.

## FEEDERS

The emergency feeders run from the emergency switchboards (figs. 5-10 and 5-11) and terminate in manual or automatic bus transfer equipment at the distribution panels or loads for which emergency power is provided. The emergency power distribution system is a 450-volt, 3-phase, 60-cycle system with transformer banks at the emergency distribution switchboards to provide 120-volt, 3-phase power for the emergency lighting system.

The emergency generators and switchboards are located in separate spaces from those containing the ship's service generators and distribution switchboards. As previously stated, the normal and alternate ship service feeders are located below the waterline on opposite sides of the ship. The emergency feeders are located near the centerline and higher in the ship (above the waterline). This arrangement provides for horizontal separation between the normal and alternate ship service feeders and vertical separation between these feeders and the emergency feeders, thereby minimizing the possibility of damaging all three types of feeders simultaneously.

## PREFERRED AND ALTERNATE SOURCE OF POWER

The emergency switchboard is connected by cables, called feeders, to at least one and usually to two different ship service switchboards. One of these switchboards is the PREFERRED, or normal, source of ship service power for the emergency switchboard and the other is the ALTERNATE source (fig. 5-12). The emergency switchboard and distribution system are normally energized from the preferred source of ship service power. If this source of power should fail, bus-transfer equipment automatically transfers the emergency switchboard to the alternate source of the ship

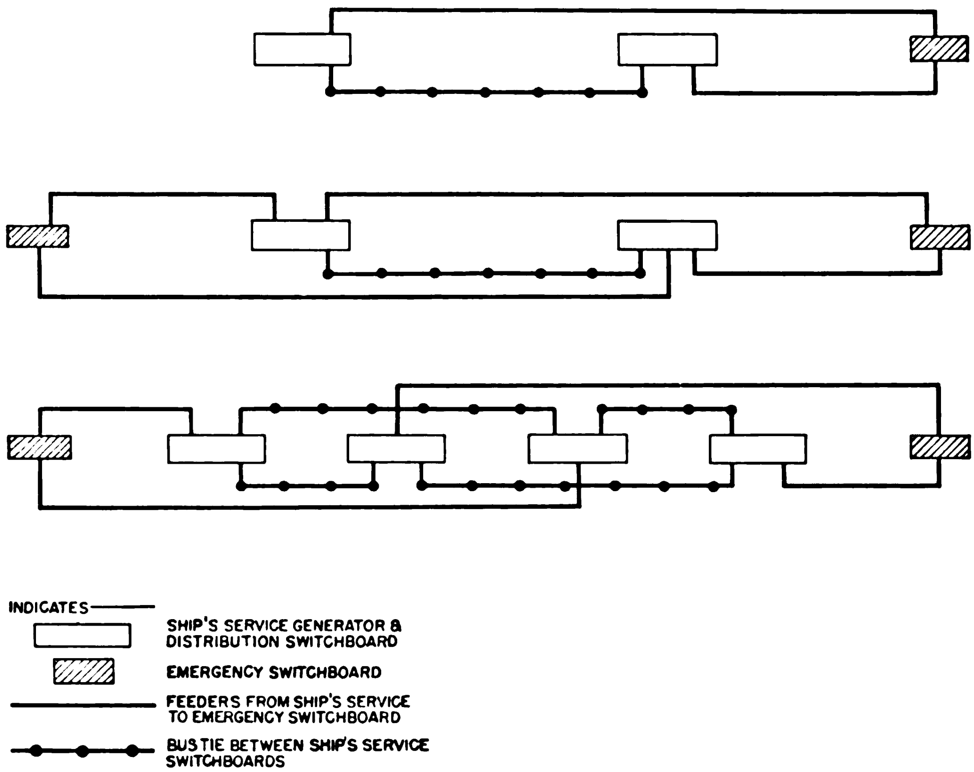



Figure 5-12.—Emergency and ship's service distribution system interconnections.

service power. If both the preferred and alternate sources of ship's service power fail, the diesel-driven emergency generator starts automatically, and the emergency switchboard is automatically transferred to the emergency generator.

When the voltage is restored on either the preferred or alternate source of the ship service power, the emergency switchboard is automatically retransferred to the source that is available or the preferred source if voltage is restored on both the preferred and alternate sources. The emergency generator must be manually shut down. Hence, the emergency switchboard and distribution system are always energized either by a ship service generator or by the emergency generator. Therefore, the emergency distribution system can always supply power to a vital load if both the normal and alternate sources of the ship service power to this load fail. The emergency generator is not started if the emergency switchboard can receive power from a ship service generator.

## FEEDBACK TIE

A switch and cable arrangement, designated a feedback tie (fig. 5-11), is provided in most ships. The feedback tie feeds power back to the ship service switchboard, thus a selected portion of the ship service switchboard load may be supplied from the emergency generator. This feature facilitates starting up the machinery after major steam alterations and repairs, and provides power to operate necessary auxiliaries and lighting during repair periods when shore power and ship service power are not available.

## CASUALTY POWER SYSTEM

The casualty power distribution system is provided for making temporary connections to supply electric power to certain vital auxiliaries if the permanently installed ship service and emergency distribution systems are damaged. The system is not intended to supply circuits to all the electrical equipment in the ship but is confined to the facilities necessary to keep the ship afloat and to get it away from a danger area. The system also supplies a limited amount of armament, such as antiaircraft guns and their directors, that may be necessary to protect the ship when in a damaged condition. The casualty power system for rigging temporary circuits is separate and distinct from the electrical damage control equipment, which consists of tools and appliances for cutting cables and making splices for temporary repairs to the permanently installed ship service and emergency distribution system.

The casualty power system includes portable cables, bulkhead terminals, risers, switchboard terminals, and portable switches. Portable cables in suitable lengths are stowed throughout the ship in convenient locations. The bulkhead terminals are installed in watertight bulkheads so that horizontal runs of portable cables can be connected on the opposite sides of the bulkhead terminal to transmit power through the bulkheads without the loss of watertight integrity. The risers are permanently installed vertical cables for transmitting power through decks without impairing the watertight integrity of the ship. A riser consists of a cable that extends from one deck to another with a riser terminal connected to each and for attaching portable cables.

Suitable terminals are provided at switchboards and some distribution panels for connecting portable cables at these points to obtain power from or supply power to the bus bars. Casualty power circuit breakers are installed at switchboards so that the terminals can be deenergized when the cables are connected. The portable switches are stowed in repair party lockers and are used when necessary for connecting and disconnecting the circuits. The locations of the portable cables, bulkhead terminals, and risers are selected so that connections can be made to many vital electrical auxiliaries from any of the ship's service or emergency generators. Casualty power cables should be rigged only when required for use, or for practice in rigging the casualty power system. When rigging the casualty power cables, make the connections from the load to the supply to avoid handling energized cables.

The riser terminals, bulkhead terminals, and portable cables are marked to identify the A, B, and C phases (both visually and by touch) when illumination is insufficient for visual identification.

If the ship service and emergency circuits fail, temporary circuits can be rigged with the casualty power distribution system and used to supply power to vital auxiliaries if any of the ship service or emergency generators can be operated.

## QUIZ

1. What are the functions of I.C. switchboards?
2. Where are I.C. switchboards installed aboard ship to afford maximum protection?
3. Name the three power sources that may energize an I.C. switchboard.
4. Name the four types of I.C. switchboards.
5. What is the advantage of the design of the dead-front, front-service I.C. switchboard in reference to operation and maintenance?
6. What is the function of the A.C.O. switchboard (or section)?
7. Where is the A.C.O. switchboard (or section) located aboard ship?
8. A.C.O. switching is limited to what class of circuits?
9. How are the number of switches on A.C.O. sections reduced?
10. What is the purpose of I.C. switchboards located in each engineroom?
11. What three sources of power can the type-ABT-A3 bus transfer switch select for the I.C. switchboard?
12. What condition is indicated by a continual flashing of the neon lamp in the secondary circuit of an overload transformer with a multiple rotary switch?
13. When should I.C. and A.C.O. switchboards be cleaned and inspected?

# CHAPTER 6

# POWER DISTRIBUTION SWITCHBOARDS

## Introduction

A generator and distribution switchboard or switchgear group is provided for each generator or group of generators to control the operation of the associated generators and to control, through appropriate switching equipment, the distribution of electric power. Many of the components that comprise a distribution system are mounted on the switchboards or switchgear groups and include measuring instruments (voltmeters, ammeters, etc.); switching equipment (circuit breakers, bus-transfer equipment, switches, current and voltage-sensitive relays); voltage regulation equipment; protective equipment (circuit breakers and fuses); and conductors (bus bars and cables).

A switchboard may consist of a single section or of several sections that are physically separated and are connected by cables to form a switchgear group. This arrangement provides sufficient separation between sections to minimize damage from shock, to LOCALIZE damage from fire, and to permit easy removal of damaged sections for repairs or replacement.

On dead-front switchboards (fig. 6-1) the equipment is grouped to form a number of units each complete with a separate front panel and all the required apparatus, such as the a-c generator control unit, a-c bus-tie unit, power distribution unit, and lighting distribution unit. A number of units mounted on a common base comprises a section or several sections that are physically separated and are connected by cables to form a switchgear group.

### CONTROL BENCHBOARD

A separate control benchboard (fig. 6-2) is provided in the switchgear groups for cruisers and aircraft carriers. This benchboard mounts generator control equipment, measuring instruments, and remote controls for some electrically operated equipment. This arrangement provides for a centralized control of the generators and major switching operations. The control benchboard in ships equipped with four ship's service switchgear groups is provided with a mimic bus (a small switchboard plan) that has indicating lights to show which generator circuit breaker and which bus-tie circuit breakers are closed throughout the ship. In ships not provided with control benchboards the metering and control equipments are mounted on the front panels of the units in the switchboards or switchgear groups.

### SHIP'S SERVICE

The ship's service switchboards, which consist of switchgear groups 1S and 2S (fig. 6-3), are located in the forward and after engine rooms, respectively.

The forward ship's service switchgear group (fig. 6-3A) is designated as the control switchboard because it is provided with instruments and governor control (for the forward generator) to allow for dividing the load. All paralleling of the generators is accomplished at the ship's service switchboard associated with the incoming generator.

The after ship's service switchgear group (fig. 6-3B) is very similar to the forward ship's service switchgear group and consists of the same number of corresponding designated panels.

Generator switchboards are equipped with meters to indicate the generator voltage, current, watts, frequency, and power factor. Synchroscopes and synchronizing lamps are provided for paralleling generators. Indicator lamps are provided for visual indication of the operating conditions of various circuits.

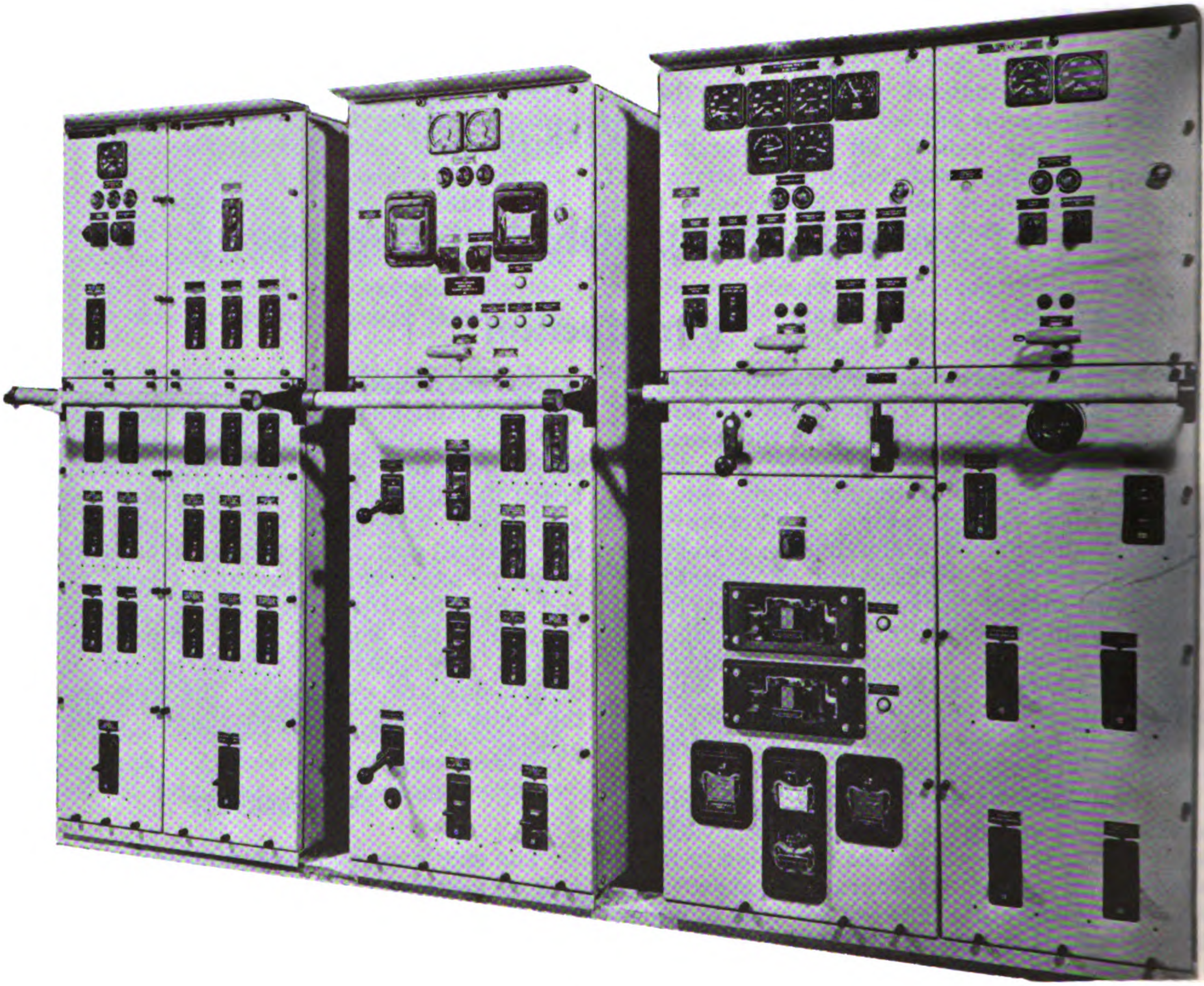


Figure 6-1.—Dead-front switchboard.

The frequency is controlled by the generator speed. The speed is automatically controlled by the governor of the prime mover. The governors for large machines can be set to the required speed by a governor motor controlled from the switchboard.

To prevent the generator from operating as a motor when running in parallel with other generators, the generator circuit breaker is equipped with a reverse power relay that trips the breaker and takes the generator off the line when power is fed from the line to the generator instead of from the generator to the line.

Protection against overspeed is provided in the governing mechanism of the prime mover.

## COMPONENTS

### GROUND DETECTOR LAMPS

A set of three ground detector lamps (fig. 6-4) is connected (through transformers) to the main bus of each ship's service switchgear group and to the emergency bus, enabling the Electrician's Mate to check for grounds on any phase of the 3-phase bus.

To check for a ground, turn switch S on and observe the brilliancy of the three lights. If the lights are equally bright, no ground exists, and all lights receive the same voltage. If

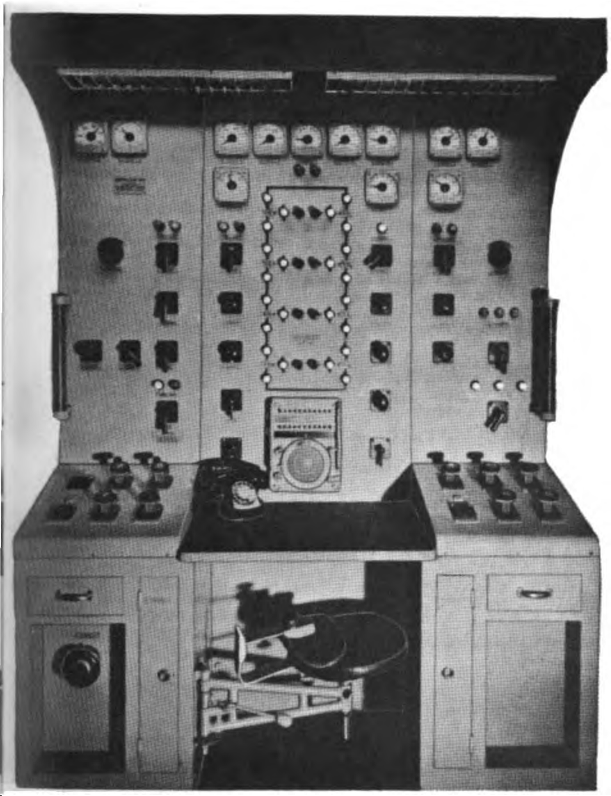


Figure 6-2.—Control benchboard.

lamp A is dark and lamps B and C are bright, phase A is grounded. In this case, the primary of the transformer on phase A is shunted by ground and receives no voltage. Similarly, if lamp B is dark and lamps A and C are bright, a ground will exist on phase B. If lamp C is dark and lamps A and B are bright, a ground will exist on phase C.

## BUS TIES

The connections between the ship's service and the emergency generating units and their associated switchboards and the interconnections between the switchboard are illustrated in the schematic line diagram in figure 6-5. The a-c buses on the forward and after ship's service switchboards can be connected together, and the d-c buses on these switchboards can also be connected together. This arrangement enables one generating unit to supply power to both ship's service switchboards when the other unit is out of service, and also provides for parallel operations of the two ship's service generating units (1SG and 2SG). However, when operating SPLIT PLANT the generators are operated separately, each unit supplying power for its own section of the ship.

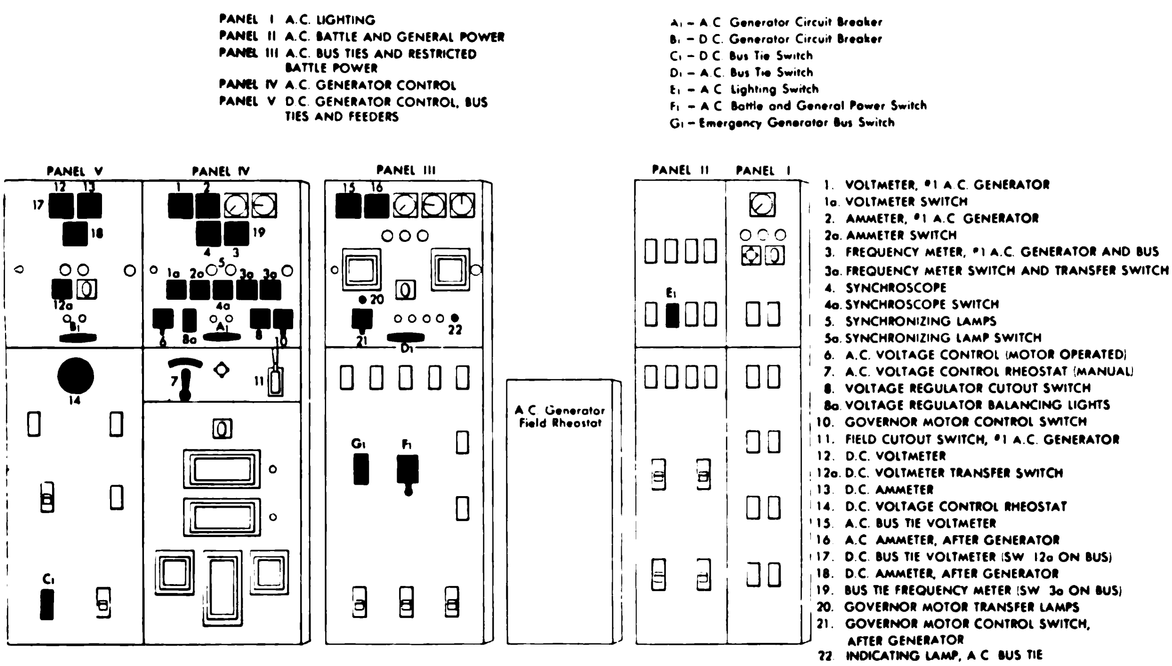



Figure 6-3A.—Forward generator and distribution switchboard.

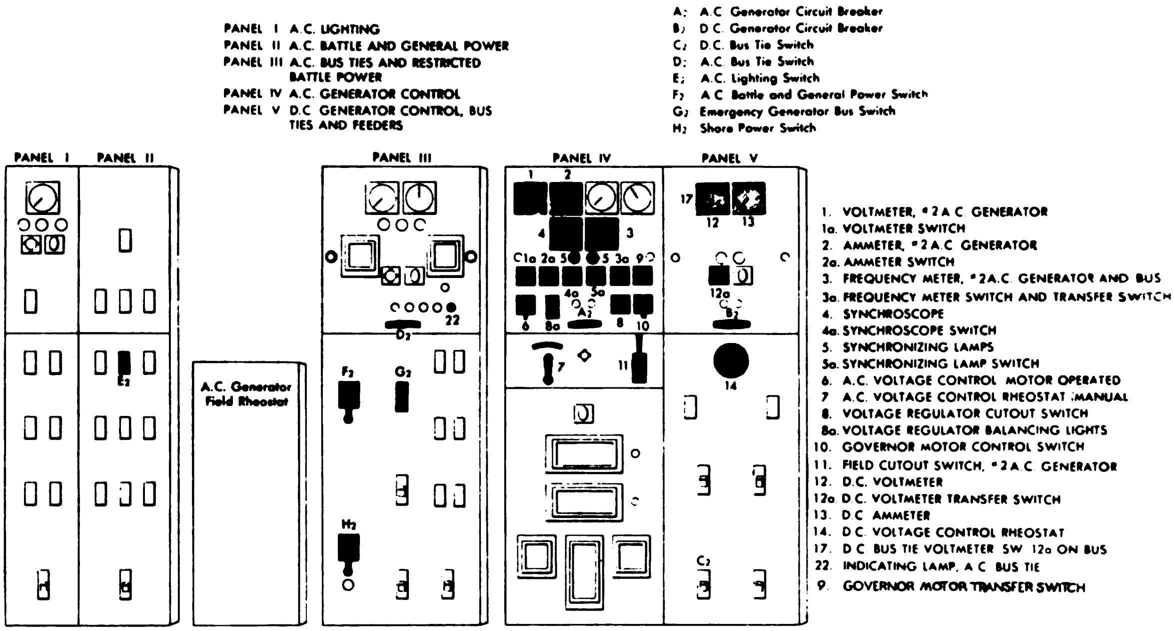



Figure 6-3B.—After generator and distribution switchboard.

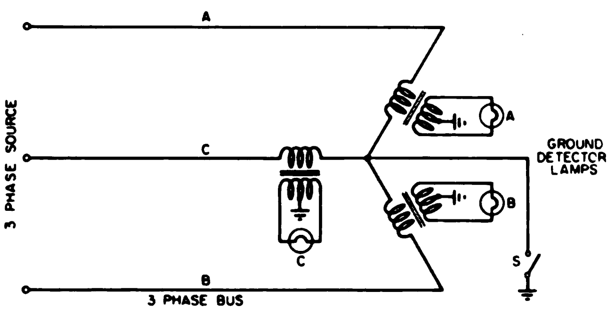



Figure 6-4.—A-c ground detector lamp circuit.

## BUS-TRANSFER EQUIPMENT

Power to the emergency switchboards can be supplied from the associated ship's service switchboard or from either emergency generator. An automatic bus-transfer contactor (fig. 6-6) is mounted in each emergency switchboard and is normally set to select power from one of the ship's service switchboards for the emergency distribution section. If a loss of power occurs from the associated ship's service switchboard supply, the automatic bus transfer contactor will start the diesel emergency generator, remove the ship's service supply from the local emergency power bus, and connect the emergency diesel generator to the local emergency power bus. The vital loads are shifted either automatically or manually at the loads to the emergency supply. When the ship's service voltage is restored, the emergency generator is automatically disconnected, and the emergency switchboard is again energized from the ship's service switchboard. However, retransfer from emergency generator supply must be made manually on some ships.

The standard bus-transfer contactor consists of (1) a motor-operated contactor unit and (2) a separate control panel designed for mounting in dead-front switchgear.

The contactor unit (fig. 6-6A) consists essentially of two 3-pole, cam-operated contactors for main line connection; six auxiliary cam-operated contacts for control and indicating light circuits; two pilot motors for automatic operation; and a handwheel for manual operation. The two sets of main contactors are operated from a camshaft driven by the two pilot motors. When the camshaft moves from one extreme position to the other, the cams by means of springs open one contactor and close the other. Both contactors cannot be closed at the same time, but both can be opened. One pilot motor drives the shaft in one direction, and the other motor drives it in the opposite direction. The

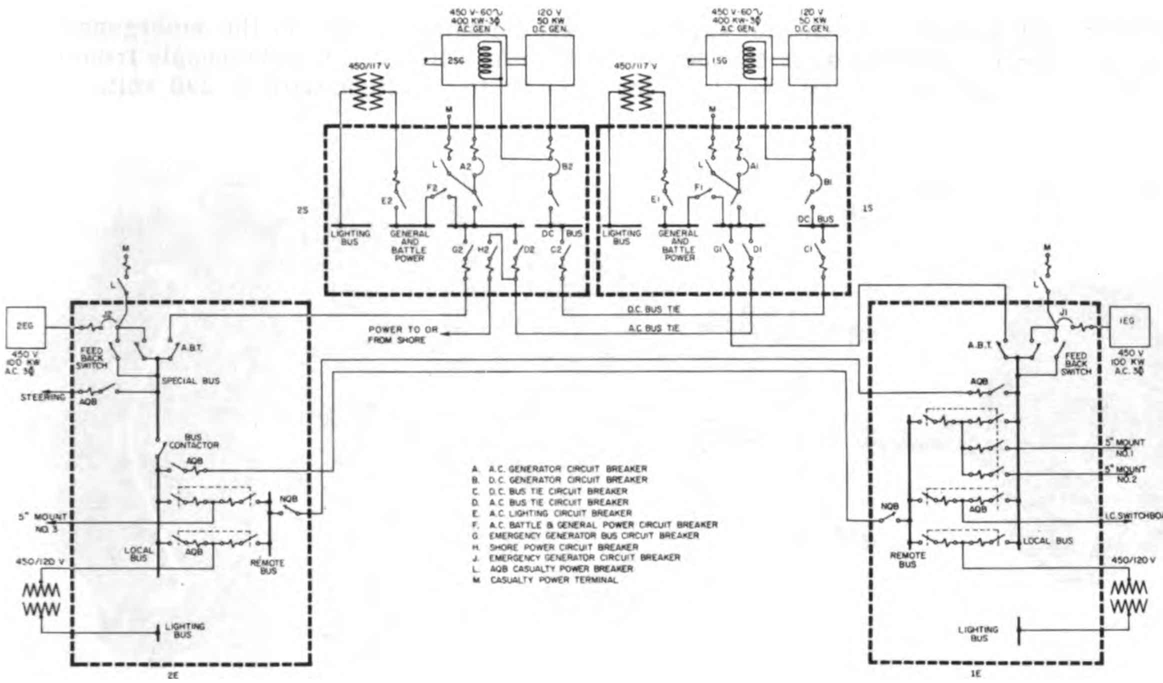



**Figure 6-5.—Ship's service and emergency switchboard interconnections.**

uxiliary contacts are used to control the ontactor-position indicator lights, and to de-nergize either motor when the shaft reaches ne limit of its travel. An automatic-manual ransfer switch permits manual operation of ne bus transfer controller. The control panel 'ig. 6-6B) consists of an insulating base on hich are mounted two voltage-sensitive relays ith associated rectifiers and transformers.

The setup for automatic operation of the us-transfer equipment located on the after mergency switchboard in a 692-class destroyer s illustrated in figure 6-7. The voltage-ensitive relays, VN and VE, have two operating oils connected in series and four (three a and ne b) contacts. When the relay is energized, ne a contacts are closed and the b contacts re open. Conversely, when the relay is de-nergized, the a contacts are open and the b ontacts are closed. Relay VN is shown in the nergized position and relay VE in the de-nergized position (fig. 6-7). The relay is d-c perated by a 450-160-volt transformer and opper oxide rectifier. Relay VN is operated y transformer T1 and rectifier CR1, and relay E is operated by transformer T2 and rec-ifier CR2. The VN relay connected in the fter ship's service supply is adjusted to pick p at 395 volts and drop out at 290 volts. The VE relay connected in the emergency supply is adjusted to pick up at 420 volts.

The automatic-manual transfer switch (AM1) has three contacts. When the transfer switch is in the AUTOMATIC position, the contacts are closed, and when the switch is in the MANUAL position, the contacts are open and prevent operation of the pilot motors. This switch is shown in the AUTOMATIC position. One pair of contacts (1-2) is in the coil circuit of motor N; one pair (3-4) in the circuit of motor E; and the other pair (5-6) is in the circuit of the transformer supplying the setup indicator light (not shown). This light indicates when the setup is properly made for automatic operation of the emergency diesel generator and the bus-transfer equipment.

A time delay relay, TD, having a single coil and two pairs of contacts, b and b1, is connected in the circuit of the bus-transfer equipment to delay the starting of the emergency diesel generator, and to delay the energizing of the rectifier for relay VE. The relay is d-c operated by means of a 450/160-volt transformer T3, and copper oxide rectifier CR3.

Under normal conditions (with either or both ship's service turbine generators in operation) the two emergency diesel generators will not be running, and the emergency switchboards will be supplied with power from the forward and after ship's service switchboards through the ship's service and emergency bus-transfer equipments located on the emergency switc boards. Hence, when the supply from the aft generator switchboard is 290 volts or abov

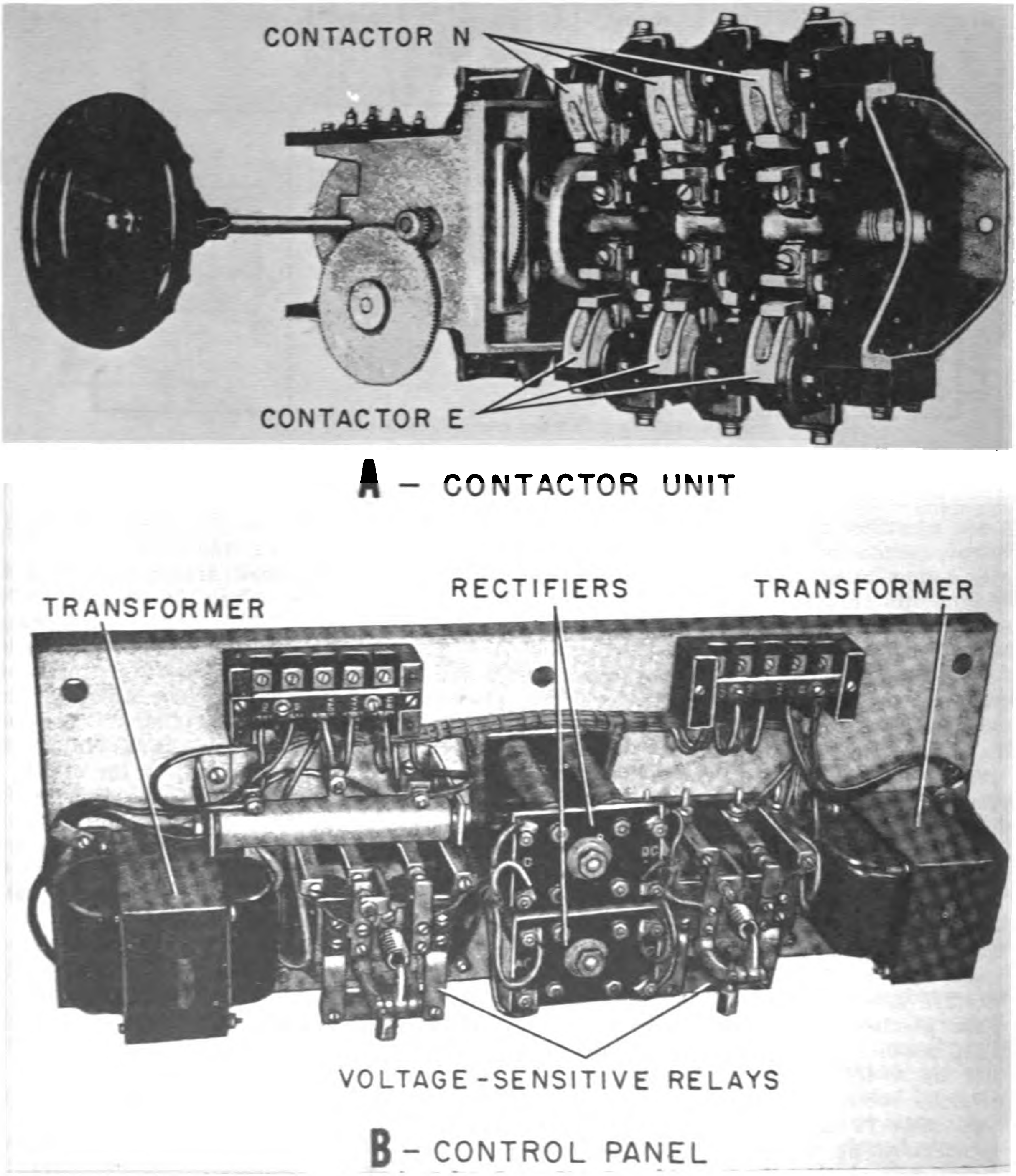



Figure 6-6.—Automatic bus-transfer controller.

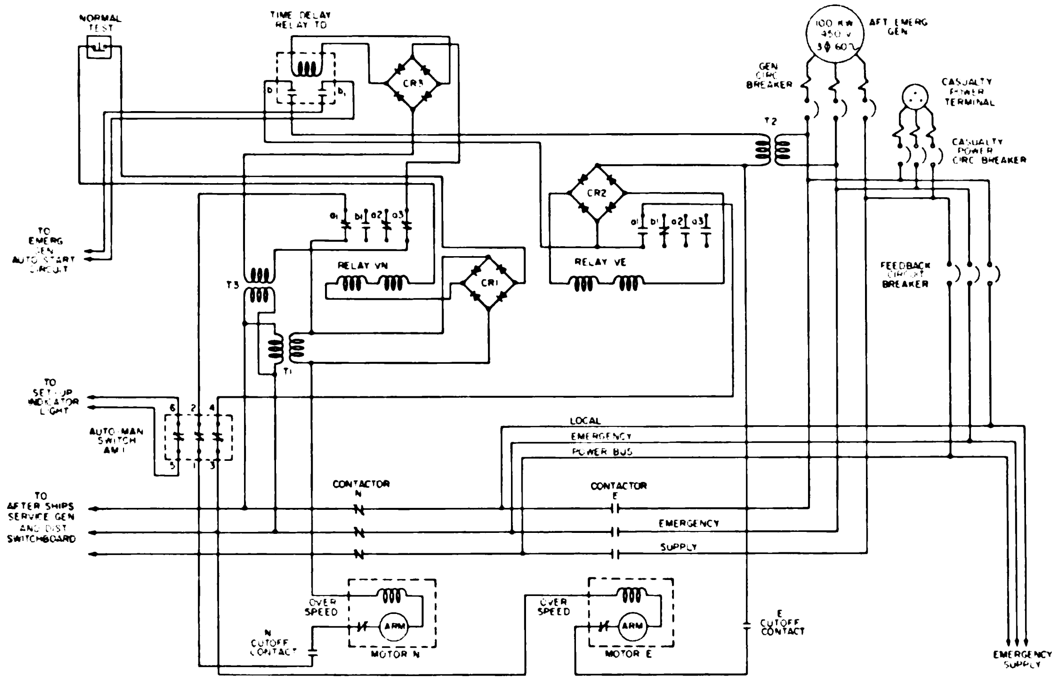



**Figure 6-7.—Automatic bus-transfer equipment in after emergency switchboard.**

elay VN will be energized, contactor N will be losed, and the 450-volt local emergency power us will be fed from the after ship's service witchboard. With contactor N normally closed, ne pilot motor for contactor N will be denergized as the cutoff contact for contactor N will be open. If the supply voltage should fall o 290 volts or below, relay VN will drop out nd open its a3 contact, which opens the circuit o rectifier CR3 that supplies relay TD.

After a brief interval, relay TD closes its contact to complete the circuit to rectifier R2 for relay VE. At the same time contact l closes to complete the starting circuit to he emergency diesel generator (not shown). he b contact of relay TD is also in the circuit o the pilot motor for contactor E. However, his motor is not energized until contact al of elay VE closes. When the emergency generaor voltage increases to 420 volts or above, ontact al of relay VE closes to complete the ircuit to the pilot motor for contactor E. ilot motor E will rotate the cam to open conactor N and close contactor E. At the same ime, auxiliary cutoff contact N closes. When ontactor E closes, its cutoff contact opens the ircuit to the pilot motor for contactor E. The 50-volt local emergency power bus on the after emergency switchboard is now supplied from the emergency generator.

If the voltage of the preferred supply should rise to 395 volts or above, relay VN will pick up and close its a1 contact to complete the circuit to the pilot motor for contactor N. Motor N will rotate the cam to open contactor E and close contactor N. When contactor N closes its cutoff contact opens the circuit to the pilot motor for contactor N. Because contact a3 is now closed, CR3 and relay TD will be energized. Contact b of relay TD will open and deenergize the circuit to rectifier CR2, thereby deenergizing relay VE and further opening the circuit to pilot motor E. However, the emergency diesel generator will continue to run until it is shut down manually.

## SELECTIVE TRIPPING

The overcurrent devices incorporated in the circuit breakers protect the circuits against extreme conditions of overcurrent. The overcurrent tripping devices of all circuit breakers are set to obtain selective tripping on all faults, within practical limits, to protect the distribution system and generators against large overcurrents. The purpose of selective tripping is to isolate the faulty section of the system and at the same time to maintain power on as much of the system as possible. Selective tripping of circuit breakers is attained by coordination of the time-current characteristics of the protective devices so that the breaker closest to the fault will open first and the breaker farthest from the fault and closest to the generator will open last.

The attainment of selective tripping requires careful coordination of the time-current characteristics for the different groups of circuit breakers. For example, if the system illustrated in figure 6-8 is operating split plant (bus ties open), and if the time-current characteristics of the ACB feeder breaker and the ACB generator breaker were interchanged, a fault at B with the overcurrent, I, would trip generator 1SG off the line but would leave the feeder connected to the switchboard. This action would disconnect power to all equipment supplied by switchboard 1S but would not isolate the faulty section. Therefore, no unauthorized changes should be made to circuit breaker trip settings because these changes may completely disrupt the scheme of protection based on selective tripping. The adjustments for selective tripping of the circuit breakers are made and sealed at the factory.

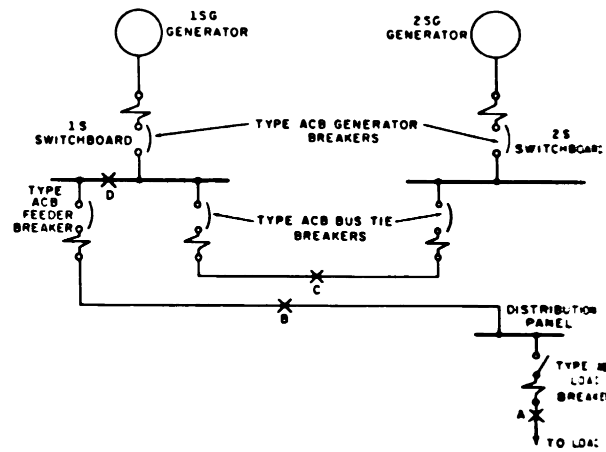



Figure 6-8.—Selective tripping of circuit breakers.

It is not feasible to provide system protection by selective tripping of circuit breakers in all types of naval vessels or for all circuits. For example, d-c distribution systems in older vessels and all lighting circuits use fuses to a great extent. Time delay can be incorporated only to the extent that is permitted by the characteristics of the fuses. The use of progressively larger fuse sizes from the load to the generator provides some degree of selectivity for overload or limited fault protection.

# Operation of Electric Plants

The ship's electric power and lighting systems are designed to provide a high degree of flexibility to ensure continuity of service to vital power and lighting loads under normal and casualty conditions. The distribution systems in most naval vessels are arranged so that the electric plants can be operated in parallel (cross connected plant) or separately (split plant).

## CROSS PLANT (PARALLEL)

The setup for cross connected plant operation requires that bus-ties between the ship's service switchboards be closed with the generators running in parallel so that any switchboard or several switchboards can supply electric power to any other switchboard. However, when the plant is operating cross connected, a casualty to one switchboard or load center may cause a short circuit that could trip all the generators off the line and result in temporary loss of all ship's service power.

## SPLIT PLANT

The setup for split plant operation is to open the bus-ties between the ship's service switchboards so that each switchboard with its generators and loads forms a system that is independent of the others. When the plant is operating split plant, a casualty to one switchboard will result in loss of power for the loads fed from this switchboard but will not affect the loads fed from the other switchboards. Hence, split-plant operation should be used under battle or other conditions where maximum assurance against loss of all ship's service power is desired.

If auxiliaries are provided with normal and alternate power supplies, the feeder circuit eakers are closed for both the normal and ernate supplies. Thus, if there is a casualty one generator plant, power will be immediately ailable at the manual transfer switch for this al equipment by means of the alternate power pply from the other generator plant. If a nerator casualty occurs (after isolating the maged equipment), battle loads not provided th alternate feeders can be supplied over the s-tie feeder.

The circuit breakers are closed on the bus- feeders between the ship's service switch- ards and the emergency switchboards to rmit the utilization of the emergency system an additional means of distributing power om the ship's service generators. If a loss ship's service power occurs on these bus-tie eders, automatic starting of the emergency nerators provides emergency power for the tal loads.

Hence, during war cruising, the normal setup to operate each generating plant separately, ich one feeding its associated switchboard or witchboards. This setup provides independent enerating plants, each receiving steam from n associated group of boilers, and one or more mergency diesel generators standing by to take ver the emergency load. The diesel emergency enerators are set for automatic starting.

## EMERGENCY GENERATOR

Emergency diesel generators can be stopped nly from within the space where the generator s located. Also, it is usually necessary to set p manually the lube oil alarm after the diesel tarts.

The automatic starting of emergency diesel generators should be secured when shifting rom ship to shore power, or vice versa. Ship's service and emergency generators must not be operated in parallel with each other or with shore power. Therefore, at the instant of transferring a ship's service switchboard from ship's service power to shore power, or vice versa, the switchboard will be dead. As previously stated, emergency switchboards are always energized from the ship's service switchboards, and when loss of voltage occurs from the ship's supply to any emergency switchboard, the emergency generator associated with the switchboard will start automatically. Therefore, before making a transfer that will cause momentary loss of ship's service voltage on the emergency switchboard, the automatic diesel starting circuit should be made inoperative for the transfer period. After the transfer has been made the switchboard should be set up for automatic starting, if desired.

## CASUALTY CONDITIONS

If a switchboard is fed by two or more generators and if some of the generators are lost, split-plant operation can be continued by using the remaining generators to supply power for some of the loads fed from the switchboard, and by shifting other loads normally fed from the switchboard over to the alternate feeders that connect the load to other switchboards.

If all the generating capacity for a switchboard is lost, the bus-tie circuit breakers can be closed to energize the switchboard from one of the other switchboards. The principal use of the bus-tie connection is obtained when all generating capacity for one switchboard is lost (under split-plant conditions). The bus-tie is always in use when one switchboard is supplying power for the entire ship.

If only a part of the generating capacity for a switchboard is lost, it is good practice to continue split-plant operation instead of using the bus-tie to parallel the remaining generators with another switchboard.

### RIGGING CASUALTY POWER CABLE

When rigging casualty power cables:

1. Ensure that power is not available at the damaged panel or switchboard. The engineering officer will designate the switchboard to be used as the source of supply.
2. Ensure that all supplies are tagged, "opened." The I.C. Electrician making the connections must be provided with a voltage tester, rubber gloves, and rubber boots.
3. Ensure that no short circuits exist in the panel or equipment. If the supply cables are damaged and no switch is available, disconnect the leads.
4. Lay out the portable casualty power cables, ready for making the connections.
5. To prevent working with energized cables, connect all horizontal cables, starting at the riser or bulkhead terminal at the casualty (load), and work toward the riser or bulkhead terminal entering the space that is to provide power (supply).

6. Test, then connect the damaged equipment to the riser or bulkhead terminal leaving the space.

7. Never use a riser terminal for a connection block unless the other end of the riser is to be used to supply some piece of equipment. A portable switch should be connected in the line near the casualty to deenergize the circuit in the event of an emergency, or for reversing the leads in case of reverse-phase rotation.

8. Notify damage control central immediately when all the cables have been connected to the panel or equipment to be supplied and to the riser leading to the space that is designated as the power supply. The damage control assistant requests the bridge to pass the word, "stand clear of casualty power cables rigged on main deck from frame 82 to frame 168 starboard side." Then the damage control assistant notifies main engine control, "connect and energize casualty power to riser or bulkhead terminal 2-82-1 in the forward engine room."

9. The switchboard electrician must ensure that the casualty power circuit breaker is open and that the casualty power terminal is deenergized. He must test and connect the casualty power cable to the designated riser or bulkhead terminal, and test and connect the other end of the casualty power cable to the switchboard casualty power terminal.

10. Close the casualty power circuit breaker, test, and report to main engine control, "casualty power riser or bulkhead terminal 2-82-1 is energized."

11. Ensure that the rotation is in the correct direction. If not, reverse the direction of rotation by deenergizing the circuit at the portable switch or at the switchboard and by reversing (or interchanging) any two of the three leads.

## UNRIGGING CASUALTY POWER CABLES

The damage control assistant notifies main engine control, "deenergize and disconnect casualty power from the riser or bulkhead terminal 2-82-1." The switchboard electrician opens the casualty power circuit breaker, tests, and disconnects the casualty power cable from the switchboard terminal. When unrigging casualty power cables:

1. Test and disconnect the cable from the riser or bulkhead terminal leaving the space.

2. Report to the main engine control, "ca ualty power deenergized and disconnected fr riser terminal 2-82-1." The main engine co trol notifies damage control central. When th word is received at damage control central th the casualty power has been deenergized a disconnected, the word is passed to the repa party to unrig the casualty power cables.

3. In unrigging casualty power cables, te each riser or bulkhead terminal before re moving the cable.

4. Start first by disconnecting the cable from the switchboard (supply) and the casual (load) last.

5. Keep the leads separated, and when a three connections are broken, remove the cable When the casualty has been restored and th cables unrigged, the word is relayed to damag control central, and the damage control assistan will inform the engineering officer to energiz the appropriate supplies.

6. Notify the bridge when the casualty ha been restored and tested.

## GENERAL RULES

In the operation of any shipboard electrica installation the assigned I.C. Electrician shoul watch the switchboard instruments because they show how the system is operating. The instruments reveal overloads and the improper division of the kilowatt load or reactive curren between generators operating in parallel and other abnormal operating conditions.

The frequency (on a-c systems) and the voltage must be maintained at the correct values to obtain satisfactory operation of all equipmen supplied with electric power. Low voltage results in a marked decrease in illumination whereas, high voltage materially shortens the life of electric lamps. The operation of vital electronic, interior communications, and fire control equipment is also seriously affected Therefore, it is necessary to carefully adjust the voltage regulators and the prime mover governors to obtain satisfactory performance of this equipment.

Operating personnel must realize that no automatically operated devices are installed to protect the distribution system or the generators from damage caused by an overcurrent or power overload that is only moderately in excess of the rated capacity. The switchboard electrician must be vigilant in observing the mmeter and wattmeter readings to detect the resence of a moderate overcurrent or power verload, which, if long continued, would cause xcessive heating of the generators.

If a switchboard controls two or more genrators and less than the full number is being sed to supply power, the load on the switchoard may increase to a point that will overɔad the generators in use. When the switchoard instruments reveal this condition, another enerator should be placed in service.

Emergency switchboards are connected by ɜeders to loads that at some time may need mergency power. The capacity of the emerency generators is not sufficient to provide ower for the simultaneous operation of all ɔads that can be connected to the emergency witchboard. Hence, if the ship's service power s lost, an indiscriminate use of emergency ower can easily overload an emergency genrator and possibly stall its diesel engine. 'he only way for the switchboard electrician o reduce the load on the emergency generator s to trip the circuit breakers on some of the eeders. To utilize the emergency power most ffectively and to ensure that it will be available vhere needed the most, it is important for the ngineering force to establish an operating rocedure for the emergency switchboard so hat the switchboard electrician will know which eads should have preference, and also know he order of preference for the additional loads hat can be carried if one of the preferred loads s lost because of derangement of equipment.

Because of the limited capacity of the emerency generators, the feedback tie installed in ome ships is not to be generally utilized to upply power to the ship's service distribution ystem. The use of the feedback tie should be imited to special circumstances, such as when he ship is alongside a deck and it is necessary o secure the ship's service generators, or when t is necessary to feed power through the ship's witchboards to certain auxiliaries to start the hip's service generators. When the feedback ie is used, increased vigilance of the switchoard electrician is necessary to prevent overoading the emergency generators.

Always operate switchboards and distribution ystem equipment as if no automatic protective levices were installed. These devices are not lesigned or intended to protect the system from lamage caused by careless operating practices, ut to afford protection against damage caused y equipment failure.

Exercise care when reclosing circuit breakers after they have tripped automatically. If a circuit breaker trips immediately on the first reclosure, investigate the cause before again reclosing the breaker. However, the circuit breaker might be closed a second time without investigation if the immediate restoration of power to the circuit were important and if the interrupting disturbance that tripped the breaker were not excessive. Remember that repeated closing and tripping may result in damage to the circuit breaker and thereby increase the repair or replacement work required to place the breaker back in operation.

Use the hold-in device on circuit breakers only when it is absolutely necessary. The hold-in device enables the operator to hold a trip-free circuit breaker closed when the current is in excess of the tripping valve. The circuit breaker will open automatically as soon as the hold-in device is released if the current is above the tripping current. In an emergency it may be vitally important to obtain power even at the risk of burning out equipment by using the hold-in device. However, when a circuit breaker is held closed, the greater is the possibility of permanent damage to circuits or equipment. Do not hold a circuit breaker closed unless an emergency exists to justify the risk.

## I.C. SWITCHBOARD POWER SUPPLY

The power distribution systems and arrangements of buses for I.C. switchboard vary widely in different ships, depending upon the size of the ship, the main power system, and the F.C. system. The following discussion describes the general principles of a typical I.C. switchboard power supply.

The forward main I.C. switchboard is supplied with power from as many sources as possible. This power supply usually consists of (1) a normal supply from a main power distribution switchboard of the forward machinery group, (2) an alternate supply from a main power distribution switchboard of the after machinery group, and (3) an emergency supply from the nearer emergency-distribution switchboard.

The normal 3-phase, 450-volt, 60-cycle power supply is obtained from the forward main ship's service distribution switchboard through a circuit breaker on that board. The 450-volt supply is connected to a 450-volt bus on the main I.C. switchboard through the bus-transfer switch, as shown in figure 6-9.

This bus energizes the various 450-volt, 60-cycle circuits through individual switches and fuses. In this installation the 450/120-volt 60-cycle transformer bank is energized directly from this bus through fuses. However, in some installations the transformers are energized through a switch and fuse combination.

The I.C. transformer bank is connected delta-delta in order to operate open-delta in case of a casualty to one transformer. When operating open-delta, strip the switchboard of all but the vital circuits. The load can be reduced as necessary by opening the switches of less essential circuits.

In some ships in which the emergency power is extremely small, the main 120-volt a-c bus is divided into a restricted bus. This restricted bus supplies power to the most important circuits, and to the I.C. and F.C. buses, which are connected to the restricted bus through manual switches or contactors. The contactors open automatically upon transfer to the emergency power supply. Thus, the normal 120-volt supply is disconnected from the I.C. and F.C. buses upon transfer to the emergency supply. After the switches for less essential circuits on the I.C. and F.C. buses have been opened to reduce the load, the contactors supplying these buses are closed again.

In figure 6-9, the 120-volt, 60-cycle, bus furnishes power for the three electromechanical bus failure alarms, the constant-frequency unit, and the alternate source to the constant frequency bus. The 120-volt, 60-cycle controlled frequency is restricted to those I.C. and F.C. circuits, whose components require extremely fine regulation (within 0.1 percent). The supply to this bus is through a double-throw rotary snap switch. The switch selects either the constant frequency unit or the 120-volt, 60-cycle normal bus to supply the controlled frequency bus.

The 120-volt, d-c bus has a normal and an alternate source of power. The normal supply is from a motor generator that receives its power from the 450-volt, 60-cycle bus. The alternate source may be from a rectifier in the I.C. room, the ship's service switchboard, or from another motor generator in the after I.C. room. The type and location of the alternate d-c equipment depend on the d-c requirements of the particular ship. The double-throw switch will be manual unless a d-c voltage is required for a vital circuit.

There are two 400-cycle bus sections: 450-volt and 120-volt. The 450-volt section may be supplied by a motor generator, which receives its power from the 450-volt, 60-cycle bus at its associated switchboard. However, the 450-volt, 400-cycle section can receive power from the after 450-volt, 400-cycle bus which has its own motor generator set. The forward switchboard may be used to feed the after 450-volt, 400-cycle section. (See fig. 6-9A.) The 120-volt, 400-cycle section of each switchboard receives its power from a delta-delta connected bank of transformers, which are connected to the respective 450-volt, 400-cycle sections.

The two 400-cycle motor generators may be paralleled if provided with load division network, synchronizing lamps and switch. (See fig. 6-9B.)

A casualty power terminal is provided adjacent to the I.C. switchboard in vessels having a casualty power system. (See fig. 6-9.) Risers are not always provided in the I.C. room. It is necessary therefore, to rig portable cables to the nearest riser outlet. All I.C. Electricians must be familiar with the locations of these outlets.

Before connections are made to the casualty power system, the main power manual and automatic bus-transfer switches must be operated to the OFF position. This procedure prevents the possible paralleling of one of the power supplies to the switchboard with the casualty power system. The casualty power system is limited to the facilities necessary to keep the ship afloat and to get it out of a danger area as well as to supply power to a limited amount of armament.

Therefore, before connections are made to the casualty power system, all switches on the I.C. board except those energizing vital ship control circuits and F.C. circuits should be operated to the OFF position.

## SAFETY PRECAUTIONS

Protective grab rods and guard rails around switchboards and other equipment should always be in position when the equipment is energized unless emergency repairs are necessary while the equipment is in service. Grab rods and guard rails should be carefully maintained to insure that they are secure and will not become dislodged accidentally. The insulating mats

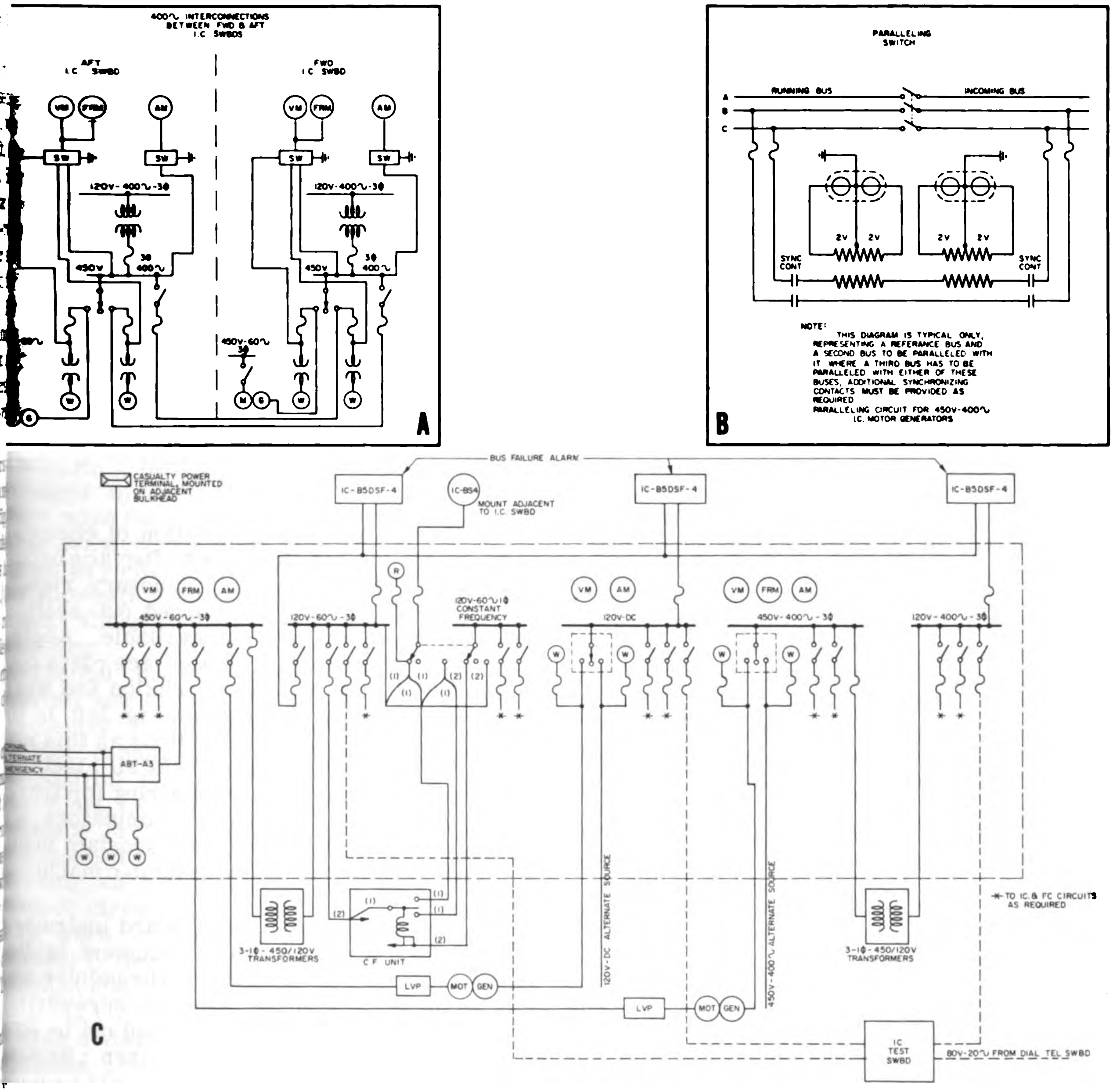



Figure 6-9.—Schematic wiring diagram of I.C. switchboards.

provided for covering the deck in the front and in the rear of switchboards should always be in place.

When performing maintenance work on a circuit, insure that the circuit is dead and that it cannot be inadvertently energized by closing a remote circuit breaker. All circuit breakers or switches that would energize the circuit should be opened, and the circuit should be tested with a voltmeter or voltage tester. These switches should be tagged, WARNING. Do not change position of switch except by direction of "NAME ______________ RATE/RANK." Warning tag, NavShips 3950 (S-51), may be used for this purpose. If more than one repair party is engaged in repair work on an electrical circuit, a tag for each party should be placed on the supply switches. After the work has been completed, each party should remove its own tag but no other. As a further precaution, metal locking devices are available that can be attached to the switch handles to prevent accidental operation.

When checking to ascertain if circuits are deenergized, check the metering and control circuits in addition to the power circuits because these circuits are often connected to the supply side of a circuit breaker. A check of the power circuits on the load side of a circuit breaker may indicate that these circuits are dead after the circuit breaker is opened, but the associated metering and control circuits may or may not be dead, and should be checked also to be certain they are dead.

## MAINTENANCE

A routine maintenance program should be established to ensure maximum performance with minimum interruption of switchboards and control equipment. It is impracticable to set up a rigid schedule of tests and inspections that will be equally applicable to every ship because the service, age, and the condition of equipment differ for each ship. However, the engineering force should set up a schedule based on past experience and the following suggested schedule. A frequent recurrence of trouble indicates that the interval between tests and inspections should be decreased.

EACH WEEK, test the circuit breakers, test the bus transfer equipment, and test the control circuits.

AFTER FIRING, if practicable inspect the switchboards, action cutout sections, and distribution panels.

EACH YEAR AND AFTER EACH OVERHAUL, inspect and clean the switchboards and distribution panels, and check overload relays.

EVERY FOUR YEARS, check the overload relays for tripping time.

Numerous derangements of electrical equipment have been caused by loose electrical connections or mechanical fastenings. Loose connections can be readily tightened, but a thorough inspection is necessary to detect them.

## INSPECTION

At least once a year and during each overhaul, each switchboard propulsion control cubicle, distribution panel, and motor controller should be deenergized for a complete inspection and cleaning of all bus work equipment. The inspection of deenergized equipment should not be limited to visual examination but should include grasping and shaking electrical connections and mechanical parts to be certain that all connections are tight and that mechanical parts are free to function. Be certain that no loose tools or other extraneous articles are left in or around switchboards and distribution panels.

Check the supports of bus work and be certain that the supports will prevent contact between bus bars and grounded parts during periods of shock. Clean the bus work and the creepage surfaces of insulating materials, and be certain that creepage distances (across which leakage currents can flow) are ample. Check the conditions of control wiring and replace if necessary.

Be certain that the ventilation of rheostats and resistors is not obstructed. Replace broken or burned out resistors. Temporary repairs can be made by bridging burned out sections when replacements are not available. Apply a light coat of petrolatum to the face plate contacts of rheostats to reduce friction and wear. Be certain that no petrolatum is left in the spaces between the contact buttons as this may cause burning and arcing. Check all electrical connections for tightness and wiring for frayed or broken leads. Service commutators and brushes of potentiometer-type rheostats in accordance with the instructions for d-c machines.

The pointer of each switchboard instrument should read zero when the instrument is disconnected from the circuits. The pointer may be brought to zero by external screwdriver adjustment. Caution: This should not be done unless proper authorization is given. Repairs to the switchboard instruments should be made only by the manufacturers, shore repair activities, or tenders.

Be certain that fuses are the right size, clips make firm contact with the fuses, lock-in devices (if provided) are properly fitted, and that all connections in the wiring to the fuses are tight.

In addition to the foregoing inspections, switchboards and distribution panels should be deenergized after firing, if practicable, and thoroughly inspected for tightness of electrical connections and mechanical fastenings.

## CLEANING

Bus bars and insulating materials can usually cleaned sufficiently by wiping with a dry ›th. A vacuum cleaner, if available, can also used to advantage. Be certain that the itchboard or distribution panel is completely ad and will remain so until the work is com- eted; avoid cleaning live parts because of the nger to personnel and equipment.

Use a dry cloth, not soap and water, on the ɔnt panels of live-front switchboards or on her panels of insulating material. The front nels of dead-front switchboards can be cleaned thout deenergizing the switchboard. These nels can usually be cleaned by wiping with a y cloth. However, a damp, soapy cloth can used to remove grease and finger prints. hen wipe the surface with a cloth dampened in ear water to remove all soap and dry with a ean, dry cloth. Cleaning cloths must be wrung it thoroughly so that no water runs down the anel. Clean a small section at a time and then ipe dry.

Circuit breakers should be carefully in- pected and cleaned at least once a year (more equently if subjected to unusually severe ervice conditions). The oil should be changed oil-film type overcurrent tripping devices very six months. A special inspection should e made of the contacts after a circuit breaker as opened on a heavy short circuit. Before orking on a circuit breaker, deenergize all ontrol circuits to which it is connected. Be- ore work is performed on draw-out circuit reakers, they should be switched to the open osition and removed. Before working on fixed- nounted circuit breakers, open the disconnecting witches ahead of the breakers. If disconnecting witches are not provided for isolating fixed- nounted circuit breakers, deenergize the supply ous to the circuit breaker, if practicable, before nspecting, adjusting, replacing parts, or doing any work on the circuit breaker.

Contacts in circuit breakers, contactors, relays, and other switching equipment should be clean and bright, free from severe pitting or burning, and properly aligned. Remove sur- face dirt, dust, or grease with a clean cloth moistened, if required, with a small amount of methyl chloroform.

CAUTION: Methyl chloroform is toxic and presents hazards to personnel. Good ventila- tion must be provided. Repeated breathing of the vapor or contact with the skin should be avoided.

Inhibited methyl chloroform should not be used on hot equipment because heat will cause vapors to be given off faster than normal. If the cleaner is exposed to open flame, phosgene gas, which is highly toxic, can be formed.

Methyl chloroform is nonflammable, but the inhibitor is flammable. If 90 percent of the cleaner is allowed to evaporate, the residue is highly flammable.

When cleaning and dressing contacts, main- tain the original shape of the contact surface and remove as little material as possible. Inspect copper contact surfaces for black, copper oxide film and clean with fine sandpaper (No. 00), if required. Severely burned or pitted copper contact surfaces should be dressed with a fine file or fine sandpaper.

Slight discoloration of solid silver or silver alloy contacts is normal and should not be re- moved. Remove heavy, black deposits, and any high spots caused by burning, with very fine sandpaper or with a fine file.

Opening and closing laminated, silver-plated contacts will aid in cleaning. If necessary, use a cloth moistened with methyl chloroform to remove dirt and grease but do not use a file or sandpaper. Do not use emery paper or emery cloth to clean contacts, and do not clean contacts when the equipment is energized.

Clean all surfaces of the circuit breaker mechanism, particularly the insulation surfaces, with a dry cloth or air hose. Before directing the air on the breaker, be certain that the water is blown out of the hose, that the air is dry, and that the pressure is not over 30 psi. Check the pins, bearings, latches, and all con- tact and mechanism springs for excessive wear or corrosion and evidence of overheating.

Before returning a circuit breaker to service, inspect all mechanical and electrical con- nections, including mounting bolts and screws, draw-out disconnect devices, and control wiring. Tighten where necessary. Give the breaker a final cleaning with a cloth or compressed air. Operate manually to be certain that all moving parts function freely. Check the insulation re- sistance.

The sealing surfaces of circuit breakers, contactors, and relay magnets should be kept clean and free from rust. Rust on the sealing surfaces decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. A light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

Oil should always be used sparingly on circuit breakers, contactors, motor controllers, relays, and other control equipment, and should not be used at all unless stated in the manufacturers' instructions or unless oil holes are provided. If working surfaces or bearings show signs of rust, disassemble the device and carefully clean the rusted surfaces. Light oil can be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit, which may cause unsatisfactory operation of the devices, particularly if the device is delicately balanced.

Arc chutes or boxes should be cleaned by scraping with a file, if wiping with a cloth is not sufficient. Replace or provide new linings when they are broken or burned too deeply. Be certain that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contactor is opened or closed.

Shunts and flexible connectors, which are flexed by the motion of moving parts, should be replaced when worn, broken, or frayed.

Operating tests that consist of operating the circuit breakers in the manner in which they are intended to function in service should be conducted regularly. For manually operated circuit breakers, simply open and close the breaker to check the mechanical operation. To check both the mechanical operation and the control wiring, electrically operated circuit breakers should be tested by means of the operating switch or control. Exercise care not to disrupt any electric power supply that is vital to the operation of the ship, or to endanger personnel by inadvertently starting motors and energizing equipment under repair.

For manual bus-transfer equipment, manually transfer a load from one power source to another and check the mechanical operation and mechanical interlocks. For automatic bus-transfer equipment, check the operation by means of the control switches. The test should include operation initiated by cutting off power (opening a feeder circuit breaker) to ascertain if an automatic transfer occurs. The precautions for circuit breaker operating tests should be observed when testing bus-transfer equipment.

During periodic inspections of motor controllers, or at least once a year, the overload relays should be examined to ascertain that they are in good mechanical condition and that there are no loose or missing parts. The size of the overload heaters should be checked to determine that they are of the proper size indicated by the motor nameplate current and heater rating table. Proper allowances should be made for short-time and intermittent duty motors by using undersized coils. Any questionable relays should be checked for proper tripping at the next availability, and repaired, if necessary. Each relay should be checked for tripping time at 150, 300, and 600 percent rated current by a naval shipyard at intervals not exceeding four years.

Control circuits should be checked to ensure circuit continuity and proper relay and contactor operation. Because of the numerous types of control circuits installed in naval vessels, it is impracticable to set up any definite operating test procedures in this training course. In general, certain control circuits, such as those for the starting of motors or motor-generator sets, or voltmeter switching circuits, are best tested by using the circuits as they are intended to operate under service conditions.

Protective circuits, such as overcurrent, reverse power, or reverse current circuits, usually cannot be tested by actual operation because of the danger involved to the equipment. These circuits should be visually checked, and, when possible, relays should be operated manually to be certain that the rest of the protective circuit performs its intended functions. Exercise extreme care not to disrupt vital power service or to damage electrical equipment.

Emergency switchboards should be tested regularly in accordance with the instructions furnished with the switchboard in order to check the operation of the automatic bus-transfer equipment and the automatic starting of the emergency generator. This test should be made in connection with the weekly operating test of emergency generators.

# QUIZ

1. A switchboard may consist of how many sections?
2. What type of control is obtained from the control benchboard in ships equipped with four ship's service switchgear groups?
3. What device enables the control benchboard operator to see, at a glance, how his plant is set up?
4. Why is the forward ship's service switchgear group designated the control switchboard?
5. What device is used with the generator circuit breaker to prevent motoring of the generator?
6. In figure 6-4, (if a ground exists on phase A) why does operating switch S cause lamp A to go dark?
7. If a loss of power occurs from the associated switchboard supply (fig. 6-5), what component will start the diesel emergency generator, remove the ship's service supply from the local emergency power bus, and connect the emergency diesel generator to the local emergency power bus?
8. The interlock on the bus-transfer controller imposes what restrictions on the opening and closing of the two sets of main contactors?

Refer to figure 6-7 for questions 9 and 10.

9. If the (preferred) supply voltage falls to 290 volts or below, what will be the effect on (a) relay VN, (b) contact a3, (c) the circuit to rectifier CR3, (d) the b contact of relay TD, (e) the circuit to rectifier CR2, (f) relay VE, and (g) the b1 contact of relay TD?
10. When the emergency generator has started and its voltage has increased to 420 volts or above, what will be the effect on (a) contact a1 of relay VE, (b) the circuit to the pilot motor for contactor E, (c) contactor N, (d) contactor E, (e) auxiliary cutoff contact N, (f) the cutoff contact of contactor E, and (g) the circuit to the pilot motor for contactor E?
11. The overcurrent tripping devices of all breakers are set to obtain what system of tripping on all faults within practical limits?
12. What is the relation between the breaker location with respect to the fault and the operating time required for the breaker to open?
13. The distribution systems in most naval vessels are arranged so that the electric plants can be operated in what two ways?
14. Should the bus ties between the ship's service switchboards be opened or closed for (a) cross-plant operation, and (b) split-plant operation?
15. Why should split-plant operation be used under battle conditions?
16. If all the generating capacity for a switchboard is lost while under cruising conditions (split plant), what action should be taken with regard to the bus-tie circuit breakers in order to restore power to the switchboard?
17. Why is it considered desirable to secure the automatic starting of the diesel generators when shifting to shore power?
18. What restriction is imposed on the operation of ship's service and emergency generators with regard to paralleling them with each other and with shore power?
19. When connecting casualty power cables, always make the connection at the load first. Why?
20. How do you reverse the phase rotation in a three-phase circuit?
21. Why should switchboards and distribution system equipments be operated as if no automatic protective devices were installed?
22. (a) What are the three power supplies from the forward I.C. switchboard called and (b) from where does each come?
23. (a) How is the I.C. transformer bank connected? (b) Why?
24. What two types of circuits are supplied by the I.C. switchboard when it is supplied by casualty power?
25. When performing preventive maintenance on a circuit, how many circuit breakers or switches must be opened and tagged?
26. If more than one party is working on a circuit, how many tags will be placed on the switches?
27. Numerous failures of electrical equipment have been caused by loose electrical connections or mechanical fastenings. How could these failures have been prevented?
28. When methyl chloroform is exposed to an open flame, what type of gas does it give off?
29. Loud humming or chattering of a circuit breaker could indicate what condition?

# CHAPTER 7

# MAINTENANCE OF MOTORS AND GENERATORS

## Introduction

This chapter describes the proper procedures for the maintenance of motors and generators. Additional information on this subject is contained in Chapter 60 of the *Bureau of Ships Manual.*

Proper maintenance is equally as important as proper installation and operation in ensuring long, satisfactory service of electric motors and generators. The I.C. Electrician should remember that the most important factor in the maintenance of electric motors and generators is to keep the equipment clean and free of oil, water, dirt, and other foreign particles. Oil vapor, metallic dust, and moisture are present in the air inside a ship. These elements are especially prevalent in the air of machinery spaces where major electric motors and generators are located. All machines require ventilation to dissipate the heat generated by their operation, and, since most motors and generators utilize the air within the compartments in which they are located for this purpose, it is apparent that a considerable amount of these destructive elements will accumulate on, and inside, these machines within a relatively short time. Motors and generators must be cleaned frequently, both internally and externally, and particular care must be taken to keep all air ducts clean.

## Motor-Generator Set

The motor-generator set furnished as part of the shipboard dial telephone system is a direct-connected motor-generator which consists of a driving motor and a diverter-pole generator mounted as a single unit. The motor is designed to operate from a 440-v, 3-phase, 60-cycle a-c input, and the generator to deliver 50 amperes at 56 v.

The motor rotor and the generator armature are on a common shaft, which rotates in ball-bearing mountings. With the set placed as shown in figure 7-1, the rotor is at the left-hand end of the shaft and the generator armature and commutator are at the right-hand end. As viewed from the commutator end of the generator, the direction of rotation is clockwise. The direction of rotation is indicated on the machine frame by an arrow. The unit is housed in a drip-proof case made of sheet steel and copper screen, and the case is fitted with a removable cover on its right (with respect to the box side of the set) end. With the cover removed, the commutator and brushes are accessible. The set is foot mounted and is arranged to bolt through the feet to the deck. Figure 7-1 is a side view of the motor-generator set as it is when it comes from the factory and before it has been bolted to the deck.

Four carbon brushes ride on the generator commutator. The brush holders are brass, and are designed to incline the brushes to the commutator at the angle which best minimizes friction. The correct position of the brush holders is indicated by a white mark on the support and frame. A spring associated with the brush is designed to maintain the brush face in the same plane at the same pressure, regardless of brush length. Each brush is provided with a flexible copper lead.

Mounted inside the terminal box at the right-hand end in an enclosed compartment is

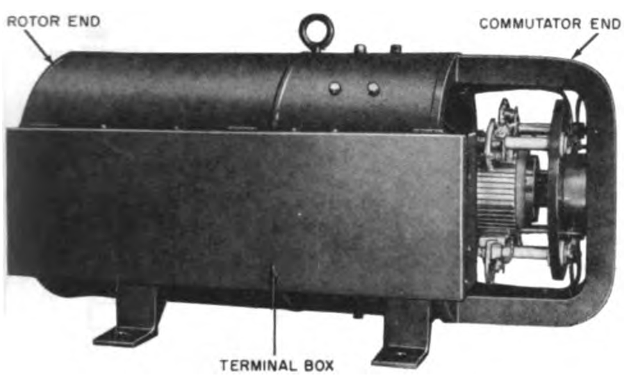



Figure 7-1.—Motor-generator set, side view.

an adjustable resistor shunt which is in multiple with the series field winding. The resistor shunt is factory-adjusted to provide the proper regulation of diverter field flux.

The generator field rheostat, which regulates the level of the generator output voltage, is mounted on the power control panel. The purpose of the motor-generator set is to convert ship's supply a-c into d-c suitable for the use in the dial telephone system. The generator furnishes current for: (1) operation of the automatic and manual switchboards, and (2) charging the 24-cell battery. The battery is the standby and overload source of power for the dial telephone system.

The starting switch, which is mounted on the forward I.C. (Interior Communication) switchboard, is a 30-amp, 500-v, a-c, triple-pole, rotary snap switch labeled, "Dial Telephone."

The motor is the squirrel-cage induction type. The motor leads are stud-terminated, and are brought out to a conduit terminal box located on the left-hand side (as viewed facing the commutator end of the generator). The input conductors are carried in conduit to the terminal box where they connect to the stud-terminated motor leads. With an input of 440-v, 3-phase, 60-cycle a-c, the motor is designed to drive the generator continuously at 1800 rpm.

## CONSTANT VOLTAGE

The d-c generator used in a telephone system must be so designed that regardless of variation in current demand, the generator will deliver current at a constant voltage. The time interval between zero and peak load may be only a matter of seconds and the generator, therefore, must be of a type that can compensate for load fluctuation almost instantly. The diverter-pole type of circuit (fig. 7-2) provides such compensation, and the field rheostat can be adjusted so that the generator will deliver current at approximately 51.6 volts regardless of load fluctuation.

The diverter-pole type field winding includes four main poles, which are shunt wound (connected across the generator circuit). Associated with each main pole is an interpole (the diverter pole), which is series wound (the armature coil and interpole are in series with the load). The main pole and associated diverter pole are connected by a magnetic bridge, which includes a restricted section. The restricted section performs two functions: (1) it limits leakage of magnetic flux from the main pole to the diverter pole, and (2) it serves as a magnetic choke to regulate the magnetic flux passing to the armature from the inner face of the diverter pole.

The magnetic field at no-load is shown in figure 7-3. Part of the magnetic flux resulting from current in the shunt winding on the main pole is diverted through the diverter pole via the magnetic bridge. This diverted flux is shown in dotted line in figure 7-3A. Since there is no load, the series winding on the diverter pole has no magnetomotive force.

As the load on the generator increases, the flow of current through the series winding on the diverter pole increases, and increases the magnetomotive force of the diverter pole winding. The shunt winding on the main pole and the series winding on the diverter pole are in opposition, and therefore as the load on the generator increases, the flux produced by the diverter pole winding offers increasing opposition in the magnetic bridge to the flux from the main pole winding. With the magnetic bridge path blocked, a greater proportion of the flux from the main pole is diverted to the armature. Therefore as the load increases, the armature cuts an increasingly greater number of lines of force, and the level of the generated voltage rises accordingly, thereby overcoming the IR and cross-magnetization losses to hold the voltage at a constant level. Figure 7-3B, indicates increasing flux from the diverter pole winding. Note that there are fewer lines of force (dotted lines) from the main pole winding through the magnetic bridge and diverter pole, and that increasing lines of force (unbroken

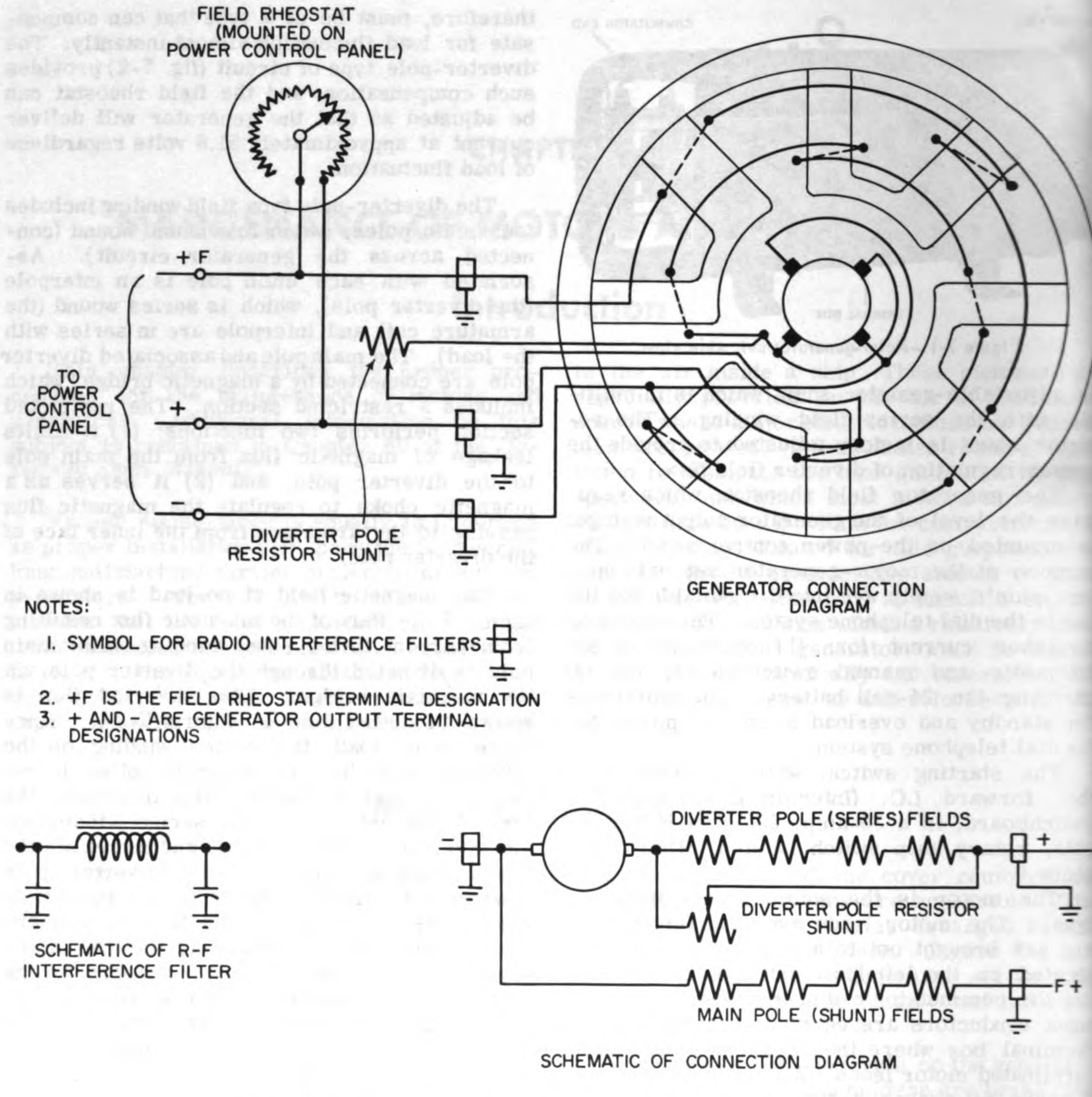



Figure 7-2.—Connection diagram for generator of motor-generator set.

lines) are being diverted into the armature path.

At full load, flux from the diverter pole winding almost entirely blocks the passage of flux from the main pole through the magnetic bridge and therefore practically all of the flux from the main pole winding is diverted into the armature path (fig. 7-3C). Thus, the level of voltage generated is raised sufficiently to compensate for internal losses, and the output voltage thereby is maintained at a constant level.

At some value of load current above 100 percent, the ampere turns on the diverter pole

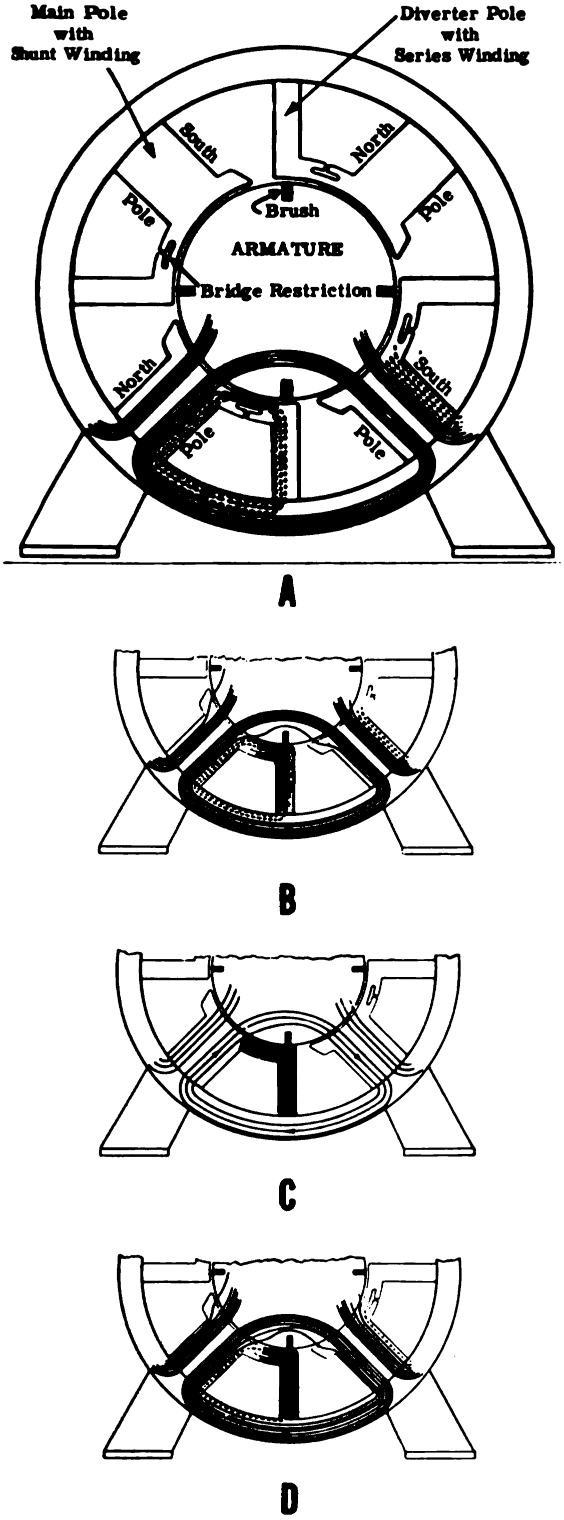



Figure 7-3.—Partial pictorial schematic diverter-pole type field.

will equal those on the main pole. At this point, flux from the diverter pole winding will completely block the magnetic bridge, and all main-pole flux will be diverted into the armature path. When load is increased, but before it becomes dangerous, diverter pole magnetomotive force becomes strong enough to block the passage of main-pole flux to the armature. This condition is indicated in figure 7-3D, by the decrease in lines of force in the armature path. With the armature cutting fewer lines of force, generator voltage drops under an overload condition, thereby protecting the generator against excessive current.

The power supply for the shipboard dial telephone system is the motor-generator set and a 24-cell battery, connected in parallel, as shown in figure 7-4. Any current demand up to the capacity of the generator will be drawn from the generator; any demand beyond the capacity of the generator will be supplied directly from the battery. The power-supply control and alarm circuits are on the power control panel.

The control apparatus and meters associated with the power equipment (battery and motor-generator set) are mounted on the control panel (fig. 7-5). The assemblies include an ammeter for measuring the current being drawn from the battery, an ammeter for measuring the current being delivered by the generator, a voltmeter for determining the voltage of the battery or of the generator, a switch associated with the voltmeter, two switches associated with the generator, a rheostat for regulating the output voltage of the generator, a reverse-current relay for cutting the generator into and out of the power-supply circuit, fuses, parts, and assemblies that make up the alarm circuits.

The 110-120-v, a-c, single-phase alarm supply is obtained through a switch on the forward I.C. switchboard. This switch is a 10-amp, 120-v, a-c, rotary snap switch labeled, "Dial Telephone Alarm."

The starting switch for the motor-generator set is the supply switch for circuit "J" on the forward main I.C. switchboard. (Note that the starting switch is not mounted on the power control panel with the rest of the switches and meters associated with the set.)

# Adjustments and Tests

## POLARITY

Before cutting the generator into service, check the polarity of the generator with a d-c voltmeter. Proceed as follows:

(a) Move the starting switch (on the I.C. switchboard) to the ON position, to start the machine.

(b) At the motor-generator set, use a d-c voltmeter to check polarity at the "+" and "-" generator terminals. (These terminals are located in the right-hand (generator) section of the input-output compartment.) If the polarity at the generator terminals is not in accordance with the markings, proceed as described in the paragraph below.

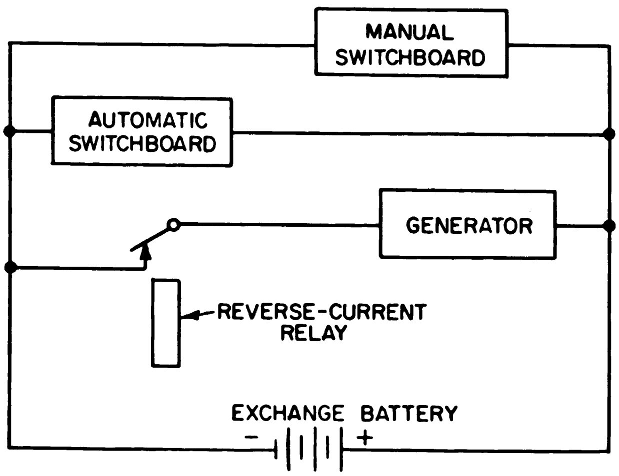



Figure 7-4.—Shipboard dial telephone system power supply arrangement, block diagram.

## POLARITY CHANGE

If the polarity of the generator voltage is not the same as the marking at the generator terminals, proceed as follows:

(a) Trace the conductors outgoing from the "+" and "-" generator terminals to the power control panel, and check the connections there. These conductors should connect at the Switchboard Battery terminal block to the terminals designated respectively + Gen and - Gen.

(b) If it is found that connections were improperly made, reverse them so that the conductor outgoing from the "+" terminal at the generator connects to the + Gen terminal at the power control panel, and the "-" conductor connects to the -Gen terminal.

(c) Recheck polarity at the generator "+" and "-" terminals, as described in (b) above.

(d) If the polarity at the generator terminals is still not in accordance with the markings, move the motor-generator starting switch (at the I.C. switchboard) to the OFF position, to stop the generator.

(e) At the motor-generator set, lift (or insulate) all brushes from the face of the generator commutator so that the electrical circuit between the brushes and the commutator will be broken. To reach the brushes and commutator, remove the cover on the right (with respect to the terminal box side) end. The cover is held in place by four thumbscrews. Remove the screws, and draw the cover off.

(f) At the power control panel, open the panel.

(g) With a small piece of wood or other insulator, close the main contactor on the reverse-current relay by hand for about 10 seconds.

(h) With the main contactor closed, current from the battery will flow into the generator fields, and thus magnetism will be induced in the right direction in the poles.

(i) At the motor-generator set, replace the brushes (or remove the insulation) and check that the brushes seat properly on the commutator.

(j) At the I.C. switchboard, operate the starting switch to the "on" position.

(k) At the motor-generator set, again check with the d-c voltmeter the polarity at the generator terminals. The voltage should be in accordance with the terminal markings.

(l) The generator now is ready to be placed in service.

In addition to checking the motor-generator set performance by means of readings taken from the meters on the power control panel, the set may be disconnected and cut back into service, to observe performance. Another indication that the power equipment is in good operating condition is successful completion of a test of the alarm apparatus.

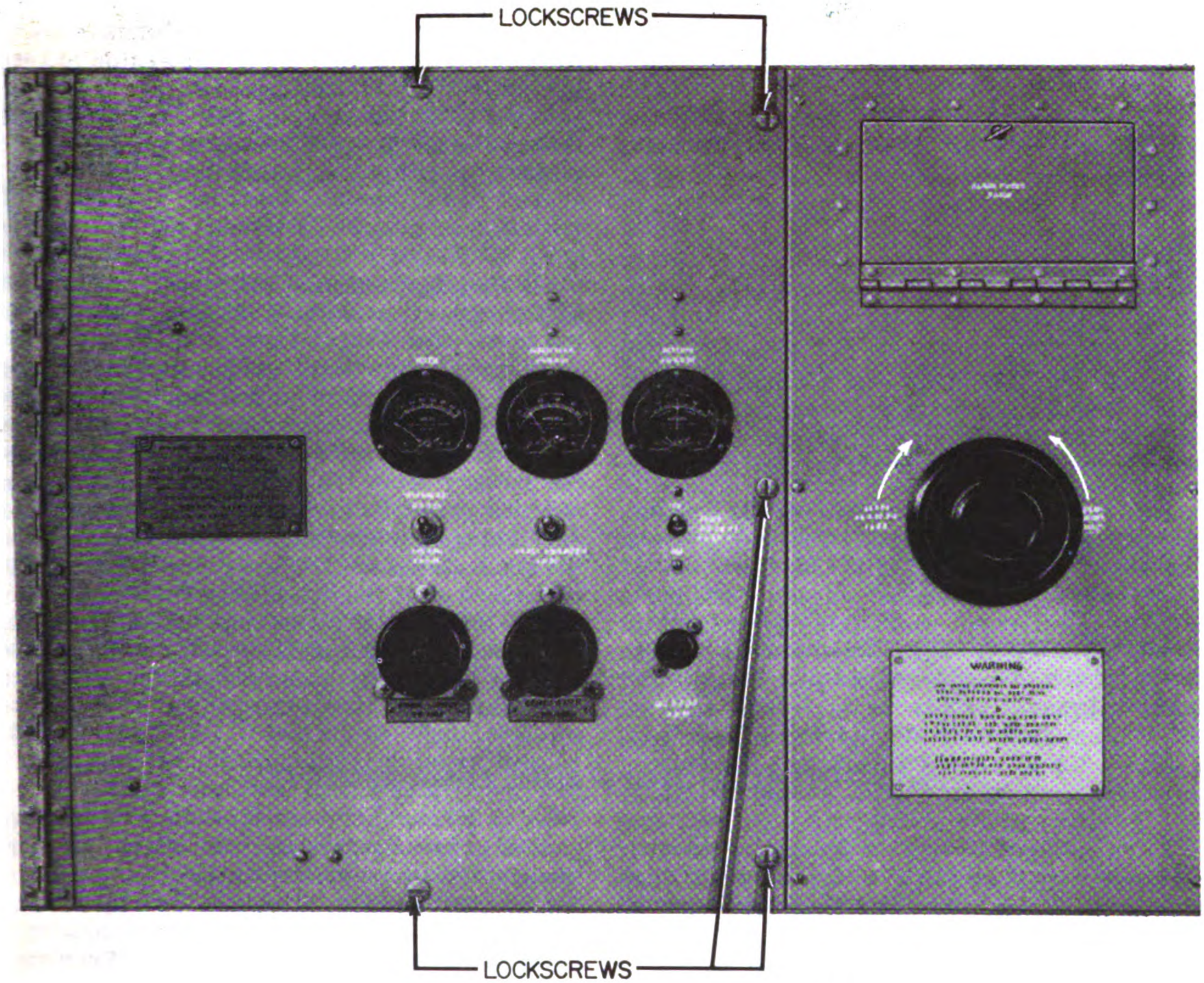



Figure 7-5.—Power control panel, front view.

## STARTING

The procedure for starting the motor-generator set is described in the following paragraphs. The starting switch is the supply switch for the dial telephone system on the I.C. switchboard, and the other switches and the meters referred to are mounted on the power control panel.

(a) Operate the motor-generator set starting switch (on the I.C. switchboard).

(b) Resistance in the motor-generator field circuit is controlled by the rheostat wheel mounted on the control panel. Turn the wheel in the lower generator volts direction as far as it will go to cut maximum resistance into the field circuit.

(c) Operate the Motor-Gen Output-1 switch to the On position.

(d) Operate the Generator Voltage Battery Voltage switch to Battery Voltage, and read the battery voltage on the voltmeter.

(e) Operate the Generator Voltage Battery Voltage switch to Generator Voltage.

(f) Turn the rheostat in the raise generator volts direction until the voltmeter reading shows the generator voltage to be approximately the same as the voltage noted for the battery.

(g) Operate the Motor-Gen Output-2 switch momentarily.

(h) Carefully adjust the rheostat until the generator voltage (as shown on the voltmeter) is 51.6 v.

(i) Until the generator reaches normal operating temperature (in approximately 2 hours), periodically check the reading of the voltmeter to determine the voltage the generator is delivering. If the generator voltage deviates from 51.6 v, adjust the rheostat in such direction that the generator voltage is maintained at 51.6 v. After the generator has reached normal operating temperature, normally the rheostat setting requires no further attention.

CAUTION: The switchboard voltage (reading on voltmeter with voltmeter switch at Battery Voltage) after generator is cut in, never should be allowed to exceed 56 v.

RECOMMENDATION: The motor-generator never should be stopped except for routine maintenance.

### STOPPING

(a) Operate the Motor-Gen Output-1 switch to OFF. Turn off the motor-generator starting switch (on the I.C. switchboard).

CAUTION: Always operate the Motor-Gen Output-1 switch to OFF before turning off the motor-generator starting switch.

### CUT OUT

If for any reason it is desired to cut out the motor-generator without stopping it, operate the Motor-Gen Output 1 switch to Off.

If the voltage level of the generator output drops below 48, after there has been a flow of 10 amperes from the battery to the generator, the reverse-current relay restores to disconnect the battery from the generator, and to disconnect the generator leads from the reverse-current relay operating (shunt) coil. To reconnect the generator leads to the reverse-current relay shunt coil after the voltage level of the generator output reaches 48 volts, momentarily operate the Motor-Gen Output-2 switch. The reverse-current relay will operate again to connect the generator to the battery.

## Cleaning Motors and Generators

The four acceptable methods of cleaning motors and generators are wiping, use of suction, use of compressed air, and use of a solvent.

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

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

Compressed air must be clean and dry when used for cleaning electrical equipment. Air pressure up to 30 pounds per square inch may be used on motors or generators of 50 hp or 50 kw respectively, or less. Pressures up to 75 psi may be used to blow out machines that are over 50 hp or 50 kw. A throttling valve should be used on air lines that carry higher pressure than is suitable for blowing out a machine. Before the air blast is turned on the machine, any accumulation of water in the air pipe or hose must be thoroughly blown out, and both ends of the machine must be opened to allow a path of escape for the air and dust.

The use of solvents for cleaning electrical equipment should be avoided whenever possible. However, their use is necessary for removing grease and pasty substances consisting of oil and carbon or dirt. Alcohol will injure most types of insulating varnishes and should not be used for cleaning electrical equipment. Solvents containing highly volatile gasoline or benzine must not be used on board ship for cleaning purposes under any circumstances.

# General Maintenance

When performing any operation on electric motors or generators that produces dust, grit, or shavings, use every precaution to protect all windings and vent spaces from foreign particles. Stationary coils should be protected by a guard, and the armature should be fitted with a canvas, bound on the commutator and armature surfaces in a manner to prevent the entry of dust, grit, etc., into the interior of the machine. Vent spaces under the commutator should be stuffed with rags. After the work is completed, all exposed surfaces must be cleaned and the rags, guard, etc., removed.

Small pieces of iron, bolts, and tools must be kept away from running motors and generators. During soldering operations, do not allow drops of solder to get into the windings. Excess solder, which may later break off should be removed from the soldered joints. Bolts and mechanical fastenings on both the stationary and rotating members should be checked at regular intervals to make sure that they are tight. However, commutator clamping bolts on d-c machines must not be disturbed, because any interference with them may result in misalignment of the segments and make it necessary to turn or grind the commutator to restore it to service. When an inspection of a rotor reveals loose keys or other fastenings, a further check should be made for evidence of damage due to such looseness.

When a generator is to be inoperative for an appreciable length of time, such as may be necessary for an overhaul of the prime mover, the brushes should be lifted from the collector rings or commutator to prevent an electrolytic action between the brushes and rings or segments. The collector rings and commutator may be covered with grade A paper to prevent corrosion.

At frequent intervals, all electrical connections should be inspected to make sure they are tight. Locknuts, lockwashers, or other similar means should be used to lock connections, which tend to become loose because of vibrations. When electrical connections are opened, all oil and dirt should be cleaned from the contact surfaces before they are reconnected. Contact surfaces of uncoated copper should be sandpapered and cleaned immediately before joining. However, sandpaper must not be used on contact surfaces that are silver plated. They should be cleaned with silver polish. Steel bolts and nuts that are used for making electrical connections should be zinc or cadmium plated. Make certain that exposed electrical connections are adequately insulated to protect against moisture, and injury to personnel.

When it becomes necessary to disassemble and reassemble a motor or generator, the I.C. should follow the procedure outlined in the manufacturer's instruction book, exercising care to prevent damage to any part of the machine. The machine rotors (a-c revolving field or d-c armature) should be supported, while being moved or when stationary, by slings or blocking under the shaft or by a padded cradle or thickly folded canvas under the core laminations. To lift the rotor, rope slings (separated by a spreader to prevent the slings coming in contact with the a-c rotor or d-c armature coils) should be placed under the shaft, clear of the journals. If construction of the shaft provides no room for a sling except around the journals, they must be protected with heavy paper or canvas before applying the sling. When the whole unit (stator and rotor) is to be lifted by lifting the stator, the bottom of the air gap must be tightly shimmed unless both ends of the shaft are supported in bearings. It is easily possible, by rough handling or careless use of bars or hooks, to do more damage to a machine during disassembly and assembly than it will receive in years of normal service.

Excessive vibration in electric motors and generators may be caused by an unbalanced rotating part (d-c armature, a-c revolving field, cooling fan, etc.). Therefore, when it is necessary to repair a rotating part in such a manner as to remove or add weight at any point around its periphery, the part must be tested for balance. An unbalanced condition can be corrected by dynamically balancing the part. In dynamic balancing, the test for unbalance is made, with the part turning at normal speed, by determining the exact lengthwise location where whip is maximum, and by spotting the exact radial point at which excessive weight appears. Balancing is effected by removing weight at this point or by the addition of counterweight at a point directly opposite the point of excessive weight. Dynamic balancing requires special equipment operated by specially trained personnel. Repair ships and shipyards are equipped to perform this task.

# Commutators and Collector Rings

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

## CLEANING

One of the most effective ways of cleaning the commutator 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 stick between one-fourth and three-eighths inch thick (fig. 7-6). The canvas may be secured with rivets if they, in turn, are covered with linen tape to prevent the possibility of their contacting the commutator. When the outer layer of canvas becomes worn or dirty, it is removed to expose a clean layer. The wiper is most effective when used frequently. On ship's service generators, it may be desirable to use the wiper once each watch. When using the wiper, exercise care to keep from fouling moving parts of the machine. The manner of applying the wiper to a commutator is illustrated in figure 7-7.

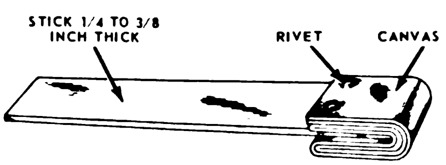



Figure 7-6.—Canvas wiper.

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

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

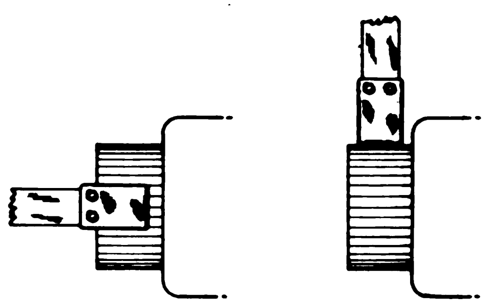


Figure 7-7.—Using the canvas wiper on a commuter.

## CARE OF COMMUTATORS

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

For handstoning, the machine should be running at, or only slightly below, rated speed. For motors, remove all except enough brushes to keep the armature turning at the proper speed. The stone to be used should fit the curvature of the commutator and have a surface substantially larger than the largest flat spot to be removed. Hold the stone in the hand and move it very slowly back and forth, parallel to the axis of the commutator, applying only enough pressure to keep the stone cutting (fig. 7-8). Crowding the stone will roughen the surface. Care must be exercised to avoid electric shock and to prevent jamming the stone between fixed and moving parts of the machine.

Either a nonrotating or a revolving stone can be used when grinding the commutator with a rigidly supported stone (fig. 7-9). Irrespective of which stone is used or whether the grinding is done with the commutator within the machine or in a lathe, extreme care must be taken to align the supports so that the motion of the stone is accurately parallel to the axis of the commutator. Failure to properly align the supports will taper the commutator, and failure to maintain the support rigid will cause the stone to dig into the commutator.

For turning, the armature should be supported in a lathe (fig. 7-10). A cutting tool that is rounded sufficiently so that the cuts will overlap must be used to make the cut. Proper cutting speed is about 100 fpm with the feed about 0.010 in. per revolution. Depth of the cut should not exceed 0.010 in.

The windings of the machine must be adequately protected from grit during stoning and

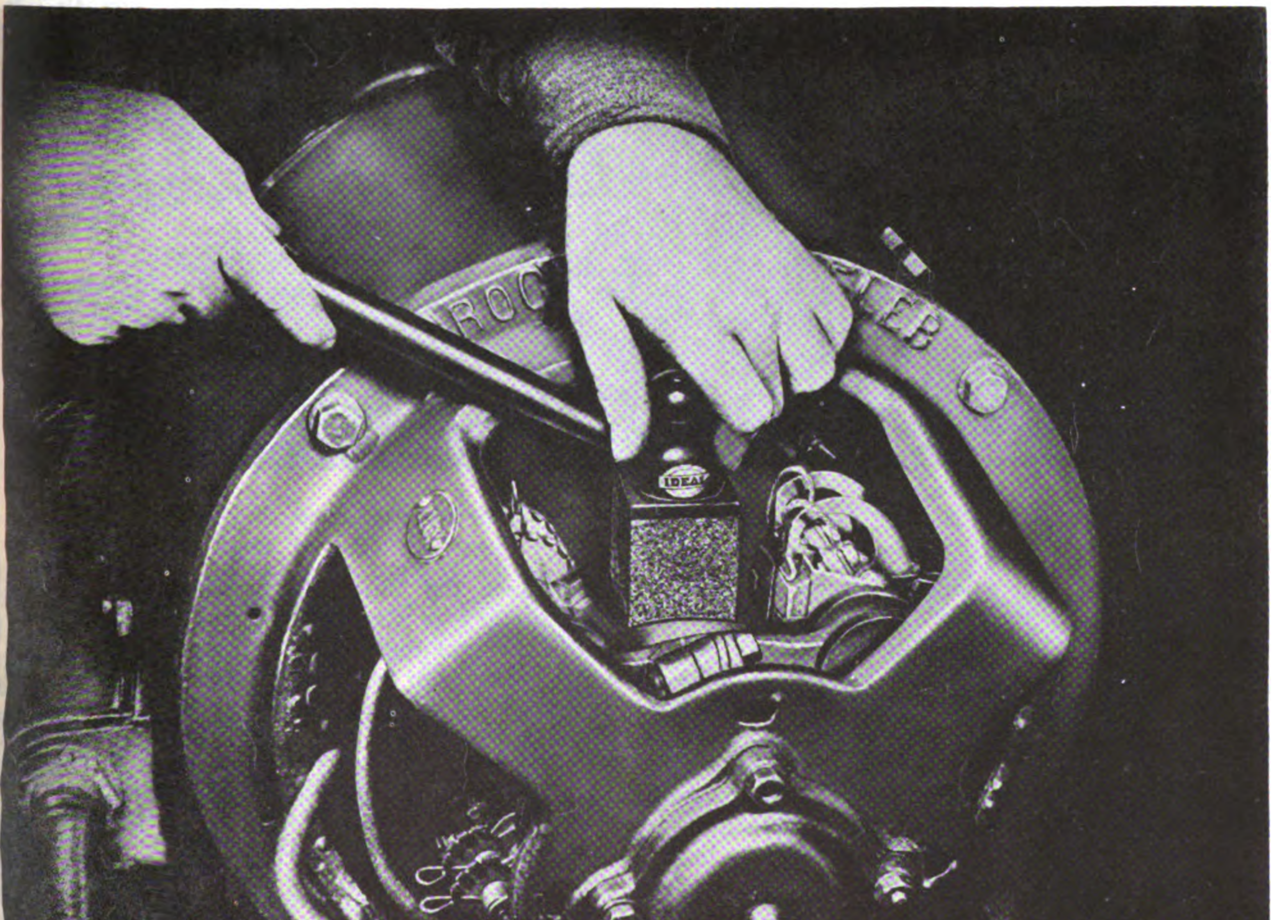


Figure 7-8.—Handstoning the commuter.

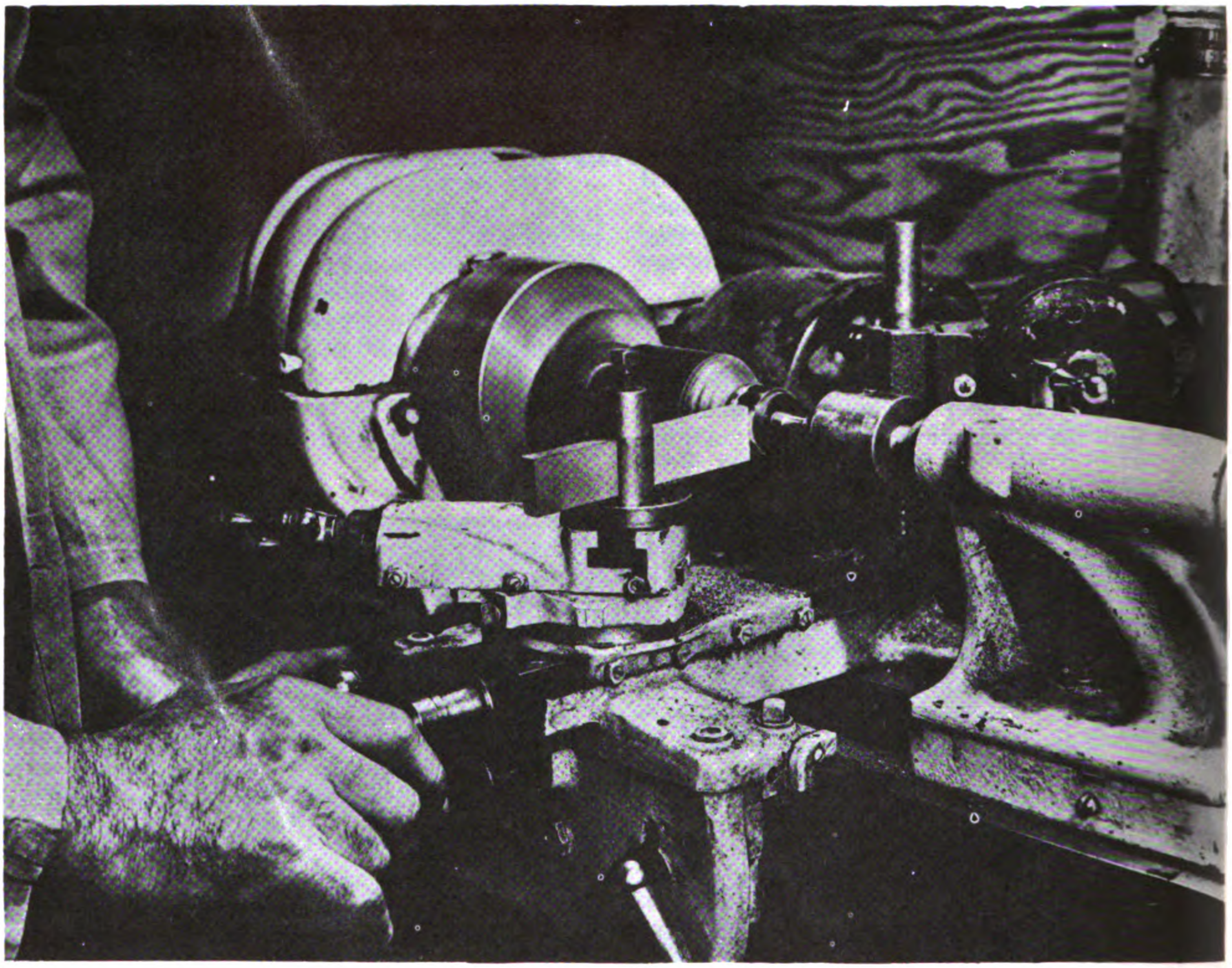


Figure 7-9.—Grinding the commuter with a rigidly supported stone.

grinding operations conducted with the commutator in the machine. Afterwards, the brushes, brush holders, and commutator must be thoroughly cleaned, and a complete insulation test should be made to determine that no grounds or short circuits exist. After the truing-up operation has been completed, regardless of the method used, always finish with a fine grade of sandpaper, undercut the mica to a depth no greater than one-sixteenth inch, and slightly bevel the edges of the commutator bars.

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

Commutator mica that has become carbonized loses its insulating value. It should be scraped out and replaced with sodium silicate or other insulating cement. Poor commutation will develop if the commutator bars are worn down to, or below, the level of the mica. The mica should be undercut to a depth of between three sixty-fourths inch and one-sixteenth inch below the level of the commutator bars. A small

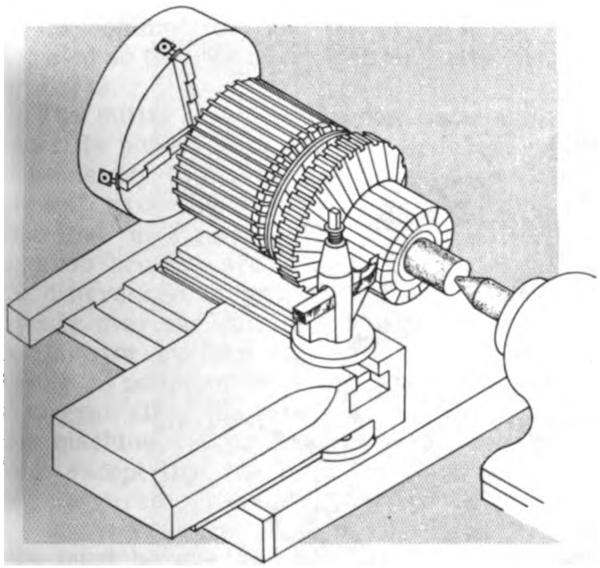


Figure 7-10.—Truing the commuter by turning.

motor-driven, circular saw especially designed for this purpose, a slotting file having an angle of 60° between faces, or a hacksaw blade that has been ground to the right thickness and fitted to a handle may be used for undercutting mica. Before using the motor-driven circular saw, install a canvas cover around the armature in a manner to prevent copper dust from becoming embedded in the armature windings. When undercutting has been completed, the edges of the bars should be beveled to a depth about one thirty-second inch below the surface. Finally, all mica, copper dust, and other foreign materials must be cleaned from the slots and commutator.

### CARE OF COLLECTOR RINGS

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

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

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

## Brushes

The brushes used in electric motors and generators are one or more plates of carbon bearing against a commutator, or collector ring (slip ring) to provide a passage for electrical current for an external circuit. The brushes are held in position by brush holders mounted on studs or brackets attached to the brush-mounting ring, or yoke. The brush-holder studs or brackets, and brush-mounting ring comprise the brush rigging. The brush rigging is insulated from, but attached to, the frame of the machine. Flexible leads (pigtails) are used to connect the brushes to the terminals of the external circuit. An adjustable spring is provided to maintain proper pressure of the brush on the commutator in order to effect good commutation. A d-c generator brush holder and brush-rigging assembly are shown in figure 7-11.

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

### CARE

If the correct grade of brushes is used, and the brushes are correctly adjusted and cared for, good commutation will result. Periodic inspections of the brushes and brush rigging are

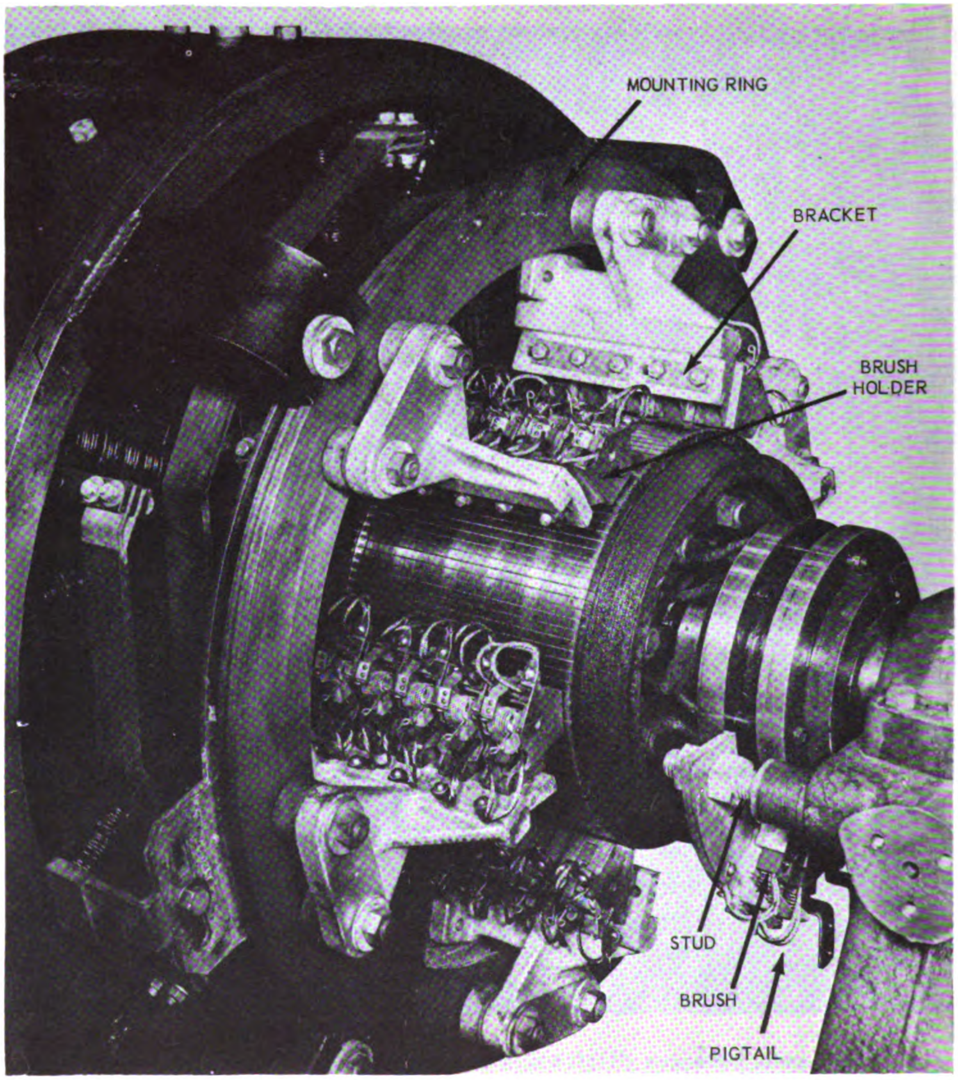



Figure 7-11.—Brush holder and brush-rigging assembly.

required to ascertain their condition. The brush pigtails must be securely connected at the brushes and terminals. Brushes should move freely in the holders, but must not be loose enough to vibrate. They should be replaced when they are worn down to half their original length or if chipping has occurred at the corners or edges of the brush.

CAUTION: Brushes that have grease and oil on them must be replaced. They cannot be cleaned because a cleaning solvent will not remove all of the oil or grease but will change the electrical characteristics of the carbon.

The brush holders and brush rigging should be cleaned before inserting the new brushes. The brush holders should be mounted so that the edges nearest the commutator are the same distance from the commutator (not more than one-eighth inch, nor less than one-sixteenth inch. The leading edges (toes) of all the brushes on each stud must be in alignment with each other and one commutator segment.

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

The pitting effect on the commutator differs under the positive and negative brushes, making it necessary to stagger the brushes in order to prevent grooving of the commutator, as illustrated in figure 7-12. The positive and negative brushes are staggered in pairs so that the differences in pitting effect are distributed equally over the full brush-contact area of the commutator surface (fig. 7-12A). In a machine having an odd number of pairs, it is impossible to stagger all of the brushes in this manner. In this machine, the brushes are staggered as before; except that the brushes of the odd pairs are staggered separately (fig. 7-12B).

As the brushes wear, the brush spring tension must be changed to keep the brush pressure approximately constant. On some machines the design of the brush holder and spring allow for changing the brush-spring setting. Unless it is stated otherwise in the instruction book for the machine, the proper brush pressure should be between 1-1/2 to 2 psi of brush-contact area. The brush pressure is easily measured. Attach a small spring balance to the pigtail end of the brush, insert one end of a strip of paper between the brush and the commutator, then exert a pull on the spring balance in the direction of the brush-holder axis (fig. 7-13). Note the reading of the spring balance when the pull is barely sufficient to release the paper so that it can be pulled from between the brush and commutator without offering resistance. Then divide this reading by the contact area of the brush to obtain the brush pressure.

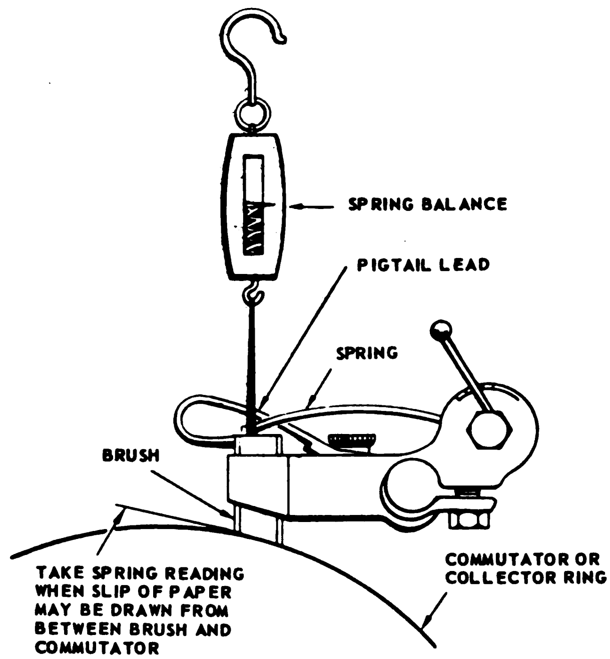



Figure 7-13.—Measuring brush tension.

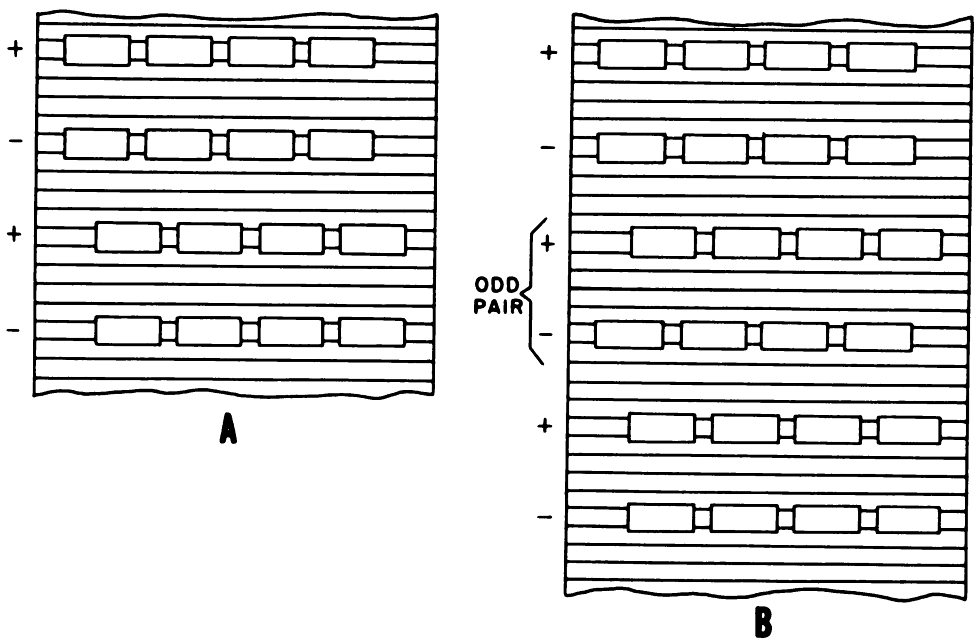



Figure 7-12.—Method of staggering brushes.

## SETTING ON NEUTRAL

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

Two methods of finding the neutral position are the mechanical and reversed rotation. In the mechanical method, the commutator is turned until the two coil sides of the same armature coil are equidistant from the centerline of one main-field pole. The position of the commutator bars to which the coil is connected will indicate the approximate mechanical neutral.

Use of the reversed rotation method is possible only where it is practicable to run a machine in either direction of rotation, with rated load applied. This method differs for motors and generators. For motors, the speed of the motor is, at first, accurately measured when the field current becomes constant under full load at line voltage with the motor running in the normal direction. Then, the rotation of the motor is reversed, full load is applied, and the speed is again measured. When the brushes are shifted so that the speed of the motor is the same in both directions, the brushes will be in the neutral position. Generators are run at the same field strength and same speed in both directions, and the brushes are shifted until the full-load terminal voltage is the same for both directions of rotation. To ensure accuracy, a reliable tachometer must be used to measure the speed of the machine for this method.

## FITTING

An accurate fit of the brushes must be assured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools to accomplish a true fit.

All power must be disconnected from the machine, and every precaution must be taken to ensure that the machine will not be inadvertently started before using sandpaper to seat the brushes. The brushes to be fitted are lifted, and a strip of fine sandpaper (No. 1) approximately the width of the commutator is inserted (sand side up) between the brushes and the commutator. With the sandpaper held tightly against the commutator surface to conform with the curvature and the brushes held down by normal spring pressure, the sandpaper is pulled in the direction of normal rotation of the machine (fig. 7-14). When returning the sandpaper for another pull, the brushes must be lifted. This operation is repeated until the fit of the brush is accurate. Always finish with a finer grade of sandpaper, No. 0. A vacuum is required for removing dust while sanding. After sanding, the commutator and windings must be thoroughly cleaned to remove all carbon dust.

The brush seater is compounded of a mildly abrasive material loosely bonded, and is formed in the shape of a stick about 5 in. in length. The brush seater is applied to the commutator while the machine is running, and every precaution should be taken to prevent injury to the person applying it. The brush seater is touched lightly, for a second or two, exactly at the heel of each brush (fig. 7-15). If placed even one-fourth inch away from the heel, only a small part of the abrasive will pass under the brush. Pressure may be applied to the brush by setting the brush spring tension at maximum or by pressing a stick of insulating material against the brush. The dust is removed during the operation, and the machine is thoroughly cleaned afterwards in the same manner as for sanding brushes.

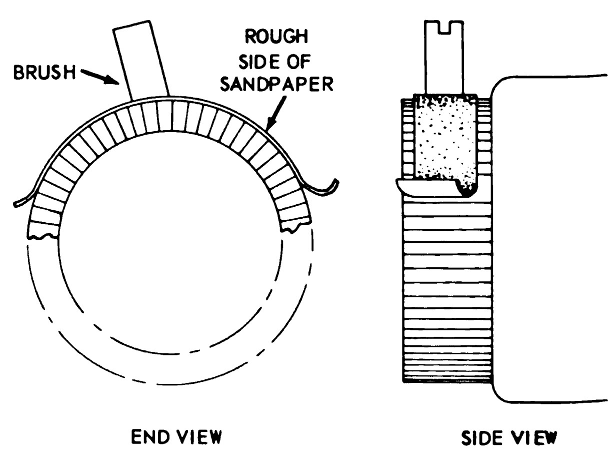



Figure 7-14.—Method of sanding brushes.

# Bearings

Bearings are of two types: SLIDING and )LLING. The three types of sliding bearings e the: right line bearing, in which the motion parallel to the elements of the sliding surce; journal bearing, in which two machine rts rotate relatively to each other; and thrust arings, in which any force acting in the direcn of the shaft axis is taken up. The type of ding bearing employed in electric motors and nerators is the journal bearing commonly lled the SLEEVE bearing. These bearings are ed in large equipment, such as turbine-driven ip's service generators and propulsion genators and motors. The bearings may be made bronze, babbitt, or steel-backed babbitt.

Preventive maintenance of sleeve bearings quires periodic inspections of bearing wear, d lubrication.

Some generators and motors equipped with eeve bearings are also provided with a gage r measuring bearing wear. Bearing wear on eeve-bearing machinery not provided with a earing gage can be obtained by measuring the ir gap.

Air gaps should be measured at each end of e machine and can be measured with an air-gap eeler (a machinist's tapered feeler gage) of ufficient length to reach into the air gap withut removing the end brackets of the machine.

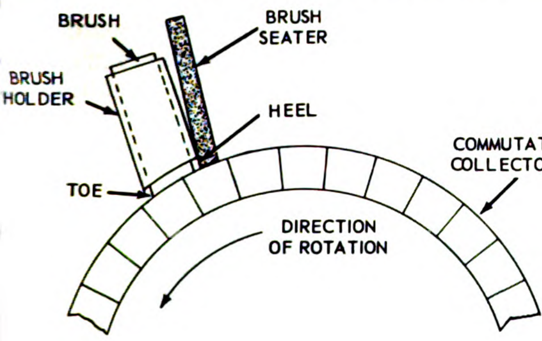



Figure 7-15.—Using the brush seater.

## BALL BEARINGS

Rolling, antifriction bearings are of two types: ball and roller bearings. Basically, all rolling bearings consist of two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped, ball bearing is the type of rolling bearing used most extensively in the construction of electric motors and generators used in the Navy. This bearing is further divided into three types dependent upon the load it is designed to bear—(1) radial, (2) angular contact, and (3) thrust. Examples of these three bearings are shown in figure 7-16.

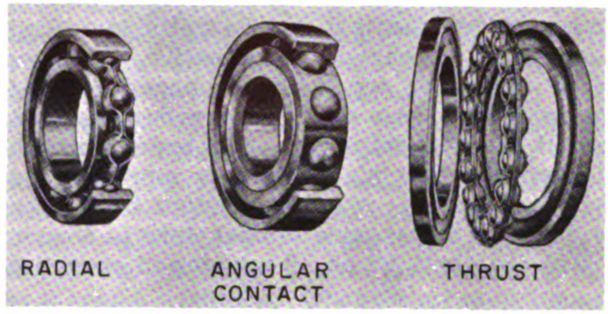



Figure 7-16.—Typical ball bearings.

The rotating element of an electric motor or generator may subject a ball bearing to any one or a combination of three loads—radial, thrust, and angular. Radial loads are the result of forces applied to the bearing perpendicular to the shaft; thrust loads are the result of forces applied to the bearing parallel to the shaft; and angular loads are the result of a combination of radial and thrust loads. Because the load carried by the bearings in electric motors and generators is almost entirely due to the weight of the rotating element, it is apparent that the method of mounting the unit is a major factor in determining the type of bearing employed in its construction. In a vertically mounted unit, the thrust bearing would be used; while the radial bearing is common to most horizontal units.

The preventive maintenance of ball bearings requires periodic checks of bearing wear, and adequate lubrication.

### WEAR

Measuring air gaps to determine bearing wear is not necessary on machines equipped with ball bearings because the construction of the machine is such as to ensure bearing alignment. Ball bearing wear of sufficient magnitude as to be readily detected by air-gap measurements would be more than enough to cause unsatisfactory operation of the machine.

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

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

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

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

The one sure method of checking ball bearing wear is also the most difficult. In this test, the bearing caps or other covers provided are removed and the actual condition of the bearing is observed. Each ball bearing should be inspected in this manner at least every two years. The condition of the lubricant in the bearing may be checked at this time; however, no attempt must be made to disassemble double-shielded or sealed-for-life bearings.

## LUBRICATION

Some electric motors and generators are equipped with permanently lubricated ball bearings, which are lubricated by the manufacturer and require no additional lubrication throughout their life. Equipment furnished with this type bearing is not provided with grease fittings or any provision for attaching grease fittings. Nameplates reading DO NOT LUBRICATE should be attached to the housing of all permanently lubricated bearings. A permanently lubricated ball bearing is shown in figure 7-17. Note the absence of grease fittings on the motor. Ball bearings other than the permanently lubricated type require periodic lubrication with grease or oil. Motors and generators using grease-lubricated bearings are equipped with grease cups attached to the bearing housing to provide a means for adding grease to the bearing. Grease cups may already be installed on the equipment when it is received aboard ship or they may have been removed and replaced with pipe plugs. In the latter case, the grease cups are delivered with the onboard repair parts or special tools. The parts of a grease-lubricated ball bearing installation are shown in figure 7-18. Whenever feasible, it is recommended that grease cups be attached to electric motors and generators only when grease is being added to the bearing. However, when the grease cup is removed it must be immediately replaced with a suitable pipe plug in order to prevent the entry of foreign particles. This procedure affords a particularly effective means of preventing overgreasing of the bearing by unauthorized personnel.

The frequency with which grease must be added to ball bearings depends on the service

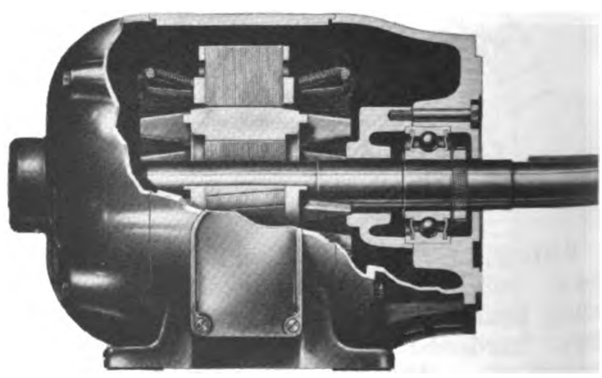


Figure 7-17.—Motor equipped with permanently lubricated ball bearings.

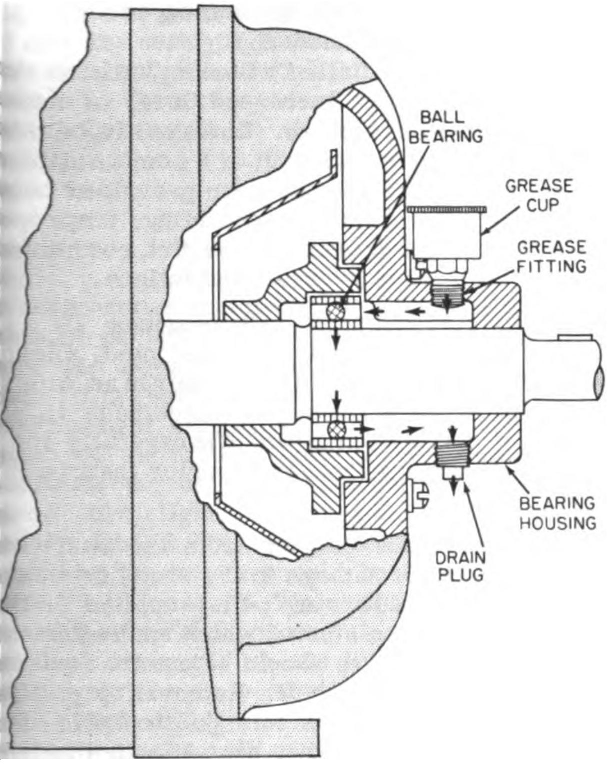



Figure 7-18.—End bell with grease cup fitting.

of the machine and the tightness of the housing seals, and is determined by the engineer officer. Usually, the addition of grease will not be necessary more often than once every 6 months. Overgreasing has been a major cause of bearing failure and must be avoided. In a bearing housing too full of lubricant, the churning of the grease generates heat, causing the grease to separate into oil and abrasive particles. The grease then becomes increasingly sticky and seals the bearing against fresh lubricant until the resulting friction, heat, and wear cause failure of the bearing.

The procedure for adding grease to a ball bearing is to first clean the outside of the grease cup, grease fitting, and drain plug. Then remove the drain plug and clear the drain by probing with a small screwdriver or similar implement. Remove and empty the grease cup, clean it thoroughly, and fill it not more than half full of the proper type grease. Empty and clean out the grease fitting down to the neck, then fill it with clean grease. Replace the grease cup and screw it down as far as it will go. This will protect the machine against overgreasing due to accidental or unauthorized turning of the grease cup if the grease fitting is not replaced with a pipe plug. Run the machine and let grease run out of the drain hole until drainage stops. This normally takes about 30 minutes. Then, replace the drain plug.

The preferred method for renewing grease is by disassembling the bearing housing. For bearings with outer bearing caps, first clean all the exterior surfaces and remove the outer bearing cap. Remove the old grease from the accessible portions of the bearing housing and clean these parts thoroughly, taking care not to allow the entry of foreign particles into the housing. Flush out the bearing cap with clean kerosene or diesel fuel oil preheated to about 120°F. Then flush out the cap with a light mineral oil no heavier than S.A.E. 10. Follow this same procedure in flushing out the bearing housing only where it is possible to positively prevent the cleaning liquids from leaking into the machine windings. When the cleaning liquids have thoroughly drained out, pack the housing half full with fresh, clean grease, and assemble the housing.

When conditions do not allow for even partial disassembly of the bearing housing, grease may be renewed without disassembling the housing if the motor is horizontal, a grease cup is provided for admitting the grease, the housing drain hole is accessible, and the machine is capable of being run continuously while renewing the grease. If all of the above provisions are met, proceed by running the machine after wiping clean all exterior surfaces. When the bearing has warmed up, remove the drain plug and drain piping and clear the drain hole of hardened grease. Remove the grease cup and clear the grease inlet. Clean the grease cup and after filling it with clean, fresh grease, screw it down as far as it will go. Keep the machine running continuously and the drain hole cleared of hardened grease. Stop adding grease when clean grease begins to emerge from the drain hole, and allow the machine to run until the drainage of grease stops. Clean and replace the drain piping and plug. During this operation, every precaution must be taken to prevent the grease from reaching the electric windings of the machine. A probable indication of excessive leakage inside the machine is the emergence of a quantity of grease around the shaft extension end of the bearing.

A grease gun should not be used to lubricate ball bearings unless there are no other means available. If used, remove the drain plug and apply just enough pressure to the gun to get the grease into the housing. Grease-gun fittings must be removed from the machine immediately after use, and replaced with a pipe plug.

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

One common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick, which also filters the oil and prevents leakage through the cup in the event momentary pressure is built up within the housing. A typical wick-fed, oil-lubricated ball bearing is shown in figure 7-19.

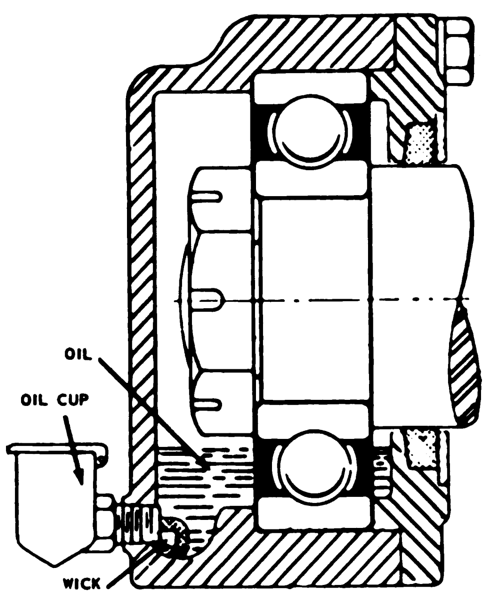



Figure 7-19.—Wick-fed ball bearing.

## CORRECTIVE MAINTENANCE

A damaged ball bearing may not necessarily be inoperative. However, if the damage continues to the extent that the bearing is no longer suitable for its intended application, it can be considered to have failed. Bearing failure may be indicated by an increased level of noise, vibration, or temperature. Damage of a bearing in service is often a result of a combination of two or more factors—the more prevalent being abuse before and during mounting, improper lubrication, wear from abrasive dirt, corrosion, passage of electric current, and fatigue.

Repair of damaged ball bearings by replacing balls should never be attempted. Cleaning ball bearings should be done only in an emergency and when a suitable replacement is not available. Even when cleaning is carefully done, more dirt may get into the bearing than is removed.

Removal of the bearing from the shaft involves the risk of damage to the shaft, or bearing, or both. A bearing puller applied to the inner race, or to a sleeve, which applies pressure to the inner race should be used to remove the bearing from the shaft. Removal by pulling on the outer race tends to make the balls dent the raceway. Care must be taken to prevent damage to the shaft when removing the bearing.

When installing bearings, use extreme care to prevent dirt or other foreign particles from entering the bearing and bearing housing. A new bearing should not be removed from its original container and wrapping until every preparation has been made to install it. If it is not possible to use a press, a drift pipe of soft steel or malleable iron may be used to mount the ball bearing on the shaft. The inside diameter of the pipe must be large enough to clear the shaft or any locknut threads, and its outer diameter must be no larger than the maximum diameter of the bearing's inner race. Mount the bearing square with the shaft; then, with the pipe fitted squarely against the inner race, lightly tap the pipe with a clean metal hammer until the inner race is seated tightly against the shaft shoulder.

The thoroughly cleaned bearing housing must be packed half full of clean, new grease and assembled. During reassembly, care must be taken not to omit bearing parts, lubricant seals, grease pipes, plugs, and fittings.

On some generators, the outboard bearing is electrically insulated from the frame to prevent the flow of shaft currents through the bearing. Insulation may be accomplished by means of a shell of insulating material installed tween the bearing shell and bearing housing, by the use of insulating shims under the destal and insulated holding-down bolts, and wels. Currents caused by the electromotive rce generated in the shaft and structural members of a generator, if of sufficient magnitude, will rapidly ruin a bearing. Therefore, make certain that the bearing insulation is not damaged or that conducting paths around the insulation are not inadvertently provided.

# Armatures

Preventive maintenance of an armature consts of periodic inspections and tests to deterine its condition, and proper cleaning prac:es to preserve the insulation.

Frequent checks must be made of the contion of the banding wire that holds down the indings of the d-c armature to see that the ires are tight, undamaged, and have not ifted (fig. 7-20). At the same time, the clips ecuring the wires should be checked to see if older has loosened. When repairs are required, anding-wire size, material, and the method of riginal assembly should be duplicated as far s possible. Only pure tin must be used for oldering banding wire.

Periodically, all end windings should be inpected and cleaned (fig. 7-20). Allow sufficient learance between the end windings and end rackets or any air deflecting shields to prevent hafing or other damage. In cases where hafing is slight or where shop overhaul is not easible, air-drying varnish may be applied to he windings by brush after they have been leaned and dried.

Risers must be inspected periodically to determine the condition of the solder that secures he windings to the segments (fig. 7-20). All lirt and lint should be removed by thorough cleaning to ensure that cooling passages will not be clogged. It may be necessary in the case of generators to do this each time the machine is secured. Cleaning is easier when performed while the machine is warm.

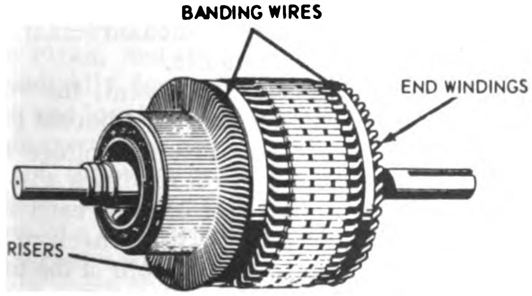



Figure 7-20.—D-c armature.

## TROUBLE INDICATIONS

Some armature troubles may be detected while making inspections of running machines. Heat and the odor of burning insulation may indicate a short-circuited armature coil. In a coil that has some turns shorted, the resistance of one turn of the coil will be very low, and the voltage generated in that turn will cause a high-current flow, resulting in excessive heating, which will cause the insulation to burn. If the armature is readily accessible, the short-circuited coil can be detected immediately after stopping the machine because the shorted coil will be much hotter than the others. In idle machines, a short-circuited coil may be identified by the presence of charred insulation.

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

When a ground occurs in an armature coil of a running machine, it will cause the ground test lamps on the main switchboard to flicker on and off as the grounded coil segment passes from brush to brush during rotation of the armature. Two grounded coils result in the same effect as a short circuit across a group of coils. Over-heating will occur in all of the coils in the group and burn out the winding. Grounded coils in idle machines can be detected by measuring insulation resistance. A megger, or similar insulation measuring device can be connected to the commutator and to the shaft or frame of the machine in order to properly measure the resistance of the insulation of the coils.

## LOCATING TROUBLES

D-c armature troubles are usually confined to one coil or group of coils, and if not readily apparent, the segments to which they are connected can be located by a bar-to-bar test. In some cases, this test may be conducted with the armature installed in the machine. A low-voltage, d-c source, such as a storage battery, lighting circuit, or welding set, is required for this test. The machine must be disconnected from its normal power supply before the test is made and all except one pair of brushes lifted from the commutator. The voltage is applied across the + and - brushes through a resistance, lamp, lamp bank, or rheostat. A low-reading voltmeter or millivoltmeter is necessary for taking measurements.

To locate a ground in a d-c armature coil, one lead of the voltmeter is connected to the shaft, and, with the armature in a fixed position, the other lead is touched to each commutator bar in turn. If there is a ground, two or more bars will indicate practically zero readings. Some of these will be real and others will be phantom grounds (fig. 7-21A). All such bars should be marked with chalk. The armature is then rotated a few degrees and tested again. The real grounds will remain in the same bars while the phantom ones will shift to other bars (fig. 7-21B). For example, in figure 7-21B, the phantom ground has shifted from bar b to bar c, while the real ground has remained in bar a. The ground will be in a coil connected to the bar, showing a real ground with the lowest voltage reading.

To locate an open or short circuit in a d-c armature, remove all brushes except those of one positive brush holder and an adjacent negative brush holder. Connect the low-voltage potential to these brushes and adjust the current, if need be, so that the readings obtained with the millivoltmeter will be roughly one-third

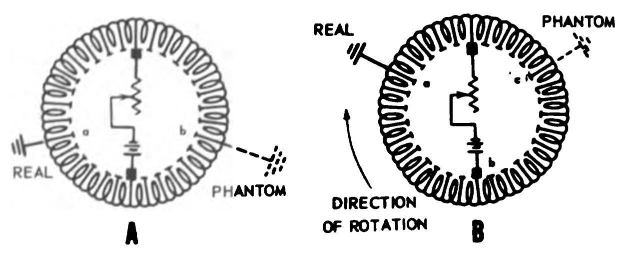



Figure 7-21.—Real and phantom grounds in a bar-to-bar test.

to one-half full scale. The current must not exceed one-fourth that normally carried by one set of brushes. The voltage drop between two adjacent commutator bars is measured with a millivoltmeter. The armature is held in a fixed position, and the meter leads are moved from one pair of adjacent bars to the next until a test has been made of all the pairs of bars included between the brushes (fig. 7-22). The armature is then turned to bring different bars between the brushes, and these bars are tested. This is repeated as necessary to test all around the commutator. In a simplex winding, an open coil is located where the meter reading is a maximum and a shorted coil, where the reading is a minimum.

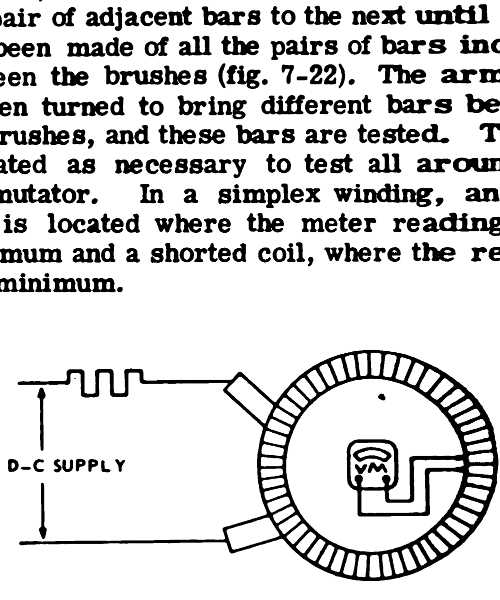



Figure 7-22.—Testing for an open coil.

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

When an open circuit is present, the voltmeter reading across one pair of adjacent bars will be approximately equal to the voltage between the brushes, and zero readings will be obtained on several pairs of bars on each side of the pair with high reading. The open-circuited coil will be connected to one or both of the bars in the pair with the high reading. Should the voltmeter readings taken between adjacent pairs

: bars increase or decrease in magnitude and be ternately plus and minus, a duplex winding is dicated. A further test by measuring the voltge drop between alternate bars is then necesary to locate the open circuit. When a reading pproximating the voltage between the brushes thus obtained, the open-circuited coil will be nnected to one or both of the bars in the pair ith the high reading.

When a short circuit is present, the interpretion of the indication given by readings between djacent bars or between alternate bars (duplex indings) depends upon whether the armature as a lap or a wave winding. In an armature aving a lap winding, a voltmeter reading conderably lower than the others will indicate a hort-circuited coil is connected between the air of bars that shows the low reading. A hort-circuited coil in an armature with a wave inding will cause low readings to be obtained n as many pairs of bars as there are pairs of oles, and the short circuit will be in a coil onnected to bars in these pairs.

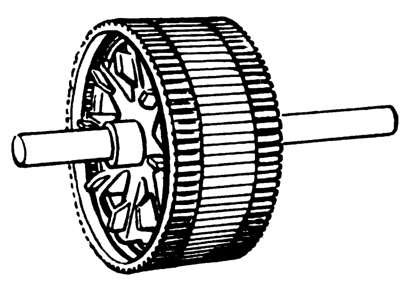
The best method for locating the ends of a ulty coil in a wave-wound armature is to eparate the coil from the rest of the winding n the following manner. In a six-pole machine, short-circuited coil in a wave-wound armature would be indicated at three positions during the test. These positions should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

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

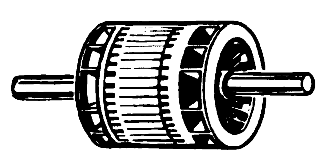
# A-C Rotors

Basically, the rotors in a-c machines are of wo types: the cage rotor (fig. 7-23) and the vound rotor. The cage rotor usually consists f heavy copper or aluminum bars fitted into lots in the rotor frame. These bars are conected to short-circuiting end rings by bolts r rivets and are then brazed or welded together fig. 7-23A). In some cases, the cage rotor is manufactured by die-casting the rotor bars, end rings, and cooling fans into one piece (fig. 7-23B). The cage rotor requires less attention than the vound rotor. However, the cage rotor should be kept clean, and the rotor bars must be checked periodically for evidence of loose or fractured bars and localized overheating.

In the wound rotor, the uninsulated bar winding of the cage rotor is replaced with a distributed winding of preformed coils similar to those of a d-c armature. The windings are wyeconnected and the ends are brought out to collector rings (fig. 7-24). Wound rotors, like other windings, require periodic inspections, tests,



A - WELDED ROTOR BARS AND END RINGS



B - DIE-CAST ROTOR BARS AND END RINGS

Figure 7-23.—Cage-rotors.

and cleaning. The insulation resistance of the winding may be tested with a megger to determine if grounds are present.

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

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

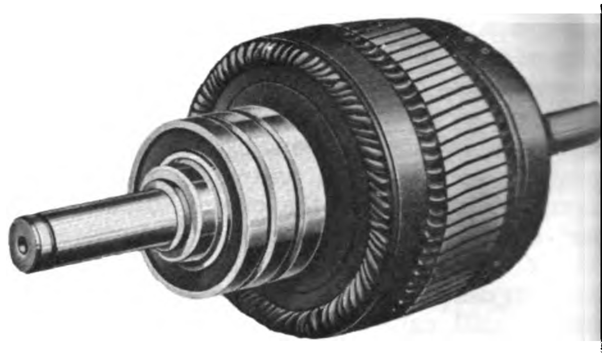


Figure 7-24.—Wound rotor.

# Field Coils

Preventive maintenance of field coils requires periodic inspections and tests to determine the condition of the coil. Coils should be cleaned periodically to remove any foreign particles, which might have collected on them.

### LOCATING TROUBLES

The insulation on field coils should be tested periodically to determine its condition. A megger or similar resistance-measuring device may be used for this purpose. If a ground is detected in the field circuits (shunt, series, and interpole) of a d-c machine, the circuits must be disconnected from each other and tested separately to locate the grounded circuit. Then all the coils in that circuit must be opened and tested separately to locate the grounded coil, which can be repaired or replaced as necessary.

If an open circuit develops in the field windings of an a-c or d-c generator that is carrying load, it will be indicated by immediate loss of load and voltage. An open in the shunt field winding of an operating d-c motor may be indicated by an increase in motor speed, excessive armature current, heavy sparking, or stalling of the motor. When an open occurs in the field circuit of a machine, it must be secured immediately and examined to locate the faulty circuit. The open circuit will usually occur at the connections between the coils and can be detected by visual inspection. An open in the coils generally causes enough damage to permit detection by visual inspection. If the faulty coil is not readily apparent, it can be located by applying a low-voltage source (dry batteries) to the terminals of the field winding and using a low-range voltmeter to measure the difference of potential between the terminals of each coil (fig. 7-25). The open-circuited coil will develop the greatest difference in potential between its terminals.

A short-circuited field coil in a machine develops an unbalanced magnetic pull and causes vibration. If the short circuit is severe, smoke or the odor of burning insulation will be present. In a generator, a shorted field coil is indicated when it becomes necessary to increase field current in order to maintain voltage with the machine running at normal speed. A machine

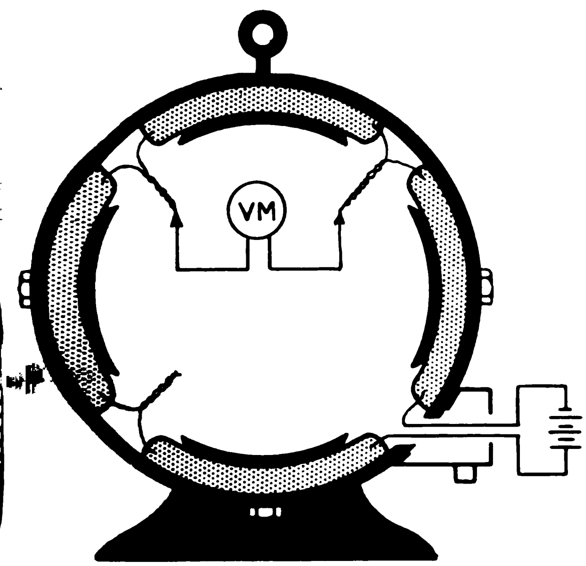



Figure 7-25.—Testing for an open-circuited field coil.

th a shorted field coil must be secured immediately. The faulty coil can be located by ssing normal current through the field circuit d measuring the voltage drop across each il. The coil indicating the lowest voltage will the shorted coil.

### REPLACING COILS

A field coil may be removed from a large achine without removing the armature. However, the armature should be covered with avy paper or canvas to prevent damaging it hile the coil is being removed. To remove e coil, the field windings are disconnected, and then the bolts securing the pole piece to the frame are removed. The coil and pole piece can be slid from the machine intact. Care must be taken not to lose or misplace any of the shims found on the pole piece.

Before installing a new or repaired coil, its polarity must be determined and it should be tested for shorts, opens, and grounds. A small magnetic compass may be used to determine the polarity of a field coil. A small battery is connected to the coil leads, and the compass is held several inches above the coil. If the south pole points toward the center of the coil, the face of the coil nearest the compass will be a north pole. This will indicate that the coil should be placed on a north pole in the same position it was in during the test, and the field current should flow through the coil in the same direction.

To protect the armature, the same precautions that were observed during the removal of the coil must be observed when installing it. All of the shims originally removed from the pole piece must be in position when it is replaced. With the coil in position in the machine, it should be temporarily connected to the other coils in the field circuit and a compass and battery again used to check its polarity. For this test, connect the battery to the proper field leads and check the polarity of all the coils with the compass (fig. 7-26). Adjacent poles must be of opposite polarity. If need be, polarity of the new coil can be reversed by reversing its leads. When the polarity is correct, the coil is connected, and the pole-piece bolts are tightened. Air gaps should be measured to ensure uniformity. Before starting the machine, test it thoroughly to ascertain that no grounds, shorts, or opens exist as a result of the repairs.

## A-C Stator Coils

A-c stator windings require the same ıreful attention as other electrical windings. or a machine to function properly, the stator indings must be free from grounds, short ircuits, and open circuits. Frequent tests and ıspections are necessary to determine the conition of the windings, and they must be kept lean to preserve the insulation.

A short circuit in the stator of an a-c mahine will produce smoke, flame, or the odor f charred insulation. The machine must be secured immediately; the faulty coil may be located if the coil ends are felt before they have time to cool. The shorted coil ends will feel perceptibly hotter than those adjacent to it. Emergency repairs of a faulty stator coil may be effected by cutting it out in the same manner as cutting out a faulty armature coil. However, a new coil must be installed as soon as possible.

Open circuits in a-c stator windings can sometimes be found by visual inspection because

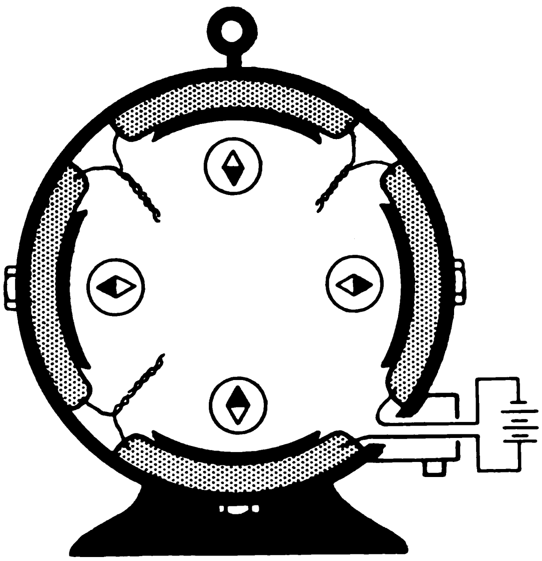


Figure 7-26.—Testing polarity of field coils.

the open is usually the result of damaged connections where the coils and circuits are connected together. Should visual inspection fail, resistance measurements between the phase terminals will reveal the presence of open-circuited coils. The coil ends in the faulty phase are tested with an ohmmeter to locate t open-circuited coil. When the open circuit is an inaccessible location and cannot be reach for repairs, the machine can be repaired f emergency use by cutting out the faulty coil.

Grounds in a-c stator windings can be d tected with a megger or similar resistanc measuring instrument. Both ends of each pha are opened and tested to locate the ground phase. Then, each circuit in the grounded pha is opened and tested to locate the grounded ci cuit. Finally, the ends of each coil in t grounded circuit are opened and tested until t grounded coil is located.

New or repaired stator coils should tested (before and after installing) for ground shorts, and opens. Polarity of the coil must checked after installation by employing a l d-c voltage source and a small compass, as the polarity test for field coils. The compa needle will reverse itself at each adjacent po if the stator is properly connected. When t same compass needle indication is obtain from two adjacent poles, a reversed coil is i dicated. The coil connections must be chang to correct the polarity.

## Periodic Tests and Inspections

To determine whether or not proper maintenance procedures for motors and generators are being carried out, a check-off list of the maintenance schedule should be prepared and maintained. To be effective, the check-off list must identify the equipment and indicate when and by whom the maintenance was accomplished. The list should be inspected periodically by the electrical officer or engineer officer, and, when applicable, entries to the effect that certain maintenance has or has not been performed should be made in the appropriate electrical history, current ship's maintenance project, or operating logs.

It may not be possible to carry out a complete maintenance schedule on some shipboard equipment because of its inaccessible location. However, the Bureau of Ship's required maintenance schedule for motors and generators which follows, should be carried out so far as practicable, and if experience or manufacturer's instructions dictate, should be supplemented by additional or more frequent tests and inspections.

DAILY:

1. Check oil level and condition of oil rin in oil-lubricated bearings, and flow of oil ( sight gage) in force-feed lubricated bearing
2. Inspect motor and generator surroundin for dripping water, oil, steam, acid, excessi dirt, dust, or chips, and any loose gear th might interfere with ventilation or jam movi parts.
3. Observe running motors for vibration a unusual or excessive noise.
4. Examine each running generator set f cleanliness, vibration, unusual or excessi noise, heating, and condition of brushes, com mutators, collector rings, bearings, bolts a mechanical fastenings.

WEEKLY:

1. Check temperatures of bearings a frames. Estimate by touch, and, if temperatur appears to be excessive, measure with a ther mometer.
2. Inspect for leakage of lubricant fro generator and motor bearings, as shown by o or grease on the shaft extension or lubrica creeping towards the winding.

3. Inspect for leakage of lubricant from the rings of prime movers that drive genera- s.

4. Inspect commutators of idle machines for mutator conditions.

5. Inspect collector rings of idle machines evidence of corrosion.

6. Inspect all running motors for unusual rking.

7. Run each generator at partial or full d for at least 30 minutes once a week, and ord in log. If it is not practicable to run h set every week because of naval shipyard rk, extensive overhaul, or casualty an entry ll be made in the log stating the facts.

8. If operating conditions permit, measure insulation resistance of each ship's service emergency generator and exciter, and of pulsion generators, motors, and exciters in ctric drive ships. Record results of the ts on the appropriate megger cards.

9. Blow out generators that have been in use th clean, dry, compressed air, and wipe with intless cloth.

MONTHLY:

1. Run each generator continuously for at ast 4 hours once a month at full-rated load d voltage. Record in log. If it is not prac- able to apply full load, the maximum load ssible should be used, and an entry should made in the log, giving the load used, and e reason why full load was not practicable. it is not practicable to run each generator r this test every month, an entry should be ade in the log stating the facts.

2. Inspect the zincs in motors and genera- rs equipped with air coolers.

3. Remove the drain plugs provided in Navy lass A spraytight, watertight, and submersible otor enclosures to drain off water that may ive collected in the enclosures. Be sure to place the drain plugs immediately after drain- g the motor enclosures. The draining of the otor enclosures should be entered in the log r electrical history, as appropriate, together ith an entry giving a rough idea of the amount f water drained off.

QUARTERLY:

1. Inspect pulleys, belts, belt guards, ounting-frame bolts, end-shield bolts, and echanical fastenings for mechanical soundness nd tightness.

2. Check clearance between bearings and haft on machines with sleeve bearings.

3. Check air gaps, if accessible for measurement, on machines with sleeve bearings. Record measurements taken on appropriate electrical history card.

4. Check end play of motor and generator shafts.

5. Rotate motors through one complete turn and inspect the commutator.

6. Replace worn-out brushes.

7. Inspect and tighten brush "pigtails."

8. Check brush alignment parallel to commutator segments.

9. Check distance of brush holders from the commutator.

10. Check brush pressure.

11. Make sure that brush holders are clean and that the brushes move freely in the holders.

12. Blow out and clean motors thoroughly to remove dirt from the commutator, ventilation ducts, and insulation.

13. Measure and record the insulation resistance and temperature of motors.

14. Operate motors at normal load and temperature.

SEMIANNUALLY:

1. Drain, flush out, and renew oil in sleeve bearings.

2. Add grease to ball bearings if required. Record the date and the fact that the machine was lubricated.

3. Inspect all gaskets, particularly lubricant seals. Replace worn gaskets and seals.

4. Inspect armature banding and slot wedges.

5. Inspect the connections of armature coils to commutator risers.

6. Inspect and tighten all electrical connections.

7. Inspect commutator clamping ring.

8. Clean out slots in the commutator and undercut mica if necessary.

9. Inspect the ends of cage rotors for evidence of loose or broken bars or localized overheating.

10. Inspect fans for loose or broken blades.

ANNUALLY:

Inspect all windings and insulation. Clean and repair insulation as necessary.

EVERY TWO YEARS:

Remove bearing caps or other covers as may be provided and observe the condition of ball bearings and lubricant. If no repairs are indicated, flush out the old grease, and replace with fresh, clean grease.

# QUIZ

1. What is the most important factor in the maintenance of electric motors and generators?
2. What is the purpose of the motor-generator?
3. The d-c generator is so designed that regardless of load variation it will deliver what?
4. The main and diverter poles are connected by what?
5. The armature and the diverter pole are in series with the load. As the load increases (a) what happens to the magnetomotive force of the diverter pole? (b) is the field of the main poles strengthened?
6. What is the circuit designation for the dial telephone system?
7. To reverse the field of the generator the brushes are lifted from the armature and the reverse current relay is operated. The reverse current completes the circuit from the fields to what power supply? (See fig. 7-4).
8. What are four acceptable methods of cleaning motors and generators?
9. Why is the use of suction preferred to the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine?
10. What precautions should be taken in soldering operations on motors and generators?
11. When a generator is to be inoperative for an appreciable length of time, such as may be necessary for the overhaul of the prime mover, why should the brushes be lifted from the collector rings or commutator?
12. What precautions should be taken regarding all electrical connections?
13. What materials should not be used to clean contact surfaces that are silver-plated?
14. What should be the general appearance and color of the commutator of a d-c motor or generator?
15. What abrasives should never be used on commutator or collector rings?
16. What action may be corrected by reversing the d-c polarity of the slip rings of an a-c generator every few days?
17. When should brushes in motors and generators be replaced?
18. When a d-c motor or generator is running without load and with only the main-pole field windings excited, what is the point called on the commutator at which minimum voltage is induced between adjacent commutator bars?
19. In determining the no-load neutral by th mechanical method, the commutator is turn ed until the two coil sides of the same arma ture coil are what relative distance from th centerline of the main-field pole?
20. When lifting the rotor of an a-c or a d- machine (a) what precaution should be tak with respect to the rope slings placed unde the shaft and clear of the journals? (b) Why
21. (a) What is a good method of listening fo the presence of abnormal noise in a bearing (b) How is trouble indicated?
22. (a) What condition may cause the grease a bearing to churn and generate heat wi the result that the grease separates int oil and abrasive particles? (b) How doe this action affect lubrication?
23. On some generators, why is the outboar bearing electrically insulated from th frame?
24. A bright spark, which appears to pass com pletely around the commutator, is an indi cation of what type of fault in a d-c machine
25. When locating grounds in a d-c armatur coil (fig. 7-21) the voltmeter indicates wha relative magnitude between the commutato bar leading directly to the coil and th ground?
26. When shifting the commutator between read ings (fig. 7-21), how are the real ground distinguished from the phantom grounds?
27. What is the relative magnitude of the mete reading (fig. 7-22) to indicate (a) an ope coil and (b) a shorted coil?
28. What two actions are required in order t cut out a short-circuited or open circuite armature coil?
29. What two basic types of rotors are foun in a-c induction motors?
30. Reduced torque in a form-wound rotor in duction motor accompanied by a growlin noise or failure to start under load ar symptoms of what kind of trouble?
31. An increase in motor speed, excessiv armature current, heavy sparking, or stall ing of the motor are symptoms of wha kind of trouble in a d-c motor?
32. In locating an open field coil (fig. 7-25) th voltmeter reading has what relative magni tude when connected across the ends of th open coil?
33. What two devices may be used to determin the polarity of the field coil?

, What is the purpose of a checkoff list of the maintenance schedule for motors and generators?

How often should running motors be observed for vibration and unusual or excessive noise?

How often should the temperatures of bearings and frames be checked?

37. How often should the zincs in motors and generators equipped with air coolers be inspected?

38. How often should the end play of motor and generator shafts be checked?

39. How often should sleeve bearings be drained, flushed out, and the oil renewed?

# CHAPTER 8

# ALARM AND WARNING SYSTEMS

## Switches

The principal components of shipboard alarm and warning systems are (1) switches, (2) relays, (3) push switches, (4) thermostats, (5) audible signals, and (6) visual signals, or indicators.

Alarm and warning systems are provided in naval vessels to indicate abnormal or dangerous conditions that may cause casualties to machinery and personnel. The lubricating-oil, low-pressure alarm system, for example, must provide an audible signal to indicate improper operation of the lube-oil system for a particular engine before dangerous conditions occur.

The various alarm and warning systems used aboard ship are usually the simplest types of I.C. circuits. The majority of these systems consists of one or more switches that complete an electric circuit to various types of audible and visible alarm equipment. There are many kinds of switches in use and the type depends upon the circuit in which it is installed.

### MANUAL SWITCH

The most commonly used type of manually operated switch is an enclosed, watertight, base-mounted, lever-operated switch shown in chapter 4 (fig. 4-9) of this training course.

Manually operated switches are used as the actuating devices for the following systems.

EB Boiler-feed signal
GD Diving alarm
EA Fireroom-emergency signal
FC Flight-crash signal
FL Flight-deck landing observer's signal
FW Flight-deck warning signal
G General and chemical-attack alarm
CA Collision-alarm signal
RW Rocket and torpedo warning
LB Steering-emergency signal
RF Traffic-control ready-light
RA Turret-emergency alarm
W Whistle operating

### PRESSURE SWITCH TYPE IC/L

Pressure-operated switches are norma single-pole, single-throw, quick-acti switches. They contain either a bellows o diaphragm that works against an adjusta spring. The spring causes the contacts to cl automatically when the operating pressure fa below a specified value. The pressure at wh the switches operate is adjustable within ranges of 0-15, 15-50, and 50-100 psi. M this adjustment at the screw marked, hig (fig. 8-1). These switches can be used also indicate an increase in pressure above a pr determined point.

Pressure-operated switches are used w the lubricating oil, low-pressure alarm sy tem; air-pressure alarm system; and booste feed pressure alarm system.

### THERMOSTATIC SWITCH TYPE IC/N

Thermostatic, or temperature-operat switches are usually single-pole, single-thr quick-acting, normally open switches. The switches contain a bellows that works agai an adjustable spring (fig. 8-2). The spri causes the contacts to close automatically wh the operating temperature exceeds a specifi value. The bellows motion is produced by sealed-in liquid that expands with rising te perature. The sensitive element contain this liquid may be built into the switch or l cated in a remote space and connected to t switch by a capillary tube. The temperatu

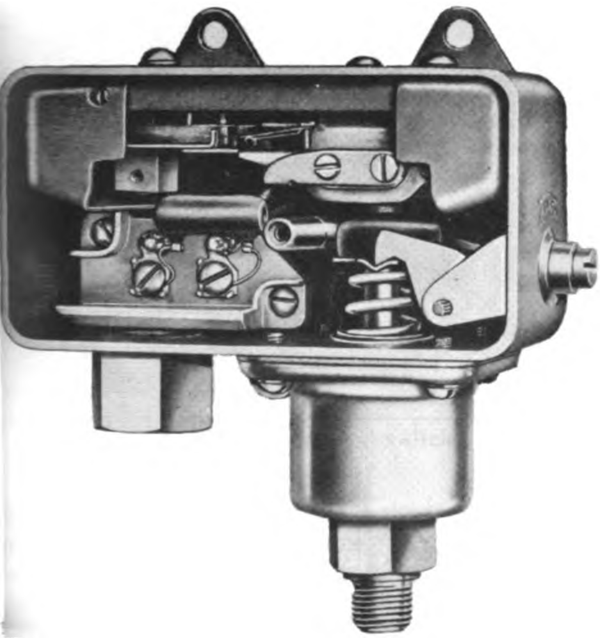


Figure 8-1.—Pressure Switch Type IC/L.

ange at which the switches operate is adjustable between 100° and 225°F.

Temperature-operated switches are used ith the circulating-water, high-temperature larm system; cruising-turbine exhaust alarm ystem; and generator-air, high-temperature larm system.

## MECHANICAL SWITCH

The types of mechanically operated switches re the push-action (type A-S) and the camction (types P and P1). The push-operated witch, provided for bulkhead mounting, is a ingle-throw or multiple-throw, momentary acion, normally open push switch. The pushction mechanism utilizes a straight-line moveent of the shaft to operate the electrical ontacts.

The cam-action switch consists of two ingle-pole, double-throw micro switches oprated by two adjustable cams mounted on the otor shaft (fig. 8-3). The cam-action mechnism utilizes a rotary motion of the shaft to nove cams, which in turn operate sensitive witches. The points of operation of the sensiive switches are varied by adjusting the angular ositions of the cams with respect to the shaft on which they are mounted. Mechanical switches are used with the following systems:

QA Air-lock indicator
PW Clutch-position indicator
SP Shaft-position alarm
LS Submersible steering-gear alarm
DW Wrong-direction alarm
PW Clutch position indicator
TR Hull-opening indicator
VS Valve-position indicator

## WATER SWITCH

Water switches consist of a pair of terminals mounted in an insulated base within a cast fitting (fig. 8-4). There is a 7000-ohm, 5-watt resistor connected across the two terminals, which limits the current to the required value for the supervisory circuit when the switch casting is dry. The switch is mounted in the magazine flooding system, and a sprinkling control valve is installed between the switch and the firemain. When the sprinkling control valve is opened, water floods the switch casting and shorts out the 5-watt resistor. With the supervisory resistor shorted, a current of sufficient value to operate the alarm will flow in the circuit.

Water switches are used principally in sprinkling alarm systems (circuit FH).

## PUSH SWITCHES

Push switches have nonwatertight, watertight, and pressure-proof types of enclosures.

The nonwater tight type is a single-pole, single-throw, momentary-action, normally open push switch. It is supported in a molded phenolic enclosure provided for surface mounting.

The watertight type is a single-pole, single-throw, momentary-action, normally open push switch. It is provided with a single switch or in two, three, four, or five groups. This push switch is housed in a sheet-steel enclosure provided for surface mounting.

The pressure-proof type of push switch, installed on the bridge of submarines, is a single-pole, single-throw, momentary-action normally open push switch. It has a metal diaphragm on which is mounted a device that actuates a sensitive switch. It is necessary to distort the diaphragm to operate the sensitive switch. Steady pressure against the diaphragm

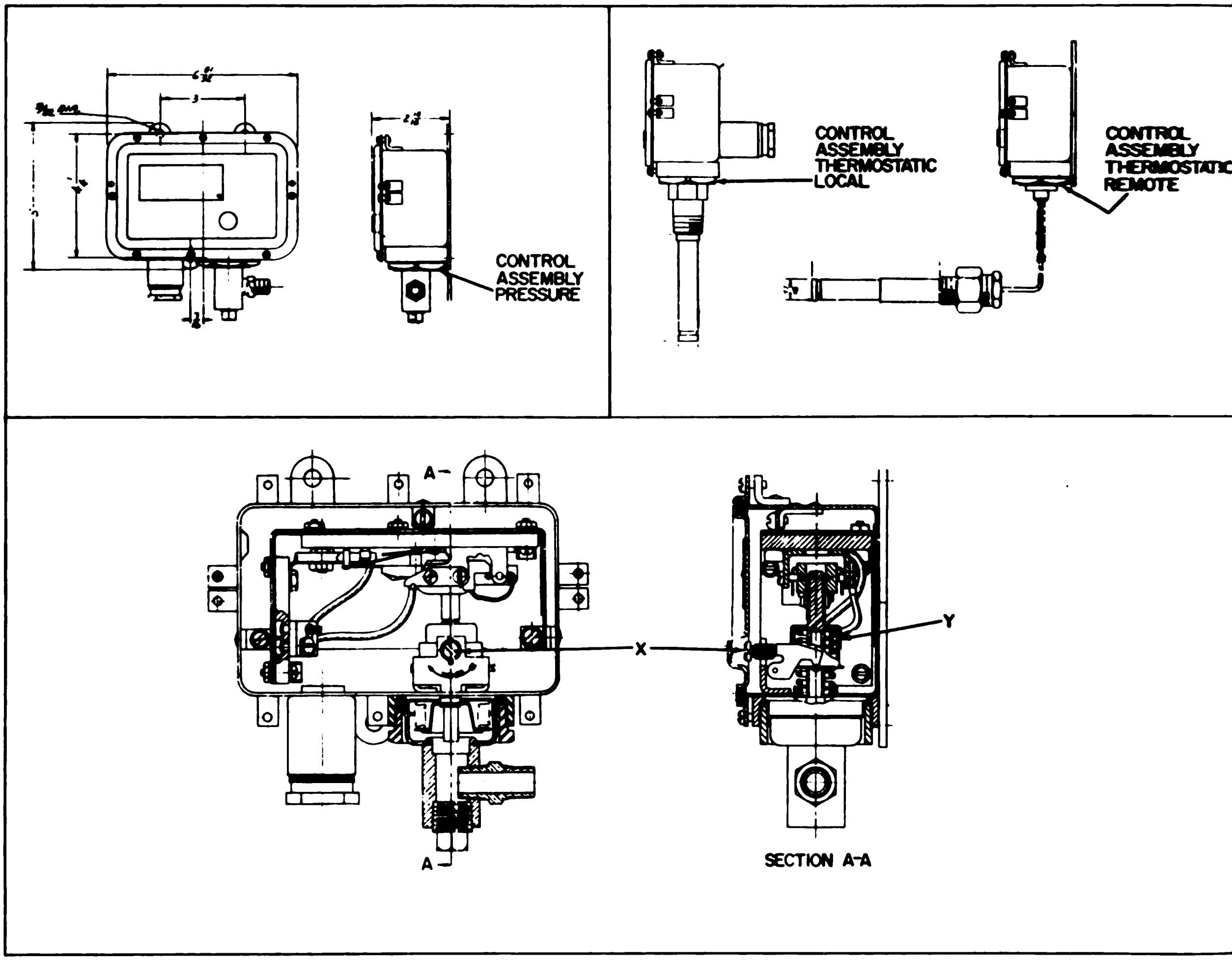



Figure 8-2.—Temperature-operated switches.

up to rated pressure of 550 psi causes a uniform inward motion of the diaphragm without distortion, and the switch does not operate. Pressing the button distorts the diaphragm slightly and operates the sensitive switch.

The push switches are housed in a bronze enclosure provided for surface mounting. They are used in the (1) officer's call-bell system, (2) voice-tube and sound-powered telephone call-bell system, and (3) train-warning signal system.

## Relays

A relay (fig. 8-5) is an electromechanical device by means of which a current change in one circuit causes its contacts to open or close to produce a change in the electrical conditions in its own or other circuits.

A common type of relay consists of a coil wound on a soft-iron core, an armature, an L-shaped heelpiece, and a contact assembly. A washer of insulating material is fastened near each end of the iron core to hold the turns of wire on the core. The heelpiece is secured to one end of the core and extends along the side of the coil to the armature pivot assembly.

When current flows through the coil, a magnetic field is set up around the coil. The magnetic circuit consists of the core, the heelpiece,

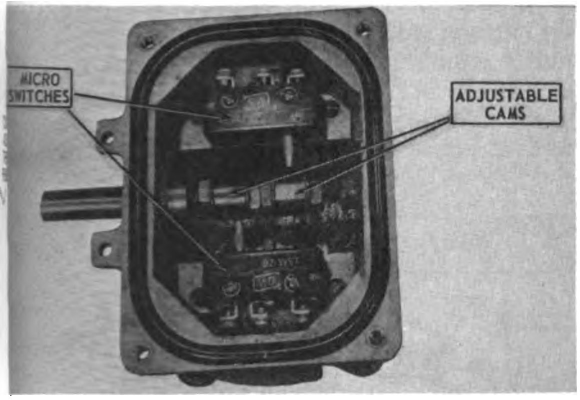



Figure 8-3.—Mechanical switch.

d the armature. The magnetic field attracts e armature toward the core against the spring essure of the contact assembly. The contact ssembly may consist of an armature that operates contact springs, a lever arm that operates sensitive switch, or other similar mechanical rangement. For all practical purposes, the lay is a magnetic switch designed to operate hen the current through the coil or the voltage ross the coil increases or decreases to a ecified value.

Relays are used in alarm and warning systems to open and close circuits that may operate indicating lights, annunciator drops, and/or audible signals.

### MOTOR-OPERATED RELAY

Motor-operated relays consist of cams, contacts, a motor, and a relay mounted on a panel and enclosed in a splash-proof case (fig. 8-6).

When a manually operated general alarm switch at a remote station is closed for a period of 2 seconds, the motor-operated relay is energized, and closes and opens the contacts of a primary (controlled) circuit at a prearranged rate. This prearranged rate of closing and opening the contacts is 90 times per minute (one-third second closed and one-third second opened) for a period of 15 seconds.

When a manually operated, chemical-attack alarm switch at a remote station is closed, the motor-operated relay holds the contacts of the primary circuit closed until the manually operated switch is released.

Motor-operated relays are used in the general and chemical-attack alarm systems where these systems are not incorporated as a part of the battle announcing system.

## Fire Detection

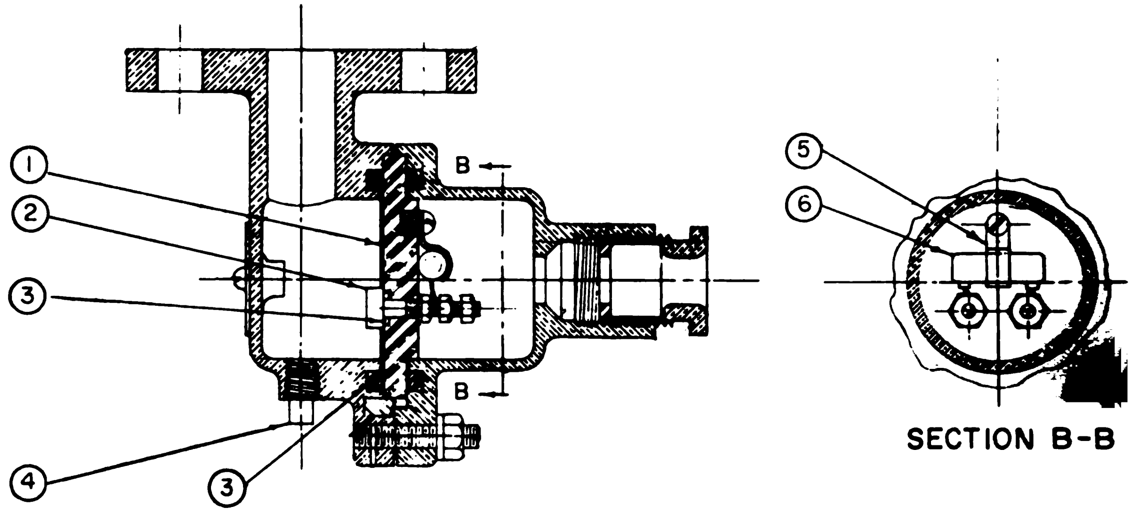
There are three indications of fire: heat or temperature rise, smoke or combustible gases, and flame. The Navy uses two methods of detection in its circuit "F" fire alarms. The temperature-rise method, which uses a mercurial thermostat, is found on the older naval ship. On new construction, conversions, and ammunition ships, in addition to the temperature-rise system, there is a combustible gas and smoke detector system.

### MERCURIAL THERMOSTAT

The MERCURIAL THERMOSTAT is a glass mercurial thermometer with three electrical connections (fig. 8-7). The connections are brought into the unit so that the mercury will complete a circuit between the connections. The connections are made at points that would represent -55° F, -45° F, and a high value of 105° F, 125° F, or 150° F on a thermometer. There is a 5-watt, 7000-ohm resistor connected between the two upper contacts on blue and white leads. This resistor is designated as the supervisory resistor. The mercurial thermostat is housed in a light-weight aluminum enclosure provided for overhead mounting. The thermostat element contains hydrogen gas at a pressure of at least 5 atmospheres to minimize separation of the mercury column under shock. The element is molded into a rubber shock mount, which becomes an integral part of the cover.

### SMOKE AND COMBUSTION GAS DETECTION

The SMOKE AND COMBUSTION GAS DETECTOR HEAD (fig. 8-8) has a four-pin polarized plug, which fits into a socket base for



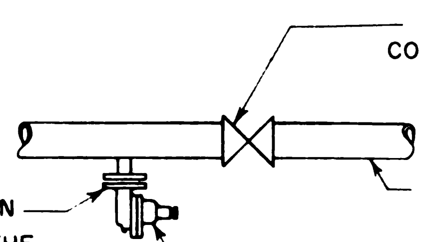




**Figure 8-4.—Water switch.**

quick replacement. The detector head may be divided into three major units: the inner and outer chambers and the gas discharge (cold cathode) tube. The detector compares the air in the inner chamber, which is inaccessible with the air in the exposed outer chamber. The tube furnishes the current required to operate the alarm relay.

The sensitive element of the detector head is the ionization chambers in which the air is made conductive by a small quantity of radium. The alpha particles given off by the radium have the ability to ionize air or separate it into positive ions and negative electrons. If this ionized air is introduced into an electric field, the charges on the ions and electrons will cause them to move and will give rise to a current. This principle is shown in figure 8-9. A potential from a battery B is applied to the plates, P1 and P2. The air between the plates is ionized by the radium, Ra. The charged particles move in the direction indicated by the arrows. A sensitive galvanometer measures the current, the value of which depends on the strength of e radioactive source and, within limits, on e voltage of battery B. With low applied potentials, part of the ions and electrons collides id neutralizes each other.

It is only when the potential reaches a certain limit that all of the ions formed reach the electrodes. This is known as the saturation point. Beyond this point, the current remains

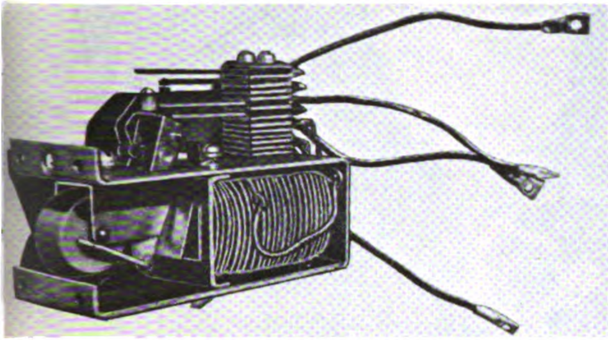


Figure 8-5.—Relay.

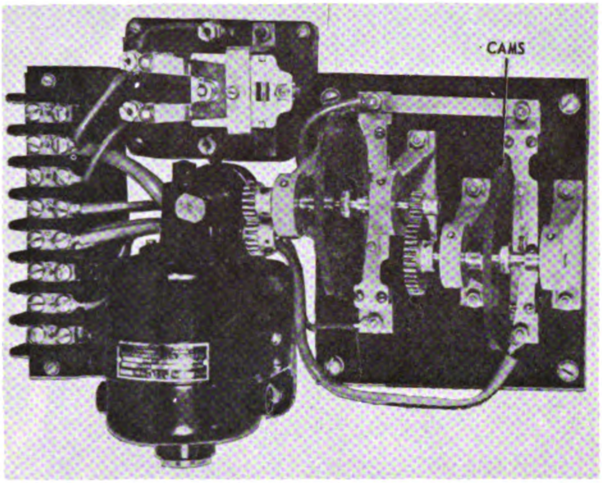



Figure 8-6.—Motor operated relay.

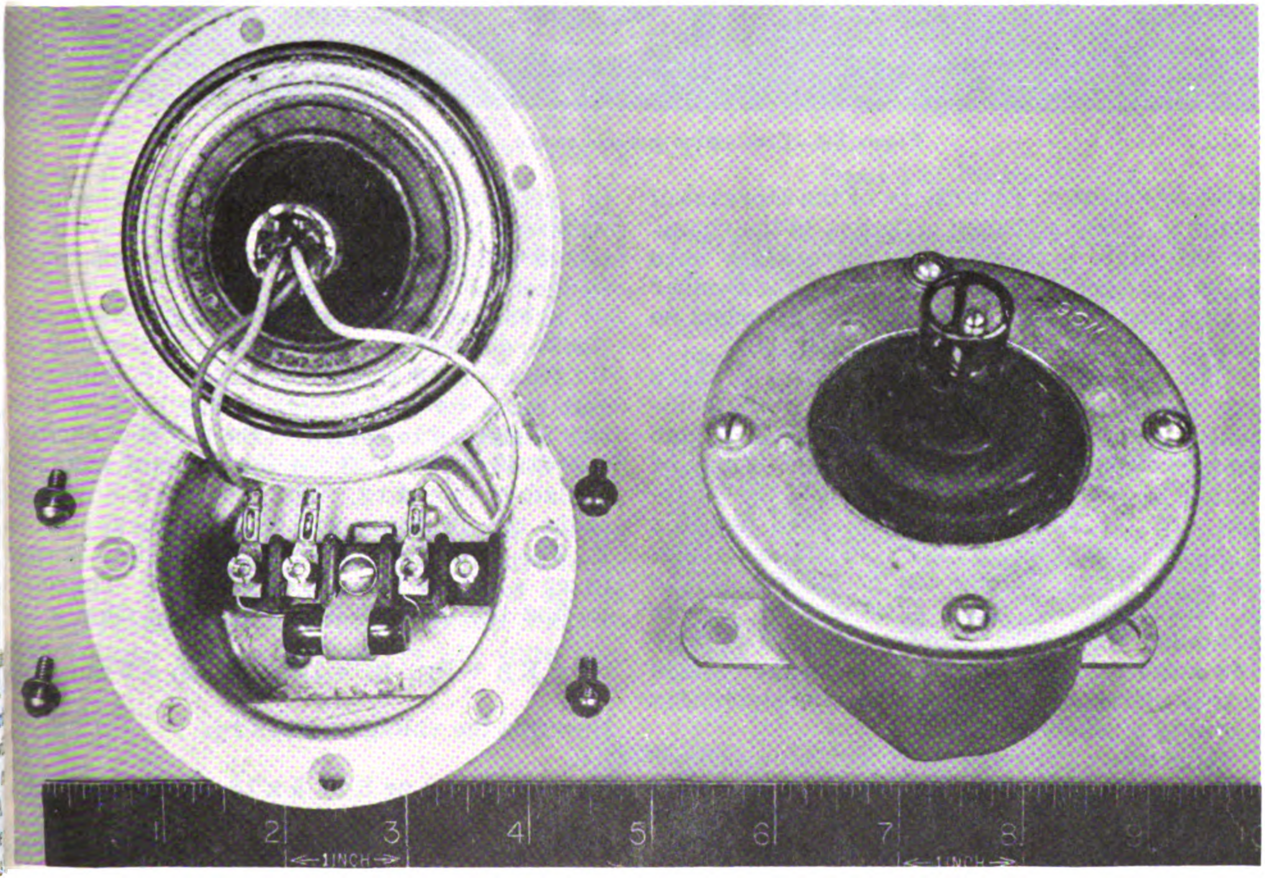



Figure 8-7.—Assembly and disassembly view of thermostats type IC/J-125.

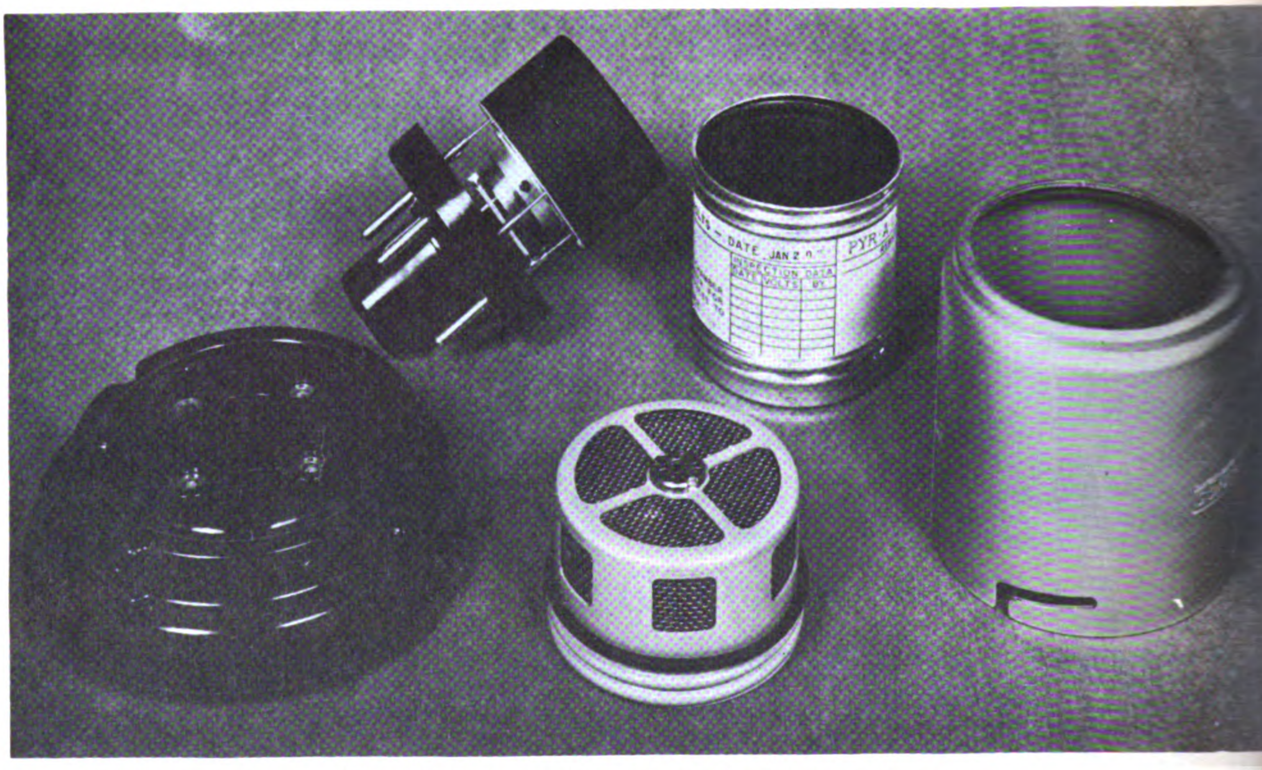


Figure 8-8.—Combustion gas and smoke detector system.

virtually constant, regardless of the increase of potential. Only a change in the gas in the chamber will cause a change in the current flow when the unit is operating at saturation. The number of ions and the rate of drift are dependent on the number, size, and mass of molecules.

The products of combustion cause a sharp drop in the current flow. Nearly every combustion produces particles suspended in high concentration in the air, some of which may be visible as smoke. However, most of the particles are too small to be seen, even though a thousand times larger than an air molecule. These particles hamper the production of ions by absorption of alpha rays and by slower movement when they ionize. Because of their slow movement their chance of being neutralized by free electrons before reaching the electrodes is nearly a hundred percent.

Combuston products need not be produced in an open flame. Gas and smoke originating from smoldering or overheated materials cause a similar current drop. An alarm signal is indirectly obtained from the change in current within the ionization chamber.

As radium is extremely expensive, the unit must operate on minute currents. The current is .000000003 ampere, or .003 microampere Although a change in this current may be de tected with a galvanometer, it is more practica to detect a voltage change.

A review of Ohm's law in Basic Electricity NavPers 10086, would be helpful at this point

Figure 8-10 shows a parallel resistance cir cuit made up of two legs, A and B. Leg B has two resistors in series. Observe how changing the value of r3 changes the ratio of voltage a resistors r2 and r3. With 150 volts d-c supplie to the circuit, there will be 150 volts across le B. The resistance of leg B (fig. 8-10A) is equa to r2 + r3, or 15 + 15, or 30 ohms. Therefore to find the current of leg B, apply Ohm's law

$I_B = E_B \div R_B$, $I_B = 150 \div 30$, $I_B = 5$ amperes

Now find the voltage across $r_3$.

$E_3 = I_3 \times r_3$, or $E_3 = 5 \times 15$, or $E_3 = 75$ volts

Using the same procedure, find the voltage across $r_3$ of figure 8-10B. Note that there is 150 volts across leg B and that the resistance of the leg totals 50 ohms. Using the formula, $I_B = E_B \div R_B$, find that $I_B = 3$ amperes. Next,

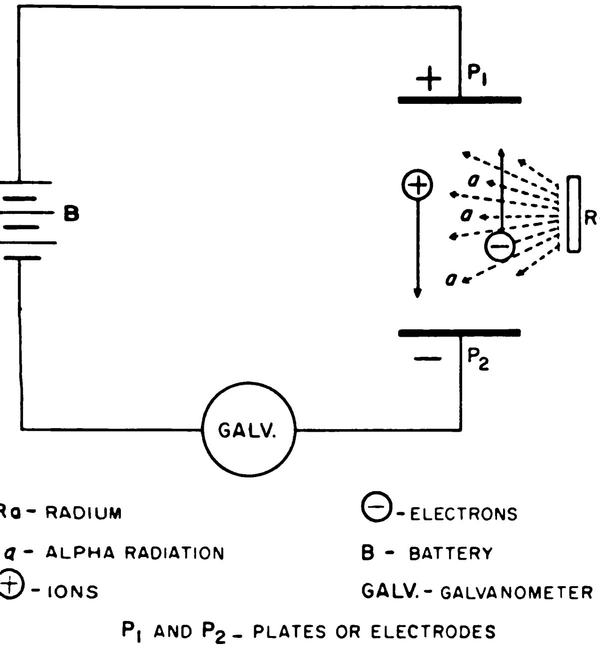
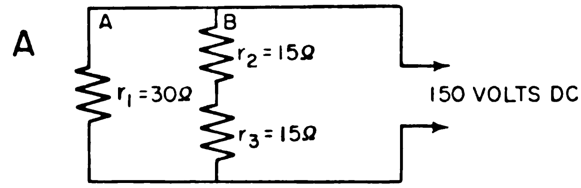
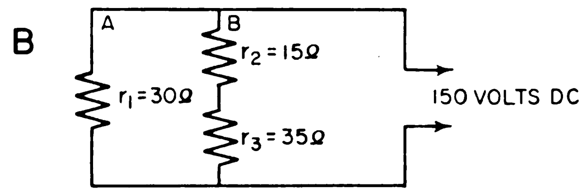



Figure 8-9.—Ionization principle.




| | | |
|---|---|---|
| $R_B = r_2 + r_3$ | $I_B = \frac{E_B}{R_B}$ | $E_3 = I_3 \times r_3$ |
| $R_B = 15\Omega + 15\Omega$ | $I_B = \frac{150}{30}$ | $E_3 = 5 \times 15$ |
| $R_B = 30\Omega$ | $I_B = 5$ AMP. | $E_3 = 75$ VOLTS |




| | | |
|---|---|---|
| $R_B = r_2 + r_3$ | $I_B = \frac{E_B}{R_B}$ | $E_3 = I_3 \times r_3$ |
| $R_B = 15\Omega + 35\Omega$ | $I_B = \frac{150}{50}$ | $E_3 = 3 \times 35$ |
| $R_B = 50\Omega$ | $I_B = 3$ AMP. | $E_3 = 105$ VOLTS |

Figure 8-10.—Parallel circuits.

using the formula $E_3 = I_3 \times r_3$, find that $E_3$= 105 volts. Now find that the voltage across $r_2$ has dropped from 75 to 45 volts.

The GAS DISCHARGE (COLD CATHODE) TUBE has three electrodes: an anode A, a cathode K, and a starter electrode S (fig. 8-11). The breakdown voltage between the anode and the cathode is greater than 270 volts. Therefore with 220 volts applied to A and K, the tube will not fire until triggered by the starter. The control electrodes, S and K, will not trigger the tube until the voltage between them reaches 110 volts.

In the basic circuit of the detector system (fig. 8-12), the normal voltage across the inner chamber X is 130 volts, and 90 volts across the outer chamber and tube elements S and K. The voltage across the tube is 220 volts d-c. There is only enough current flowing to energize the trouble target relay. The current in the circuit flows from the d-c source through the outer and inner ionization chambers, the supervisory resistor (which is in parallel with the chambers), and back to the d-c source.

When a combustion gas enters the outer chamber it increases the resistance of that chamber and causes a current drop. The voltage, across the outer chamber and the tube starter S and cathode K goes up to 110 volts. This triggers the cold cathode tube, causing it to fire from K to A. The tube furnishes the required current to operate the alarm target relay.

# Signals

## AUDIBLE SIGNALS

There are many types of audible signals in use aboard modern naval vessels. The type of signal used depends upon the noise level of the location and the kind of sound desired. Most audible signals are such that a loud and penetrating noise is necessary, but in some cases softer, less strident signals are acceptable.

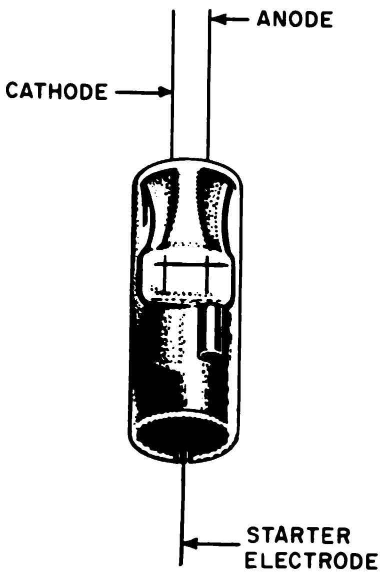
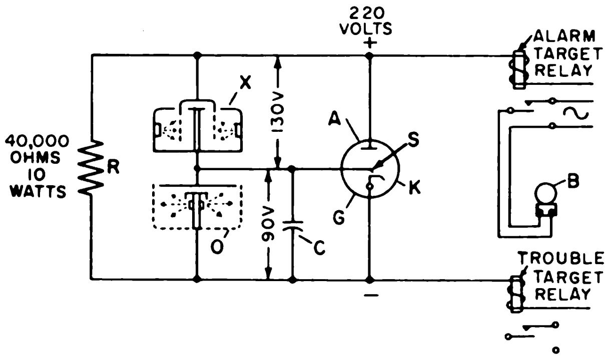



Figure 8-11.—Gas discharge (cold cathode) tube.




X - INNER OR REFERENCE CHAMBER; O - OUTER OR DETECTING CHAMBER,
G - GAS DISCHARGE (COLD CATHODE) TUBE; A - ANODE; K - CATHODE;
S - STARTER ELECTRODE; C - TRIGGER CAPACITOR;
B - ALARM BELL; R - SUPERVISORY RESISTOR.

Figure 8-12.—Basic circuit of detector system.

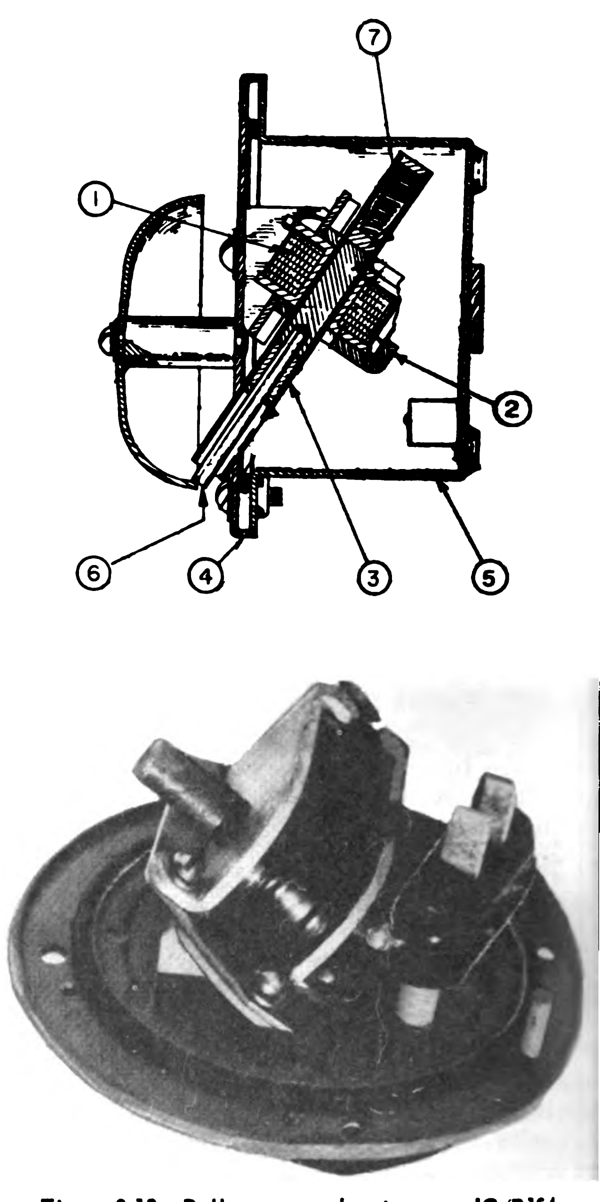



Figure 8-13.—Bell, cutaway drawing type IC/B1S4.

## BELLS

Navy-type bells are divided into two classifications: watertight (W.T.) and watertight explosion proof (W.T.-EXP). The gongs may be of the circular or cow-bell shape.

Figure 8-13 shows a cutaway of the IC/B1S4 bells (W.T.). The 3-in. gong is the circular type. The solenoid (1) and magnet (2) are mounted around the tube (3), which pierces the cover (4) of the mounting box (5). The hammer rod or plunger (6) travels in the tube, which is sealed on the inside of the cover.

When the solenoid is energized it draws the hammer rod upward with a snap against the spring (7). The spring forces the rod down through the tube to strike the gong. The solenoid and spring will continue to snap the rod back and forth as long as the solenoid is energized. Note that there are no contacts to maintain.

The IC/B1S4 (W.T.), IC/B2S4 (W.T.), IC/B2S4 (W.T.-EXP), and IC/B3S4 (W.T.) bells ll operate on the same principle and voltage: 15-volts, 60-cycles. The gong of the IC/B2S4 bell is 8 in. in diameter, and the IC/B3S4 (fig. 8-14) has a cow-bell gong, which gives it a distinctive tone.

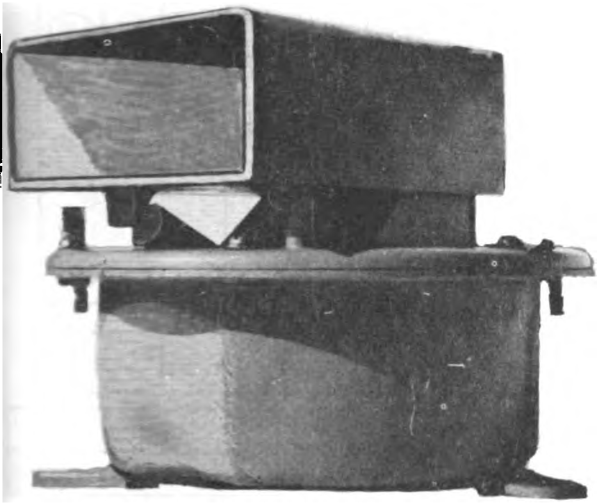


Figure 8-14.—IC/B3S4 bell (cow bell).

The drip-proof bells, IC/B5DS4 (115 volts, 0-400 cycle) and IC/B5S5 (450 volts, -60 cycles), each has two voltages supplied to its two circuits (fig. 8-15). The indicated voltage applies to the bus failure circuit, not the bell.

The 115-volt, 60-cycle motor converts electrical power into mechanical power to ring the bell. Between the motor and the clapper is an assembly of pinion gears, which wind a spiral spring. The spiral spring and star wheel produce the regular timed strokes of the clapper. The motor, designed to stay energized at all times, will wind the spiral spring and then stall. In the wiring diagram (fig. 8-15C) the relay (1) has a quick response, while relay (3) has a time-delay feature.

When the bus failure alarm system is energized, relay (1) of the bus failure circuit closes its contacts (2). This action energizes relay (3), which closes its contacts to operate the motor (6). The motor winds the spring and stalls. If either voltage applied to the motor or the relays fails, the spring will unwind and drive the clapper through the star wheel.

BUZZERS

Buzzers of the low-intensity type (fig. 8-16) are used only in quiet spaces. Type R/Z1 buzzers that operate on direct current are provided with make-and-break contacts, whereas types IC/Z/F4 and IC/Z/S4, designed for operation on alternating current, do not have contacts.

HORNS

Nonresonated horns (types IC/H1D4, IC/H 4D2, and IC/H4D3) utilize a diaphragm actuated by a vibrating armature to produce sound of the required intensity.

Resonated horns in figure 8-17A (types IC/H2S4 and IC/H2D4) also use diaphragms to produce the sound and, in addition, have resonating projections to give the sound a distinctive frequency characteristic. The resonated horn is designed in a variety of types, differing chiefly as to intensity, frequency, characteristics, or power supply.

Motor-operated horns shown in figure 8-17B (types IC/H8D3, IC/H8D4, and IC/H8S3), utilize electric motors to actuate, the sound-producing diaphragms.

SIRENS

Sirens (types IC/S1, IC/S2, IC/S3, and IC/S4) are used in very noisy spaces or to sound very urgent alarms (fig. 8-18). The sound is produced by an electric motor driving a multi-blade rotor past a series of ports, or holes, in the housing. The air being forced by the rotor through these ports gives a siren sound, the frequency of which depends upon the number of ports, the number of rotor blades, and the motor speed.

**VISUAL SIGNALS**

Visual signals are used in a great many alarm and warning systems to provide an additional means of identifying the alarm being sounded. Audible and visual signals are often used together. In noisy spaces audible signals are supplemented by visual signals, and in dark spaces visual signals are supplemented by audible signals. In many instruments the same audible device is used in combination with

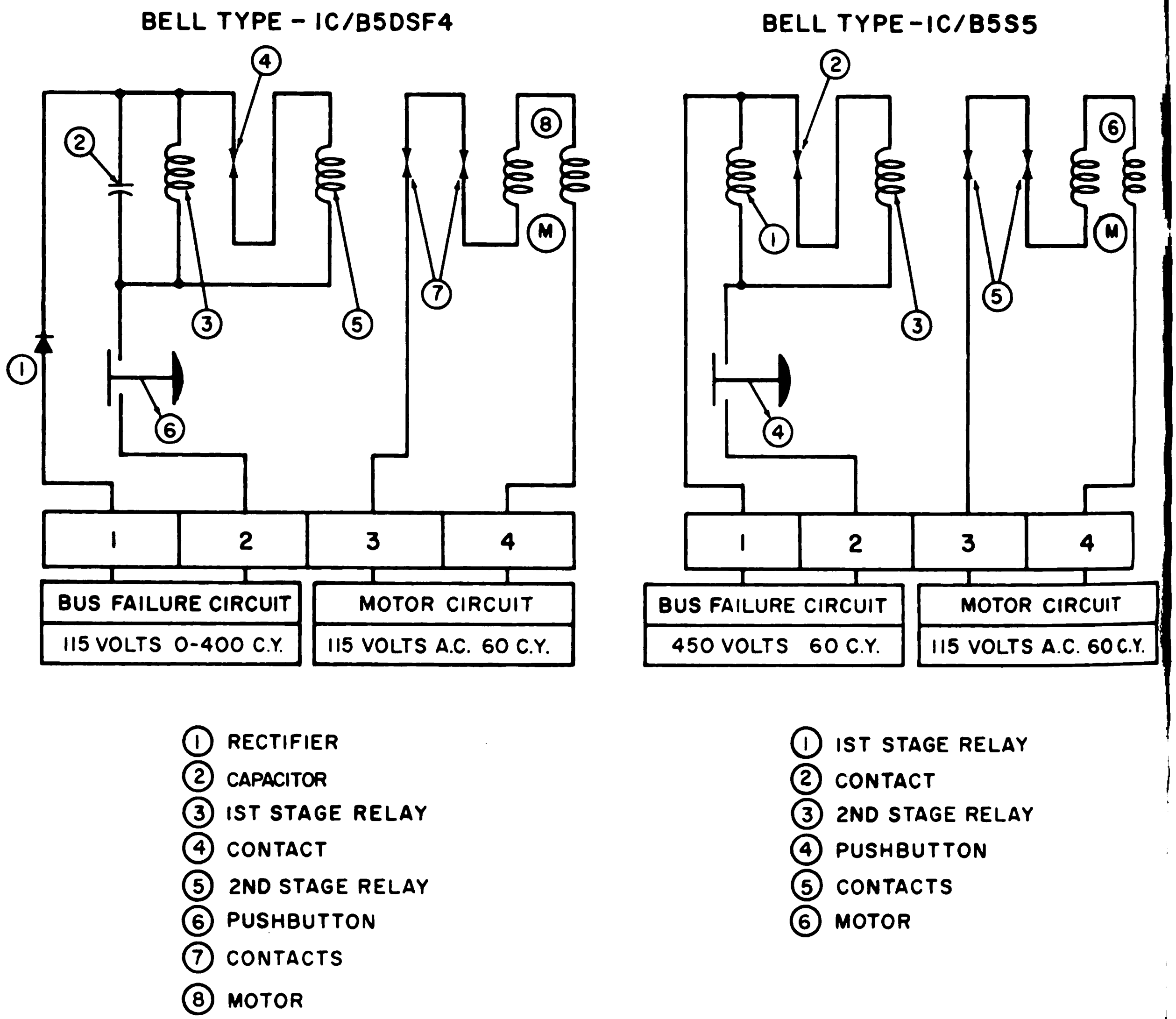



Figure 8-15.—Bell, drip-proof.

several visual indicators. The principal types of visual signals are lamp-type indicators and annunciators.

## LAMP-TYPE INDICATORS

Standard watertight, lamp-type indicators are designed as single-dial, 2-dial, 3-dial, 4-dial, and 6-dial units (fig. 8-19). The indicator contains two 115-volt lamps connected in parallel and mounted behind each dial. The use of two lamps in parallel provides protection against the loss of illumination in case one lamp burns out. A colored-glass disk and sheet-brass target engraved with the alarm identification are illuminated from the rear by the two lamps. Glass disks are furnished in eight standard colors, depending upon the application.

The 115-volt lamps are in parallel with the audible signal. When the audible signal sounds, the lamps illuminate the colored glass and brass target of the indicator and identify the alarm being sounded.

This indicator may be used in the following systems:

1. Lubricating-oil, low-pressure alarm (single-engine installation)
2. Circulating-water, high-temperature alarm (single-engine installation)

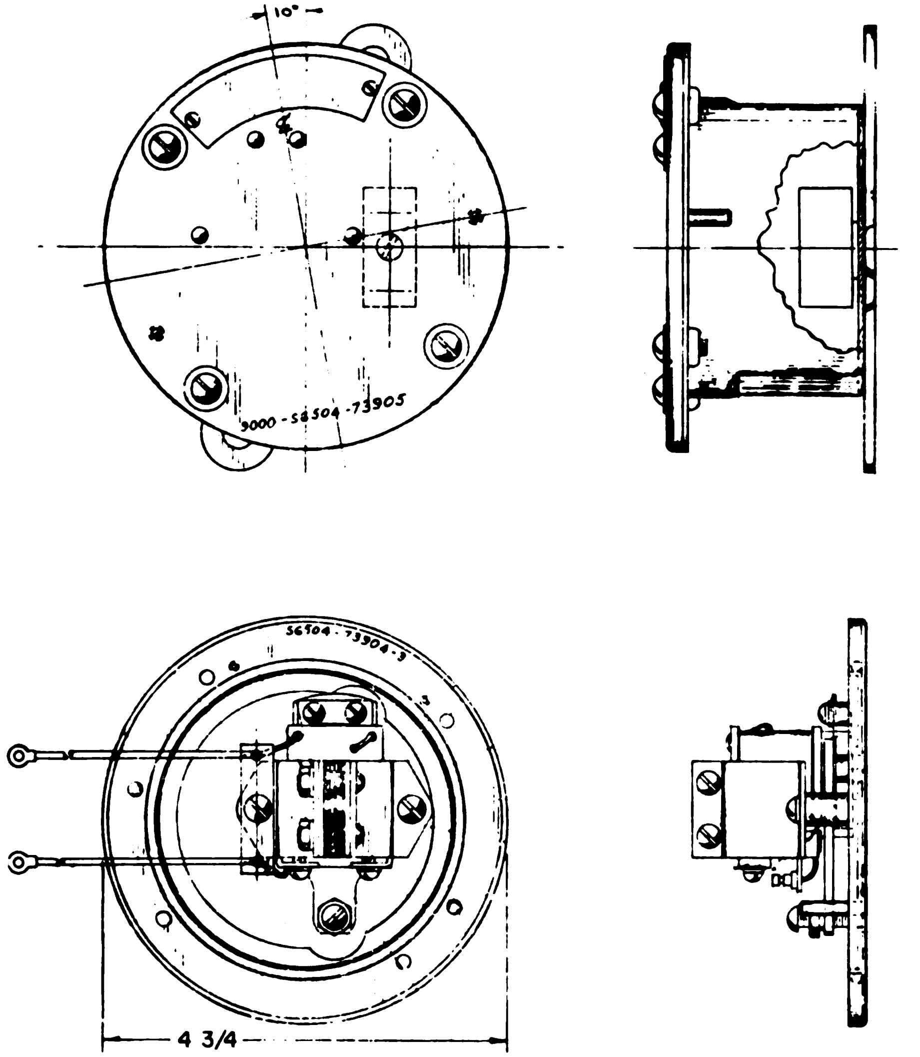
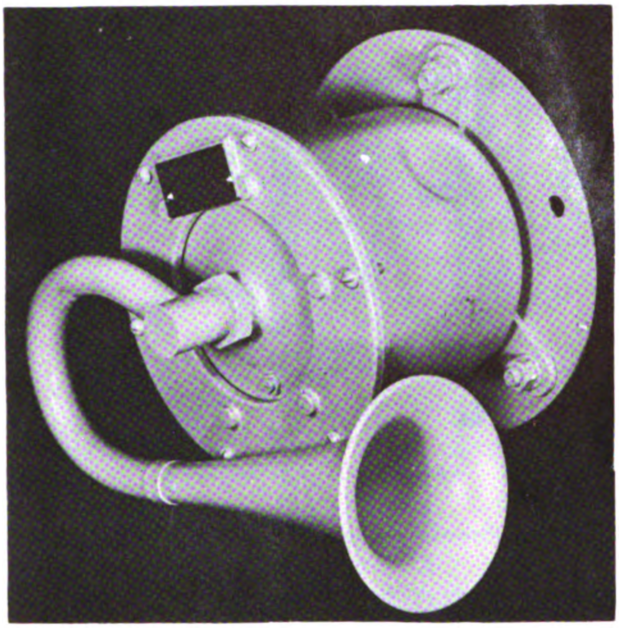



Figure 8-16.—Buzzer-watertight.

3. Fireroom emergency signal
4. Boiler feed signal
5. Hull opening indicator
6. Main ballast tank indicator
7. Boiler temperature alarm
8. Flight deck landing observer's signal
9. Engine control indicator
10. Airlock indicator
11. Traffic control ready light
12. Gasoline compartment, exhaust blower indicator
13. Catapult-control signal
14. Barrier ready light
15. Barrier-up indicator
16. Air-pressure alarm
17. Booster-feed pressure alarm
18. Carbon dioxide release alarm
19. Cruising turbine exhaust alarm
20. Generator-air, high-temperature alarm
21. Wrong-direction indicator
22. Battery-position order
23. Clutch and brake indicator
24. Valve position indicator
25. Water level indicator
26. Auxiliary low-diving plane, tilt-angle indicator
27. Auxiliary stern-diving, plane-angle indicator
28. Auxiliary rudder-angle indicator



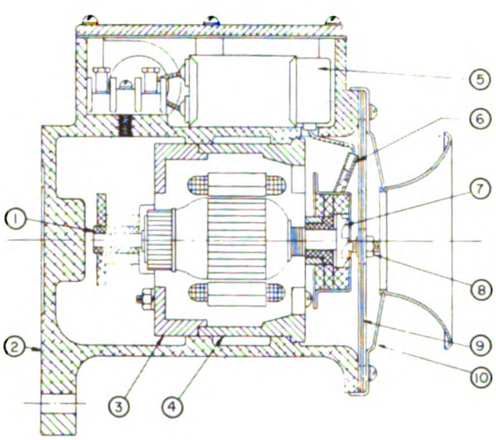



Figure 8-17.—Motor operated—resonant horn.

Standard watertight lamp-type indicators are designed also as 2-dial variable-brilliancy, 2-dial fixed-brilliancy, and 4-dial variable-brilliancy units. The indicator contains two 6-volt lamps in parallel mounted behind each

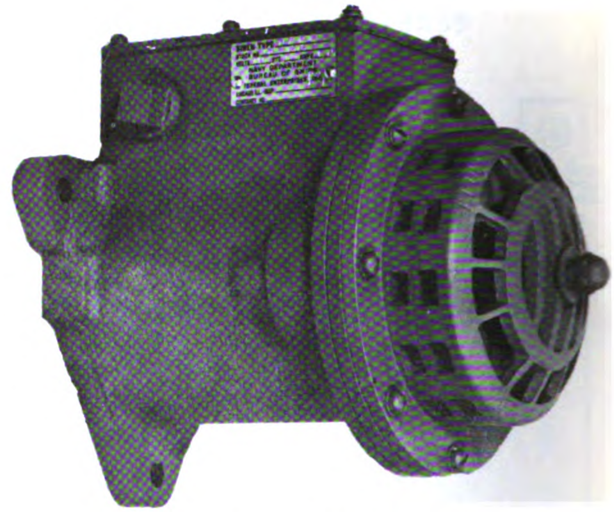


Figure 8-18.—Siren.

dial. A colored jewel disk and sheet-brass target are illuminated from the rear by the two lamps.

The 2-dial and 4-dial variable brilliancy indicators are installed in the barrier-up indicator system. The 2-dial fixed-brilliancy indicator is used with the valve-position indicating system.

Special lamp-type indicator panels are designed to give good visibility at all viewing angles. These panels contain rows of prism-shaped red and green jewels. Each indicator has two 6-volt lamps in parallel. This type of indicator is used in the main ballast tank and hull opening indicator system.

Another special lamp-type indicator consists of two indicator lights (red and green). Six 115-volt lamps in parallel are provided for each indication. This indicator is used in the traffic control ready light system.

## ALARM INDICATORS

Each two-line alarm unit provides complete equipment for supervising two circuits. Each circuit requires an alarm-target relay, a supervisory-target relay, and a three-position, toggle-type test switch. The two-line unit (fig. 8-20) has two alarm relays mounted side by side at the rear and near the bottom of the unit panel. Each relay has an indicator drum that projects into square openings in the face of the panel. The two test and cutout switches are

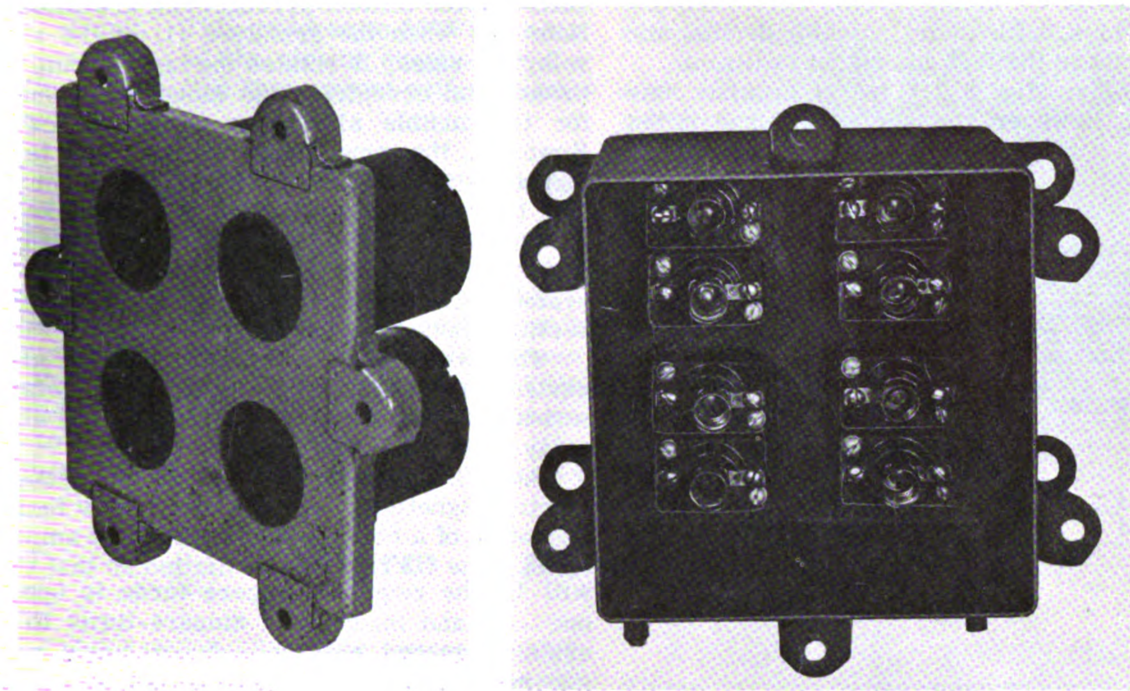


Figure 8-19.—Lamp-type indicator.

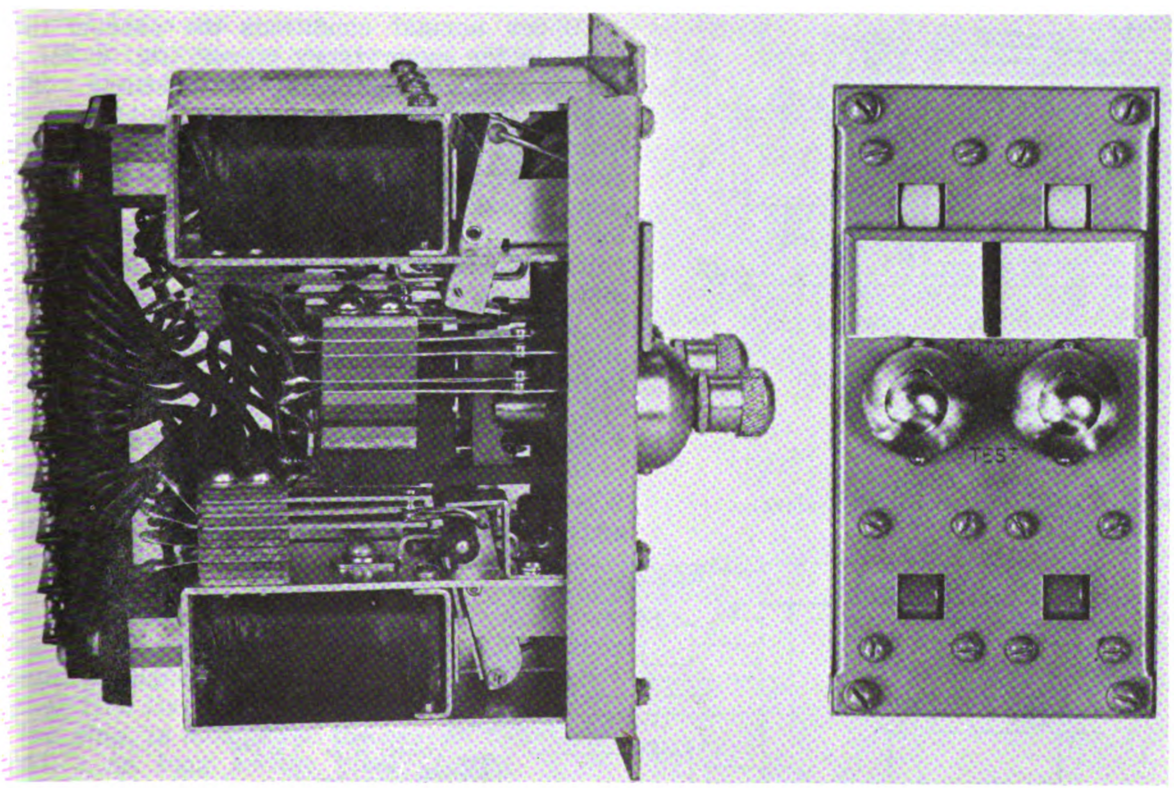


Figure 8-20.—Two-line alarm unit.

mounted above the alarm relays. The two supervisory relays, with their indicator drums, are mounted above the test and cutout switches.

The relays (fig. 8-21) are of similar construction. However, the number of turns on the coils and the contact arrangement are different. Note that when the armature (1) of the alarm relay operates, it rotates the target drum (2B) through an eccentric, and closes the contacts for the audible alarms by moving roller (3). However, the supervisory target relay is designed to be normally operated; its alarm contact is closed when the relay is deenergized.

The alarm drum has a red section that rolls into view when the alarm target relay is operated. The supervisory drum shows a yellow section when it is deenergized.

The two relays are in series with the alarm device (fig. 8-22). The supervisory relay is wound with more turns of wire than the alarm relay.

*Basic Electricity*, NavPers 10086, discusses electromagnetism. A review will show that the operation of a relay is dependent on the ampere-turns. The current can be limited so that there will be the required ampere-turns to operate one coil and insufficient ampere-turns to operate a second coil with fewer turns. The supervisory resistor (fig. 8-22) is in series with both relays under normal conditions and acts as a current-limiting device.

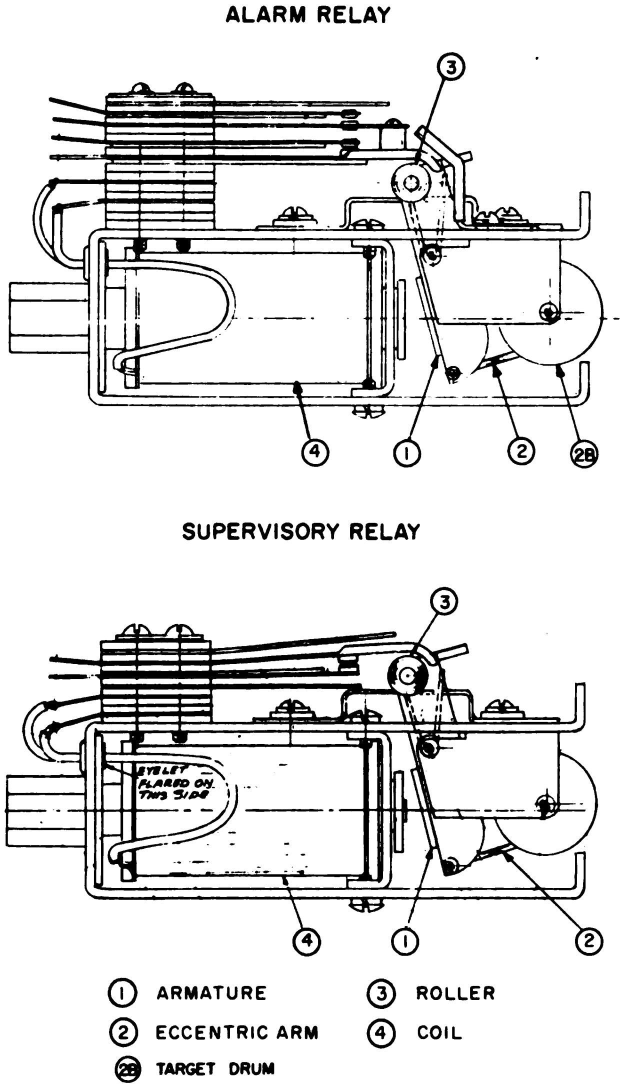



Figure 8-21.—Alarm and supervisory relays.

Under normal conditions the current that flows in the supervisory circuit (fig. 8-22) is supplied by a transformer and rectifier. The current flows from the negative side of the rectifier through the operated supervisory target relay, the supervisory resistor, the lower section of the mercurial thermostat or alarm device, the energized but not operated alarm target relay, and back to the rectifier. The total resistance of the circuit supplied by the rectifier is 9675 ohms. Assume that the rectifier is supplying 120 volts d-c, and apply Ohm's law to find the current flow.

$$I = \frac{E}{R},\ I = \frac{120}{9675} = .0124 + \text{ amp or } 12.4 + \text{ milliamps.}$$

When the temperature rises at the alarm device, and the mercury reaches the upper contact, the

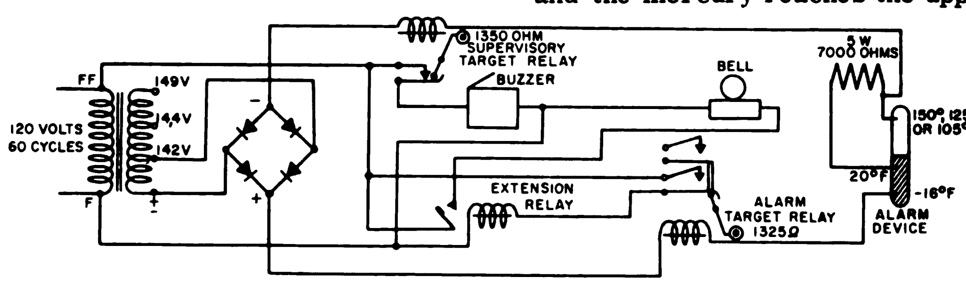



Figure 8-22.—High-temperature alarm circuit.

)00-ohm supervisory resistor is shunted out the circuit. This reduces to 2675 ohms the tal resistance of the circuit supplied by the ectifier. Now find the current with the same ssumed voltate,

$$= \frac{E}{R}, J = \frac{120}{2675} = .0448 + \text{amp or } 44.8 \text{ milliamps.}$$

This increase in current is enough to operate e alarm target relay. The alarm-target relay ı operating rotates its red target into position nd closes the contact that completes the circuit ) the extension relay, which is supplied power rom the primary side of the transformer. When e extension relay operates, it closes the contacts to complete the circuit to the bell. The ell furnishes the audible alarm and the target drum the visual signal, to indicate which circuit has the high-temperature alarm.

A loss of current in the supervisory circuit will cause the supervisory-target relay to release its armature. When the armature drops down it closes the alarm contact to complete the circuit from the primary side of the transformer to the buzzer. The target drum furnishes the visual signal of the circuit in trouble.

An open circuit in either side of the transformer, the rectifier, or the supervisory circuit will cause the buzzer to sound.

Each electromagnet actuates contacts for energizing common audible signals. A nameplate is provided on the panel to identify the alarm being sounded. A switch is provided to test the circuit and to cut off the alarm.

# Alarm Systems Equipment

The high-temperature alarm system (circuit F) is one of the alarm and warning systems you will be required to service. It is an electrical system installed aboard ship to detect and warn of fires or overheated conditions in important compartments and spaces.

All alarm systems used in naval vessels are of the closed-circuit supervisory type. Each circuit of the system consists primarily of one trouble-alarm relay, one cutout key, one alarm signal, and one thermostat or group of thermostats.

## ALARM PANELS AND SWITCHBOARDS

The alarm switchboard is installed in a station, which is continuously manned while both underway and in port. The alarm switchboard operates on 120-volt, a-c, 60-cycle, or 120-volt, d-c service supplied from the main I.C. switchboard. The alarm switchboard consists of an upper section and a lower section.

The UPPER section comprises the alarm panel (fig. 8-23). This panel contains an alarm bell, a test light, a trouble buzzer, two ground-detector lamps, a pilot lamp, a trouble test lamp, an alarm test lamp, and a test key. An extension signal relay, capable of operating up to four fire alarm bells located at other stations on the ship, is mounted at the rear of the alarm panel. As long as the power supply to the switchboard is maintained, the pilot light at the center of the panel glows.

The LOWER section consists of as many 10-line or 20-line panels as are necessary to care for the total number of high-temperature, circuit F, or water-sprinkling circuit FH stations aboard the ship. Six 10-line panels capable of taking care of 60 lines are shown in figure 8-23. The switchboard apparatus for each two lines is mounted together in a removable alarm unit. Five or ten of these 2-line units are arranged to make up a 10-line or a 20-line panel. Each line supervises one thermostat or one group of thermostats. Each circuit is provided with a separate test key with a drum trouble-indicator target above, and a drum fire-indicator target below. A nameplate located above the test key identifies the compartment or the spaces served by that line.

## THERMOSTATS

As previously mentioned, the detection of fires or overheated conditions is accomplished by means of mercurial thermostats. These thermostats are installed at selected locations throughout the ship. Thermostats are installed on the overhead and require a free circulation of air for efficient operation. Barriers that would obstruct the free circulation of air should never be placed around thermostats in any compartment. On the other hand, thermostats should not be installed in the path of supply ventilation.

The thermostats are designed to close their contacts at temperatures of 105°, 125°, or 150° F.

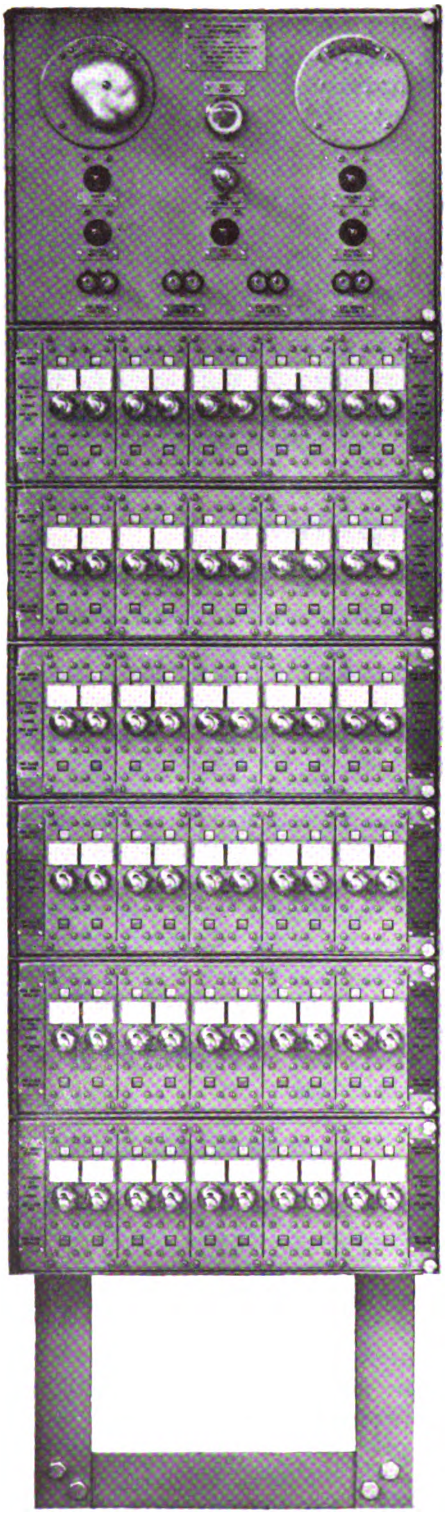


Figure 8-23.—Alarm switchboard.

## THERMOSTAT REPLACEMENT

These types are similar except for their respective temperature ratings. When a thermostat is defective, care must be exercised to replace the thermostat with one having the same temperature rating.

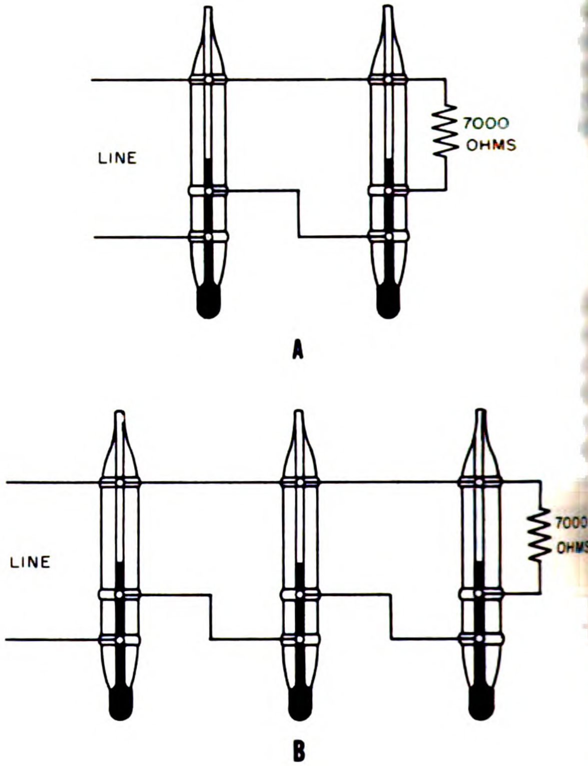



Figure 8-24.—Thermostat connections.

## TEMPERATURE RATINGS

The 125° and 150° F thermostats are normally installed in storerooms, paint lockers, and similar spaces used to house combustible stores. The 105° F thermostat is normally installed in magazines. Because its function is to detect rises in temperature above the limits that are safe for magazine spaces, the upper contact is located so that the resistor is shorted out when the temperature reaches 105° F.

As many thermostats as are needed for the rompt detection of a fire can be connected to ny one line. If more than one thermostat is sed in a compartment, only one supervisory esistor is required, as shown in figure 8-24A nd B. With such a connection, when any one of e thermostats in the group is overheated, the larm operates. These thermostats or groups f thermostats are connected to the alarm witchboard by multiconductor cable. Each circuit on the alarm switchboard is marked to desgnate one compartment, and the thermostat, r group of thermostats, installed in each comartment is connected to the circuit marked for hat compartment.

## OPERATION

When conditions are normal, direct current lows from the full-wave rectifier through the upervisory target relay, the supervisory resistor, to the intermediate contact of the thernostat, through its mercury column to the lower contact, and through the alarm target relay to he rectifier. The current is limited by the 7-k ohm resistor to a value required to operate the supervisory target relay. This value is smaller than that required by the alarm-target relay.

In case of fire or other high-temperature condition the mercury expands and rises in the thermostat, the supervisory resistor is shorted out, and the current rises to a maximum value in the circuit. The increase in current is large enough to cause the alarm target relay to operate. The relays target is revolved and the alarm contacts close, to sound the alarm.

When an open circuit occurs, such as in the secondary of the transformer or a broken thermostat bulb, the supervisory current no longer flows in the circuit and the supervisory relay deenergizes. This action closes its contacts and completes the circuit to the buzzer and the target is rolled to show yellow.

A switch is provided in each circuit for use in testing the circuit and for silencing either the fire bells or trouble buzzer when they sound an alarm. Complete tests and operating instructions are included in the manufacturer's instruction book that is provided for the alarm equipment installed in your ship. The instruction book should be studied carefully and its procedures followed closely at all times when servicing this equipment.

## SPRINKLING ALARM SYSTEM

The sprinkling alarm system, circuit FH, is basically the same as the high-temperature alarm system except that water switches are used instead of mercury thermostats.

## LUBRICATING-OIL, LOW-PRESSURE ALARM SYSTEM

The purpose of the lubricating-oil, low-pressure alarm system, circuits 1EC and 2EC, is to sound an alarm whenever the pressure in the lubricating-oil supply line to the main engine and reduction gear, or to the turbine-driven or diesel-driven generators, and other auxiliary machinery falls below a predetermined minimum limit. Where the system is used for the main engines the circuit is designated, 1EC, and when used for either turbine-driven or diesel-driven generators and other auxiliaries the circuit is designated, 2EC. Both circuits are energized from individual switches on the I.C. switchboard.

An EC circuit includes one or more pressure-type switches installed in the lubricating-oil lines of the associated equipment. A dial-light indicator, drum - type annunciator , and siren are energized when the switch is closed because of a decrease in oil pressure. The control panel of the lubricating-oil, low-pressure alarm is located near the operating control board of the machinery on which the switch is installed.

## CIRCULATING-WATER, HIGH-TEMPERATURE ALARM SYSTEM

The circulating-water, high-temperature alarm system, circuits 1EW and 2EW, automatically indicates when the circulating-water temperatureof the main propulsion diesel engines or the large auxiliary diesel engines rises above a predetermined maximum limit. When the system is used for the main engines

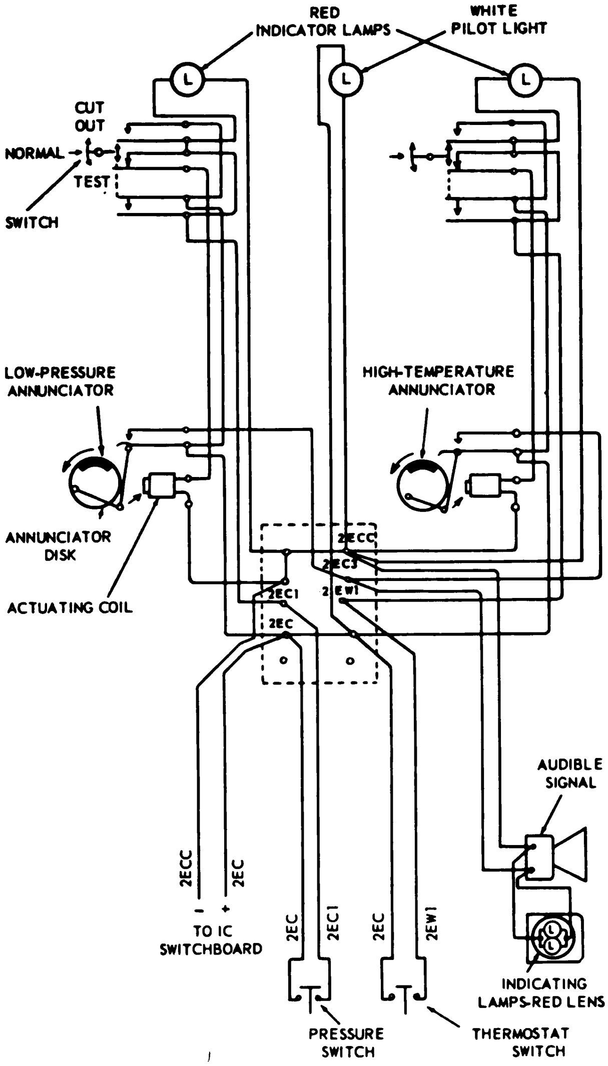



Figure 8-25.–Schematic of 2EC and 2EW circuits.

the circuit is designated, 1EW, and when used for auxiliary engines the circuit is designated, 2EW. The circulating-water, high-temperature alarm system is usually combined with the lubricating-oil, low-pressure alarm system (fig. 8-25), and consists of temperature-operated switches located in the circulating water lines of the engines. A rise in temperature above a predetermined point closes a thermostatic switch, which energizes a lamp-type indicator, drum-type annunciator, and siren, causing the alarm to sound.

## QUIZ

1. Why are alarm and warning systems used?
2. What circuit is designated by the letter, FW?
3. Where is the range adjusted on the type IC/L pressure switch? (Refer to figure 8-1.)
4. What produces the bellows motion in the type IC/N thermostatic switch?
5. Between what temperature ranges may the type IC/N thermostatic switch be adjusted?
6. How is the point of operation varied in the cam-action mechanical switch? (Refer to figure 8-3.)
7. What general type of switch is used with circuit DW, or wrong-direction alarm system?

How does the 5-watt, 7000-ohm resistor, mounted in the water switch, affect the current in the supervisory circuit when the switch casting is dry?

How does an operating relay produce a change in its own or other circuits?

What part of the relay (fig. 8-5) operates the contact springs?

Name three types of alarm and warning signals that may be operated by relays.

How is a motor-operated relay used in the primary (controlled) circuit (fig. 8-6)?

Name three types of push switches enclosures.

Name three indications of fire.

Name the two methods of fire detection used by the Navy in its circuit, F, fire alarms.

What is the function of the mercury in the mercurial thermostat (fig. 8-7)?

How may the detector head be divided into three major units?

If the ionization chamber in figure 8-9 is operating at saturation, what will cause a change in current flow?

What affect does the gas product of combustion have on current flow (fig. 8-9)?

How much current flows through R2 and R3 (fig. 8-10)? What will the current be if R3 is changed to 35 ohms? What is the voltage across the 35-ohm resistor?

What voltage will trigger the cold cathode tube?

22. What two items cause the hammer rod to to snap back and forth in the watertight bell (fig. 8-13)?
23. What is the purpose of the 110-volt, 60-cycle motor in the bus failure alarm (fig. 8-15)?
24. What are the two principal types of visual signals?
25. Why are two parallel lamps provided in the lamp-type indicator?
26. Why are the lamps in the indicator unit (fig. 8-19) connected in parallel with the audible alarm?
27. What unit may be limited so that there will be the required ampere-turns to operate one coil and insufficient ampere-turns to operate a second coil with fewer turns?
28. How does the supervisory resistor, which is in series with the two relays, act (fig. 8-22)?
29. With 120 volts d-c supplied to a series circuit with 9675 ohms, what current will flow?
30. An open circuit in what two units as well as the supervisory circuit will cause the supervisory relay to release its armature (fig. 8-22)?
31. What is the purpose of the extension signal relay (fig. 8-23)?
32. How many compartments may be protected by each circuit of the fire alarm system?

## CHAPTER 9

# SOUND-POWERED TELEPHONES

## Introduction

Telephones provide a rapid and efficient means of communication between the many stations in a modern naval vessel. A satisfactory telephone system must be reliable and not susceptible to damage during battle; it must make possible the rapid completion of calls; and it must be maintained easily by personnel aboard ship. The sound-powered telephone fulfills these requirements. As the name implies, the sound-powered telephone requires no outside power supply for its operation. The sound waves produced by the speaker's voice provide the energy necessary for the reproduction of the voice at a remote location.

### BATTLE TELEPHONE CIRCUITS

Sound-powered telephone circuits, vital to the operation of the ship, are called battle telephone circuits. In addition to the batt telephone circuits, an automatic dial-type tele phone system is installed in all large ship and in some small ones. This automatic sys tem is for administrative purposes and is n depended upon under battle conditions. The auto matic telephone is discussed in more advance IC training manuals.

### TYPES OF UNITS

The basic types of sound-powered units ar (1) cantilever unit, (2) balanced-armature unit and (3) bipolar unit. All sound-powered unit operate on the same principle. The genera theory is explained briefly.

## Sound-Powered Unit

### CONSTRUCTION

The sound-powered transmitter and receiver units are of the same general construction. Although there are a few minor differences between the transmitter and the receiver—such as the length of contacts, shape of the armature, number of turns, and size of wire in the coils—the operation of the transmitter is identical with that of the receiver.

As illustrated in figure 9-1, a unit may consist of two permanent magnets, two pole pieces, an armature, a driving rod, a diaphragm, and a coil. The armature is located between four pole tips, one pair at each end of the armature. The spacing between the pole tips at each en is such that an air space remains after th armature is inserted between them. This ai space has an intense magnetic field, which i supplied by the two magnets that are held i contact with the pole tips.

The armature is clamped rigidly at one en near one of the pairs of poles and is connecte at the other end to the diaphragm by the driv rod. Hence, any movement of the diaphragm causes the free end of the armature to move toward one of the pole pieces. The armature passes through the exact center of a coil of wire that is placed between the pole pieces in the magnetic field.

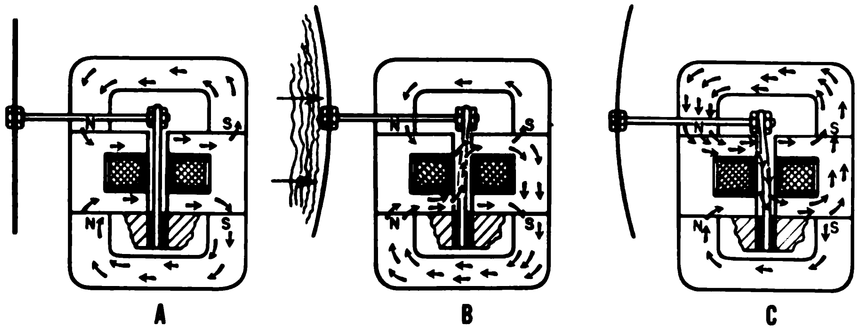



Figure 9-1.—Sound-powered transmitter unit.

## OPERATION

Sound waves are compressions and rarefactions of the medium in which they travel. When a diaphragm is placed in the path of a series of sound waves, the waves cause the diaphragm to vibrate. The armature of a transmitter unit, when there are no sound waves striking the diaphragm, is shown in figure 9-1A. Note that the armature is centered between the pole pieces with the magnetic lines of force passing from the north to the south pole and that there are no lines of force passing lengthwise through the armature.

When sound waves strike the diaphragm and cause it to vibrate, the vibrations are impressed upon the armature by means of the drive rod, as shown in figure 9-1B, and C. During the compressional part of the wave this action causes the armature to bend and reduce the air gap at the upper south pole. The reduction of the air gap decreases the reluctance between the upper south pole and the armature, while increasing the reluctance between the armature and the upper north pole. This action reduces the lines of force that travel between the two upper pole pieces. There is no large change in the reluctance at the lower poles; however, the armature has less reluctance than the lower air gap and a large number of magnetic lines of force will follow the armature to the upper south pole. Thus, an emf is induced in the coil by the lines of force that are conducted along the armature and up through the coil.

When the sound wave rarefaction reaches the diaphragm, it recoils, as shown in figure 9-1C, thus causing the armature to bend in the opposite direction. This action reduces the air gap between the armature and the north pole. Note that the reluctance between the armature and upper north pole is decreased and that the lines of force are reestablished through the armature, this time in the opposite direction. Thus, an emf is induced in the coil by the lines of force that are conducted along the armature and down through the coil. This emf is in the opposite direction to that of the emf induced when the lines of force are established, as shown in figure 9-1B.

Sound waves striking the diaphragm cause it to vibrate back and forth. The armature bends first to one side and then to the other, causing an alternating polarizing flux to pass through it, first in one direction and then in the other. These lines of force passing through the armature vary in strength and direction, depending upon the vibrations of the diaphragm. This action induces an emf of varying direction and magnitude—that is, an alternating voltage—in the coil. This alternating voltage has a frequency and waveform similar to the frequency and waveform of the sound wave striking the diaphragm.

When this unit is used as a receiver it operates in a similar manner. The alternating voltage generated in a transmitter unit is impressed upon the receiver coil, which surrounds the armature of the receiver unit (fig. 9-2). The resultant current through the coil magnetizes the armature with alternating polarity. An induced voltage in the coil of the transmitter (fig. 9-2A) causes a current to flow in the coil of the receiver (fig. 9-2B) magnetizing the free end of the armature, arbitrarily with north polarity. The free end of the armature, therefore, is repelled by the north pole and attracted by the south pole. As the direction of the current in the receiver reverses, the polarity of the armature reverses.

Thus, the position of the armature in the air gap reverses, forcing the diaphragm inward and rarefying the air before it. Hence the diaphragm vibrates in unison with the diaphragm of the transmitter and generates corresponding sound waves.

# Equipment

The two types of sound-powered telephones installed in naval vessels are (1) handsets and (2) headsets. Handsets are designed to be held in the hand, whereas headsets are designed to be worn. The receivers are mounted on a headband, and the transmitter is mounted on a chest plate. All telephones of a given type are built to the same general specification, regardless of the manufacturer. Parts made by one manufacturer, however, are not interchangeable with those made by another manufacturer even though the phones are of the same type.

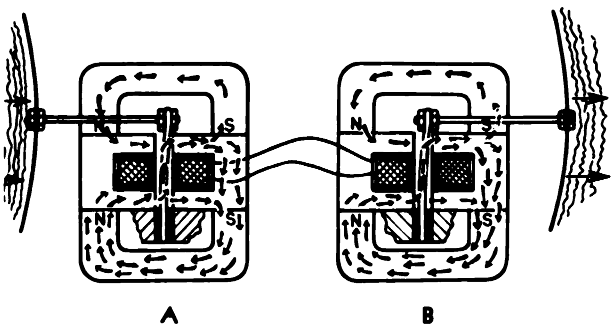



Figure 9-2.—Operation of sound-powered transmitter and receiver units.

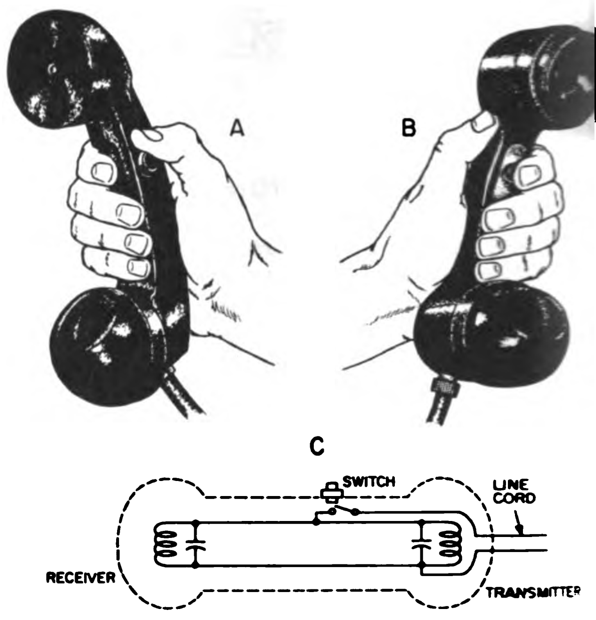



Figure 9-3.—Sound-powered telephone handsets. (A) Type-TA; (B) Type-L; (C) Wiring diagram.

## HANDSETS

### TYPE-TA

The type-TA handset (fig. 9-3A) consists of a handle or shell of molded composition that contains a sound-powered receiver unit, a transmitter unit, and a switch. When the switch is closed, the transmitter and receiver units are connected to the telephone circuit for both listening and talking (fig. 9-3C). The purpose of the switch is to prevent the pickup of external noise by the telephone when it is not in use. This feature also reduces the number of units connected on any line to those actually in use. The receiver and transmitter units are held in position in the handle by screws and are built so that they may be interchanged. The units are connected in parallel by spring contacts that make connection as the units are inserted into the housing.

The switch on the handset, which is normally open, is located on the side of the handle. A capacitor is connected in parallel with both the transmitter and receiver units to improve their operating characteristics. The line has a lagging power factor because the inductance of the sound-powered units is high. The capacitance tends to reduce the inductive effect and raise the power factor of the line nearer to unity.

Handsets are connected permanently at a jackbox selector switch, or magneto ringer, and are provided with bulkhead mounted handset holders. Each holder is equipped with a spring, which prevents the set from falling out of the holder. When not in use, handsets should always be placed firmly in these holders (fig. 9-4).

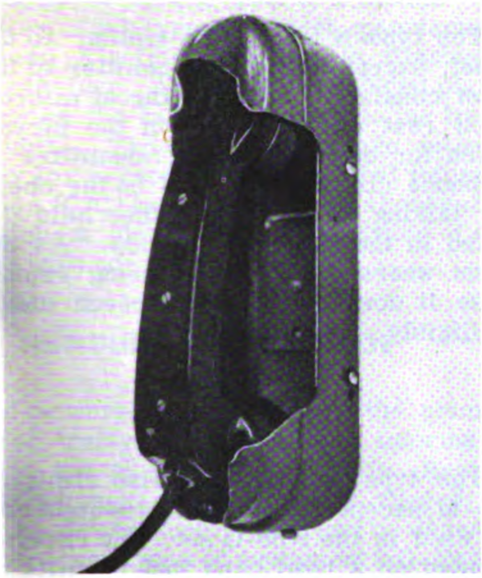


Figure 9-4.—Handset and holder.

### TYPE-L

The type-L handset (fig. 9-3B) is being re- aced by the type-TA. Although they have milar wiring, they are constructed differently.

## HEADSETS

### TYPE-SA

The type-SA headset (fig. 9-5A) consists of o receiver units with their protective shells d earcaps, a headband for holding the re- ivers in place over the ears, a chest plate which is mounted a transmitter unit in an ljustable yoke, and a junction box in which the nnecting cords are connected. A switch is ounted in the transmitter shell to connect the ansmitter unit into the telephone circuit. This ature prevents the pickup of outside noise by e transmitter when it is not in use. The but- n is depressed only when talking. Thus, it revents the volume reduction that would other- ise be caused by the low impedance of the ansmitter circuit. The impedance of the ansmitter unit is lower than that of the re- eiver units. When the telephone set is plugged n, the receivers are connected permanently into the telephone circuit. When not in use, the headset always should be disconnected from the jack box. If the set is not disconnected the receiver units act as transmitters and pick up outside noise.

Some headsets have large receiver units and thick rubber earcaps. They cannot be worn under the standard combat helmet.

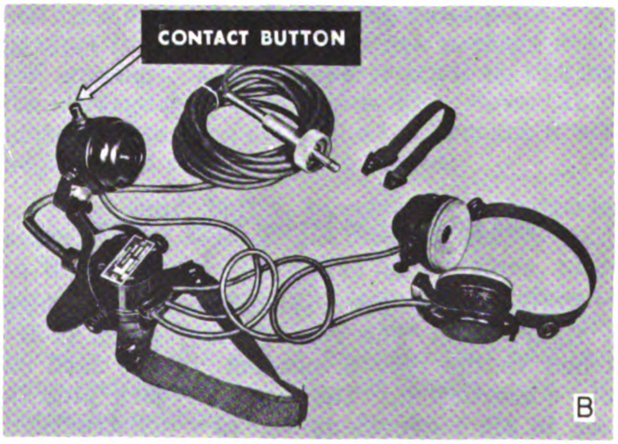




Figure 9-5.—Sound-powered telephone headsets.

The type-SA headset, an improved design, replaces the types M and O headsets. This headset is similar to the type-M headset (fig. 9-5B) except that the type-SA set is designed with thinner earpieces that may be worn under the standard helmet. The type-SA headset has greater comfort, lighter weight, and higher efficiency than any of the other sets.

The wiring diagram of the type-SA headset is shown in figure 9-6. The receivers and transmitter are in parallel with each other and with the line. The transmitter and receiver units are not interchangeable on any type of headset. The transmitter unit has a small flexible cord connecting it to the junction box on the breast plate. The receiver units are also connected to this box by means of small flexible leads. A capacitor is mounted on the chest plate in parallel with the sound-powered units to improve their operating characteristics. A long, heavy cord connects to the junction box on the chest plate at one end and to a telephone plug at the other end. This plug permits a water-tight connection to be made at the jack box. The chest plate is suspended from the neck by a neck band.

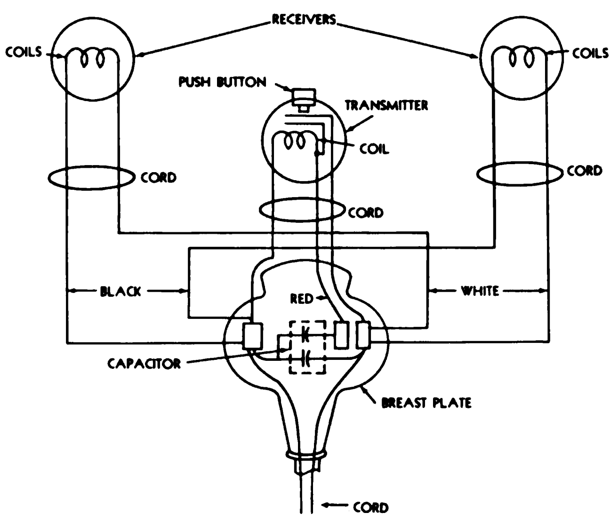



Figure 9-6.—Type-SA headset wiring diagram.

Notice the two different telephone jack plugs in figure 9-5. The type-T plug, which is attached to the type-M headset, is not used on new construction. The type-S/P jack plug is used in all conversions and new construction. When a ship has had a partial conversion, the I.C. Electrician may find both types of plugs.

## TYPE-N

The type-N headset is similar to the ty M set, except that the transmitter of the ty N set consists of a pair of throat micropho which rest on each side of the larynx. ' switch for connecting the transmitter into telephone circuit is located on the chest pl For talking, it may be either held down, locked in the CLOSED position. As this t of set wears out, it is not being replaced cause it does not produce speech clearly intelligibly.

## TYPE-O

The type-O headset is also similar to type-M, except that small light-weight receiv are used in the type-O set. The receivers mounted on a head band that permits them be worn under a standard helmet. The typ headset receivers carry the sound directly i the ear by means of ear tips that fit into ear canal. These ear tips are used to co efficiently the small receiver units to the and to shut out external noise. As exis stocks of the type-O are exhausted, they being replaced by improved types.

## TYPE-P

The type-P headset is identical to the ty N set, except that in the type-P set the mi receiver units of the type-O set are used. I cause of these small receiver units, the typ also may be worn under standard helm

## TYPE-Q

The type-Q headset replaced the type-N type-P headsets. The type-Q has the conv tional receivers and head band. The junc box, however, is fitted with a clip that all it to be attached to the wearer's belt or ot articles of clothing instead of to a chest pl This junction box also contains the press-talk switch, which may be locked in the CLOS position when desired. The transmitter of type-Q set, manufactured by R.C.A., is moun at one end of a boom, and the other end is tached to the head band assembly. The posit

the boom may be adjusted to place the trans-
tter in front of the wearer's mouth. The
ınsmitter of the type-Q headset, manufactured
Western Electric Company, is attached to
left receiver. An adjustable molded plastic
rn carries the talker's speech to the trans-
tter unit. Type-Q headsets are intended
imarily for personnel in the combat informa-
n center (CIC) and plotting rooms because the
ngling chest plate of the other types of sets
erfere with normal duties.

## HANDLING AND STOWAGE

Sound-powered telephones are the primary
ıans of relaying orders and information
roughout the ship in time of battle. Because
ese telephones are extremely rugged and
quire no power supply, they can be depended
on when other types of equipment fail. Battle-
nouncing equipment consists of many electron
es that are susceptible to damage by shock
case of a hit or near miss. Automatic tele-
ones have delicate switches and relays that
y be damaged by shock. Therefore, neither
these systems is relied upon in time of battle.

It is not possible to overemphasize the care
quired in the handling of telephone sets. The
ttle telephone equipment furnished naval ves-
ls is essentially very rugged. There are cer-
n forms of abuse, however, against which it is
actically impossible to guard in the manu-
ture of telephone equipment.

The connecting wires secured to the various
rtions of telephone sets have but one purpose—
transmit electric current. They are not pro-
led as straps for supporting the equipment
r should they be subjected to a jerk or fall.
hen a plug is removed from a jack, the BODY
the plug should be pulled—never the CORD.
nnections should be made so that a minimum
physical strain is put on the electric con-
ctors. If the talker must remove the tele-
one set from his head, he should hang the
t by the head band and the neck strap—not by
y of the connecting wires.

The unit is made as waterproof as possible,
t is should not be exposed unnecessarily to
e weather. Moisture and good telephone
rvice do not go hand-in-hand. Remember
at several conductors, which actually carry
e messages to and from the telephone, lie
derneath the rubber covering on the
rious electric cords on the set. Although these cords are quite flexible, they should not be dragged over sharp edges, pulled too hard, or allowed to kink. The cords are especially susceptible to damage because of their small size. If you instruct other men on how to handle telephones, emphasize the importance of handling the set with care so that the set will not be out of order in an emergency.

Telephone headsets used in exposed areas are stowed in boxes located on weather decks. Those sets used in protected areas are stowed on bulkhead hooks located in various compartments. The set must be made up properly for either means of stowage. Use the following procedure to make up a sound-powered telephone headset for stowage.

1. Remove the headband and hang the headband over the yoke of the transmitter.
2. Remove the phone jack and secure the jack box cover to keep out moisture and dirt. Lay the line out on the deck and remove any kinks. Begin coiling from the end that attaches to the chest plate. Coil the line with the right hand, making the loops in a clockwise direction. The loops should be about 10 inches across.
3. When the lead is coiled, remove the ear pieces from the transmitter yoke and hold the headband in the same hand with the coil.
4. Fold the transmitter yoke flat, using care not to pinch the transmitter cord.
5. Holding the headband and coil in the left hand, unhook one end of the neck strap from the chest plate.
6. Bring the top of the chest plate level with the coil and headband. Secure the chest plate in this position by winding the neck strap around the coil and headband just enough times so that there will be a short end left over. Twist this end once and refasten it to the chest plate. The headset is then made up in a neat package ready for stowing. A set properly made up fits into its stowage box without forcing. Never allow loose cord to hang out of the box because it may be damaged when the lid is closed.

Stow only battle telephones in telephone stowage boxes—never put cleaning gear or tools in these boxes. Rags give off moisture, which may ruin the phone, and soap powder gives off fumes that rapidly oxidize the aluminum diaphragm. Tools and other loose gear may prevent getting the phone out quickly, or may damage the phone.

Sound-powered handsets are fastened to a connection box by a 4 1/2 foot length of cord.

A stowage hook, or handset holder, is provided for each handset, and the set must be properly replaced in the holder at all times when not actually in use. A handset left in the bottom of the holder provides an excellent lever breakage. No special care, other than inte gent handling, is needed for handsets as they much less subject to trouble than are heads

# Troubleshooting

As an IC3, you will be required to service sound-powered telephones. Because a great deal of time is devoted to the repair of these sets, you should be thoroughly familiar with the proper methods of testing and repairing them. Many of the larger ships have a telephone shop that is devoted entirely to the repair of sound-powered telephones.

## USEFULNESS OF THE LOG

When trouble develops in a sound-powered headset, the usual procedure followed by the talker is to exchange it for a good one at the repair shop. This procedure provides each station with properly operating sets at all times and concentrates the repair of these sets in one location. Metal stamps are used to stencil the circuit and station, to which a headset is assigned. The shop maintains a log of all sets turned in and the station from which they are received. This practice aids in locating faulty circuits or talkers who continually abuse their sets.

Aboard one ship, during analysis of casualties which were logged, it was found that one man was causing extensive damage to the headset by pulling on the earpieces to relieve pressure on his ears. On investigation it was found that the man was wearing glasses and the receiver clamped his ear against the earpiece of his glasses. It was recommended that the man be put on a watch where he did not have to wear phones.

One station had excessive damage to the cord between the plug and chest plate. By observing the phone talkers, it was found that there was a scuttlebutt within cord-straining reach of the phone talker. Increasing the length of the cord remedied this trouble.

Before a talker reports a telephone headset out of order, he usually tries another set in the jackbox to determine whether the trouble is in the set or in the circuit. If the second set operates satisfactorily, then the first set is faulty. If both sets fail to operate prope however, it is probable that the circuit faulty. Many sets that are not faulty are o turned in to the telephone repair shop.

## OPEN AND SHORT CIRCUITS

The principal types of trouble that occu sound-powered telephones are (1) short circ or open circuits and (2) loss of sensitivity short circuit in a single unit renders an en telephone circuit inoperative because it paral all of the other units. An open circuit single unit renders only that particular unit operative because the other units maintain cuit continuity through their respective para connections. A continuity test of the set c ducted by means of an ohmmeter from the indicates any opens or shorts. For exam if the ohmmeter indicates normal ohms betw the tip and ring connections of the line of an R.C.A. type-M headset with the con button released, and zero ohms when the bu is depressed, the transmitter is shorted. N mal resistance for this unit is about 120 o with the button released. If a zero indicatio obtained with the contact button released, th is a short circuit in the line cord capac or in the receiver units. If the ohmme indicates infinite resistance with the con button released, there is probably an ope in the line cord instead of in both recei units.

If the continuity test shows the line c and the receivers to be satisfactory, and set is still inoperative, the trouble is proba in the transmitter. The transmitter unit sh be exchanged for a unit that is known t good. If the set still does not work, check push button and transmitter unit contacts. place all defective parts.

## LOSS OF SENSITIVITY

Loss of sensitivity, or weakening of transmission sound, is a gradual process dom is reported until the set becomes prac- ally inoperative. When a sound-powered tele- one is in good condition electrically yet the und is weak, the transmitter unit should be placed. If this procedure does not remedy trouble, the receiver units should be re- aced.

Headsets may be tested for loss of sensitiv- by depressing the talk switch, and blowing o the transmitter. If the set is operating operly, a hissing noise is heard in the re- iver units caused by the air striking the ansmitter. One receiver unit is listened to, d then the other. In most cases, the loss in nsitivity is in the transmitter unit and might caused by a displacement of the armature om the exact center of the air gap between e pole pieces.

Each sound-powered handset is tested on cation because it is connected permanently to box. The simplest test is to blow air into e transmitter. To test each individual hand- t it is not necessary to press the talk button ecause the transmitter and receiver are per- anently connected in parallel. If no sound is eard, either the transmitter or the receiver is efective. The easiest method to determine hether the transmitter or the receiver is de- ctive is to have someone talk into another one on the line and to listen to both the trans- itter and the receiver of the handset. If the lker's voice is heard on one of the units but ot the other, the unit on which the voice is ot heard is the defective one and should be eplaced. If the talker's voice cannot be heard n either unit, and the telephone circuit being sed for the test is known to be free of trouble, e fault may be traced to the line cord, switch, r internal handset circuits.

## INSPECTION

A routine inspection of sets should be made efore repairs are begun to determine whether hysically defective parts should be replaced. Many troubles may be located by inspecting the set for damaged cord or insulation; cords pulled out of units; loose units; defective or broken push buttons; and broken or damaged parts such as unit covers, neck strap, chest plate, junction box, plug, or headband.

## REPAIRS

Repairs to sound-powered units should be undertaken only by experienced personnel. If you desire to gain practice in repairing sound-powered units, practice on nonserviceable units. The present Navy policy is to replace defective units rather than to attempt extensive repairs.

The ship's allowance list does not include repair parts. However, 30 percent of the handsets and headsets listed in the allowance list are spares. As a set, hand or head, becomes inoperative, it should be cannibalized to furnish repair parts. Another set must be ordered and the old set surveyed to maintain the required number in the ship's allowance list.

In repairing sound-powered telephones observe the following precautions:

Do not attempt to repair the various units.

Do not repair telephones on a dirty workbench. The magnets in the units may attract iron filings, which are very diffcult to remove.

Never alter the internal wiring of sets.

Before disassembling a unit, make a wiring diagram showing the color coding, polarity, or terminal numbers of the lead connections. Always replace parts exactly as they were before disassembly.

## REPLACING CORDS

When it is necessary to replace a defective cord between the junction box and the transmitter or receivers of headsets, tinsel cord (FT) should be used if it is available, because it is more flexible than the standard DCP type of cord. Stocks of tinsel cord cut to the proper lengths for use with the various types of headsets and fitted with terminals are stocked at the Norfolk and Oakland supply depots and should be requisitioned for use. Bulk tinsel cordage was stocked at supply depots as standard stock. Tinsel cord has the advantage of extra flexibility but has the disadvantage of being difficult to work with. It is more difficult than standard DCP cord to strip, and much more difficult to solder properly. Always use prepared cords if possible.

If prepared cords are not available, you can make them from bulk tinsel cord by the following procedure:

1. Strip about 2 in. of the outer layer of insulation from one end of the cord.

2. Remove about one-fourth of an inch of insulation from the ends of the conductors, exercising caution not to damage the tinsel wire.

3. Wind a single layer of 32-gage tinned copper wire over the tinsel wire and extend the tinned copper wire about one-eighth of an inch over the rubber insulation.

4. Dip these whipped conductors into melted solder and flatten them slightly when cool.

5. Solder the whipped conductor to a lug or cord tip as required (fig. 9-7).

If tinsel cord is not available, use standard DCP-1/2 cord between the junction box and the receivers and TCP-1/2 between the junction box and each transmitter. Use DCP-1 1/2 cord between the junction box and the plug.

To replace a cord:

1. Open each unit connected to the cord that is to be replaced.

2. Before disconnecting the cord make a diagram showing the color coding of the wires.

3. Disconnect both ends of the cord.

4. Remove the screw that holds the tie cord or untie the cord if it is secured to an eyelet.

5. Unscrew the entrance bushing, if provided, and pull the cord through the port.

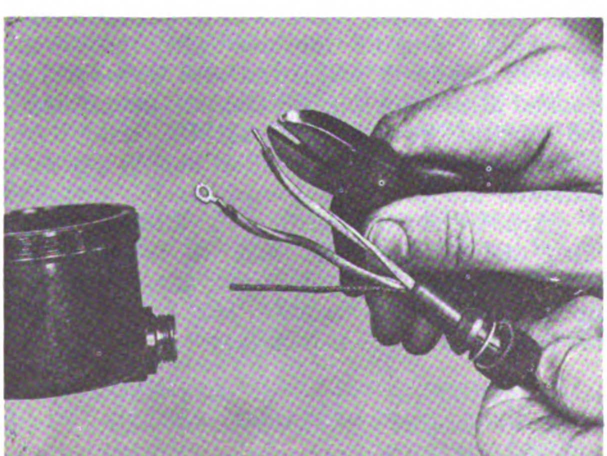


Figure 9-7.–Preparing a new tip on a tinsel cord.

6. Place the threaded entrance bushi metal washer, and rubber gasket on t new cord and insert the cord into t entrance port (fig. 9-7). The cord shou be long enough to allow slack after it connected.

7. Secure the tie cord either by anchori it under the clamping screw or by tyi it in the eyelet, as shown in figure 9- Make certain that the tie cord takes a the strain off the connections; otherwi the wires might be pulled from the terminals.

8. Connect the wires to their terminal

9. Screw the entrance bushing on the en trance port, drawing the bushing up tightl to secure the cable and to seal the por

10. Close the unit after all connections hav been visually checked.

11. Test the completed unit for operatio

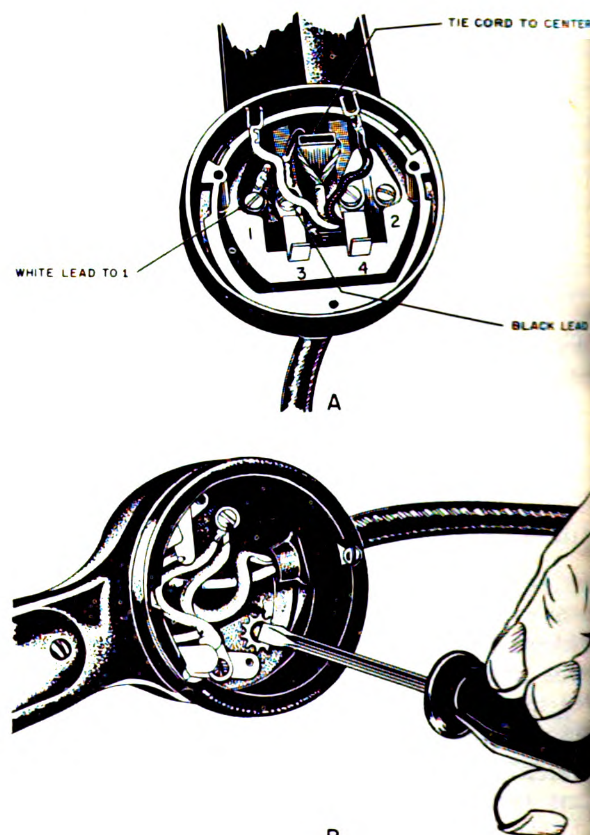



Figure 9-8.–Securing the tie cord. (A) Type-TA; (B) Type-L.

# Sound-Powered Telephone Installations

## CLASSIFICATION

There are three types of sound-powered ephone systems:

1. The primary battle telephone system—circuits JA to JZ (table 9-1)—includes all circuits used for the main channels of communications in controlling the armament, engineering, damage control, and maneuvering of a typical CVA.
2. The auxiliary battle telephone system—circuits XJA to XJZ—includes circuits duplicating certain primary battle telephone circuits as alternates in case of damage. The wiring of the auxiliary circuits is separated as much as practicable from the wiring of the corresponding primary circuits to prevent battle damage to both circuits.
3. The supplementary telephone circuit consists of a group of outlets connected together on a single line or "string," with no provision for cutting out a single outlet. A supplementary circuit may be one that is required for use at all times or at times when battle telephones are not manned. Some "string" circuits are equipped with call-bell systems.

The various sound-powered telephone sysms are classified further into (1) switch-ard circuits, (2) switch-box circuits, and (3) ring-type circuits.

### SWITCHBOARD CIRCUIT

A switchboard circuit is a circuit having ıtout switches on a switchboard. Most large ombatant ships have several sound-powered elephone switchboards installed in different entrally located and protected control staons, such as IC rooms and plotting rooms. ach switchboard (fig. 9-9) usually has several witchboard circuits and a line-disconnect witch for each line. The older type (fig. 9-9A) s replaced with the newer switchboard (fig. -9B) which has a switchjack (fig. 9-9C) at ach position. A jack is provided for each tation of a circuit. The purpose of the line witch is either to connect or disconnect a tation from its circuit. The jack either

Table 9-1.—Representative Telephone Circuits.

| Circuit | Title |
|---|---|
| JA | Captain's Battle Circuit |
| JC | Ordnance Control |
| JCT1 | Ordnance Control, Sector 1 |
| JCT2 | Ordnance Control, Sector 2 |
| JCT3 | Ordnance Control, Sector 3 |
| JCT4 | Ordnance Control, Sector 4 |
| JF | Flag Officer |
| 1JG | Aircraft Control |
| 2JG | Aircraft Information |
| 3JG | Aircraft Service |
| 4JG1 | Aviation Fuel Control |
| 4JG2 | Aviation Fuel Service Fwd |
| 4JG3 | Aviation Fuel Service Aft |
| 5JG | Aviation Ordnance |
| 6JG | Arg, Barrier and Barricade Cont |
| 10JG | Airborne Aircraft Control |
| 11JG | Mirror Dk. Landing Sight |
| JH | Swbd Cross-connections |
| JL | Lookouts |
| JO | Swbd Operators |
| 2JP1 | Dbl Purpose Cont Gr 1 |
| 2JP2 | Dbl Purpose Cont Gr 2 |
| 2JP3 | Dbl Purpose Cont Gr 3 |
| 2JP4 | Dbl Purpose Cont Gr 4 |
| 2JP5 | Dbl Purpose Cont Gr 5 |
| 2JP6 | Dbl Purpose Cont Gr 6 |
| 1JS | CIC Information |
| 20JS1 | Evaluated Radar Information |
| 20JS2 | Evaluator's Circuit |
| 20JS3 | Radar Control Officer |
| 21JS | Air Search Radar |
| 22JS | Surface Search Radar |
| 23JS | AN/SPS8 Radar |
| 24JS | AN/SRR4 AEW Radar |
| 81JS | Electronics Countermeasure |
| 82JS | Supplementary Radio |
| 1JV | Maneuvering and Docking |
| 2JV | Engineers—Engines |
| 4JV | Engineers—Fuel and Stability |
| 5JV1 | Engineers—Electrical |
| 5JV2 | Engineers—Switchboards |
| JW | Ship Control Range Finders |
| JX | Radio and Signals |
| 2JZ | Damage and Stability Control |
| 3JZ1 | Upper Deck Repair Fwd |
| 3JZ2 | Upper Deck Repair Aft |
| 4JZ | Repair Fwd |
| 5JZ | Repair Aft |
| 6JZ | Repair Amid |
| 7JZ | Engineer's Repair |
| 8JZ | Flight Deck Repair |
| 9JZ | Sprinkling and Ord Rep, Fwd |
| 10JZ | Sprinkling and Ord Rep, Aft |
| 12JZ | Fire Pump Control |

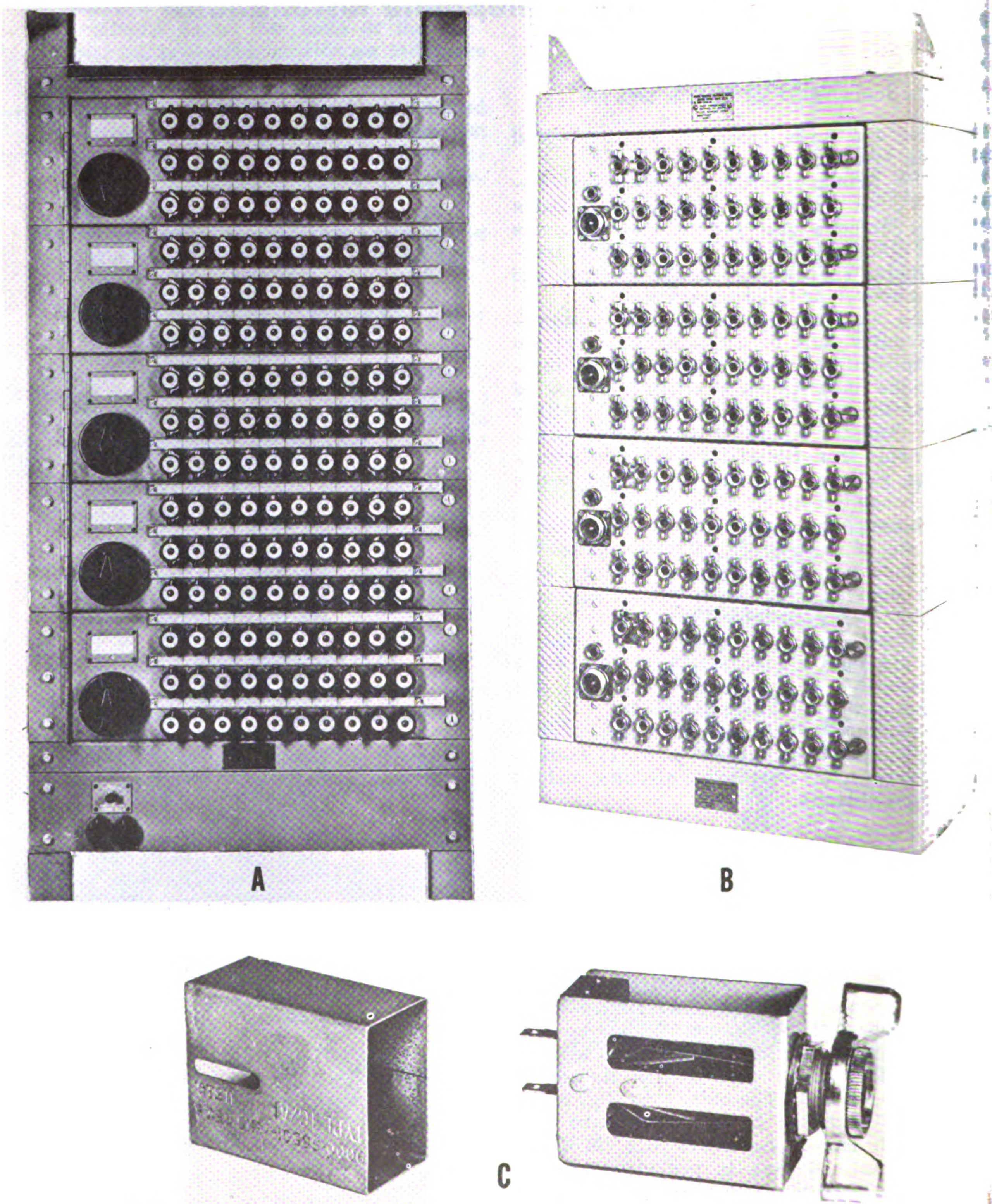



Figure 9-9.—Sound-powered telephone switchboards.

rallels that phone with another circuit or rallels two circuits. Paralleling is ac-mplished by means of a PATCHING CORD, ich is a short length of portable cord having ack plug at each end.

Opening the line switch disconnects a sta-n from its circuit. Inserting one end of a tching cord into the jack of this station and e other end of the cord into the jack of other station, makes the first station parallel th the circuit of which the second station is a rt. Leaving the line switch of the first ation closed makes the two circuits parallel. ch circuit has one or more tie switches for ralleling that circuit with other circuits on e same switchboard. Any line may be con-cted to any other circuit, line, or combination circuits on the switchboard by manipulation patching cords and individual line cutout itches.

Transfer switches at some switchboards, ch as gunnery-control switchboards, pro-ide a means of quickly disconnecting a number telephones from one circuit and connecting em to another. For example, the telephone ircuits may be shifted from the number 1 omputer to the number 2 computer or from ne plotting room to another.

## SWITCHBOX CIRCUIT

A switchbox circuit consists of several ine cutout switches mounted in a switch box. Jsually, there is only one switchbox circuit for ach switch box. Telephone switch boxes func-ion primarily as small ACO switchboards. The witch boxes are located at the principal station n the circuit, and contain either 10 or 20 witches used for connecting incoming lines to a ommon circuit bus (fig. 9-10). Each station n the circuit is connected to one of the line witches. Some of the switches may be used as ie switches connected to the circuit bus in other switch boxes. When these tie switches are closed, the circuits in the two boxes are paral-leled.

All primary circuits are provided with a tie line for cross connection with their auxiliary circuits. The tie lines are fitted with a tie switch at one end and a tie+ (tie plus) switch at the other end. The tie+ switch is different from the tie switch only in that the tie+ switch is always closed to insure that the tie line may be used at all times. With this arrangement the

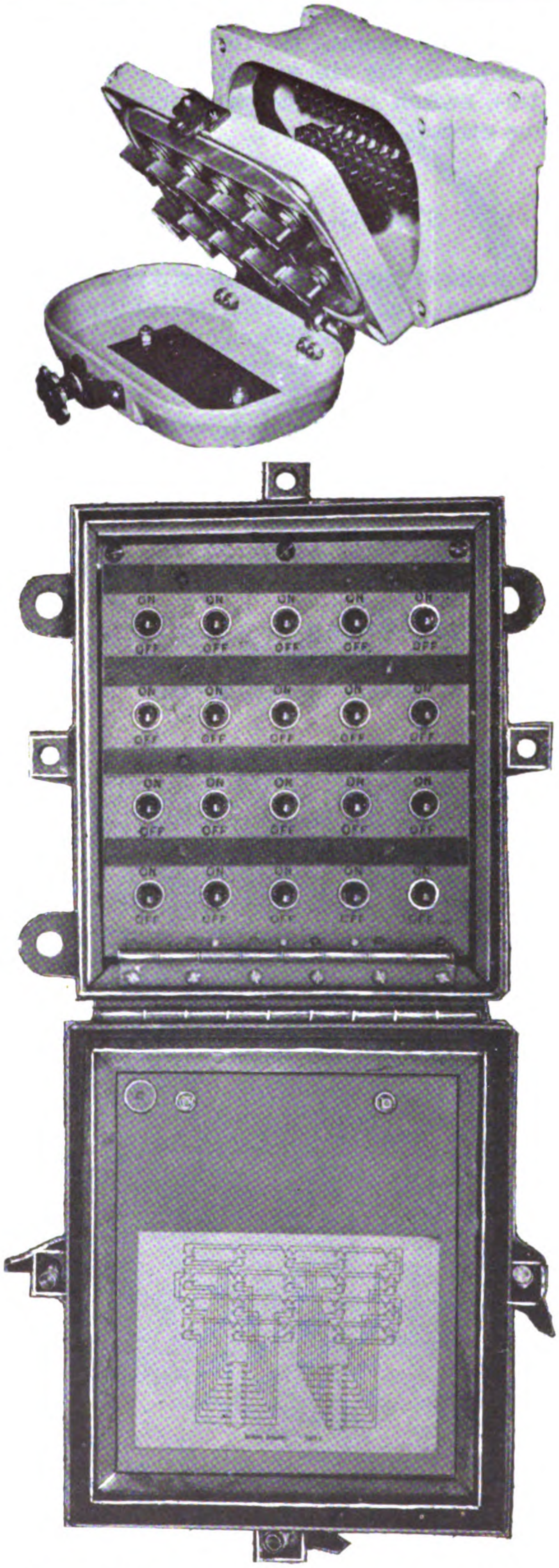


Figure 9-10.—A.C.O. switch boxes. (Top) New; (Bottom) Old.

two circuits can be tied together or separated by closing or opening the tie switch. In case of a casualty to the tie switch end of the tie line, the tie+ switch is opened to disconnect the defective circuit or tie line.

## STRING-TYPE CIRCUIT

A string-type circuit consists of a series of jack boxes connected in parallel to a single line. There are no action cutout switches for individual stations. However, some string circuits, for instance 21JS to 24JS, are connected to communication consoles, selector switches, and plotter transfer switchboards (fig. 9-11).

Some string-type circuits, for instance, X1J Captains and Admirals cruising, may be equipped with call bells, annunciators, or magneto call stations.

The X40J, casualty communication circuit, consists of individual riser cables running from jack boxes in engineering spaces and steering gear rooms to 4 gang jack boxes on the damage control deck.

All horizontal runs are made as required by damage control parties with rolls of cables which are made up on reels with plugs on each end.

## SELECTOR AND TRANSFER SWITCHES

Selector and transfer switches are of the rotary type. Selector switches are located in the most important stations throughout the ship to enable the officer in charge, or his talker, to connect his telephone at will to any one of a group of circuits without having to change from one jack outlet to another.

Transfer switches are usually installed at the telephone switchboards and are used to connect the lines of one group of circuits to one of several other groups of circuits. Two switches capable of handling 16 circuits are shown in figure 9-12. The type-A26A-16 switch is used in new construction. In a ship fitted

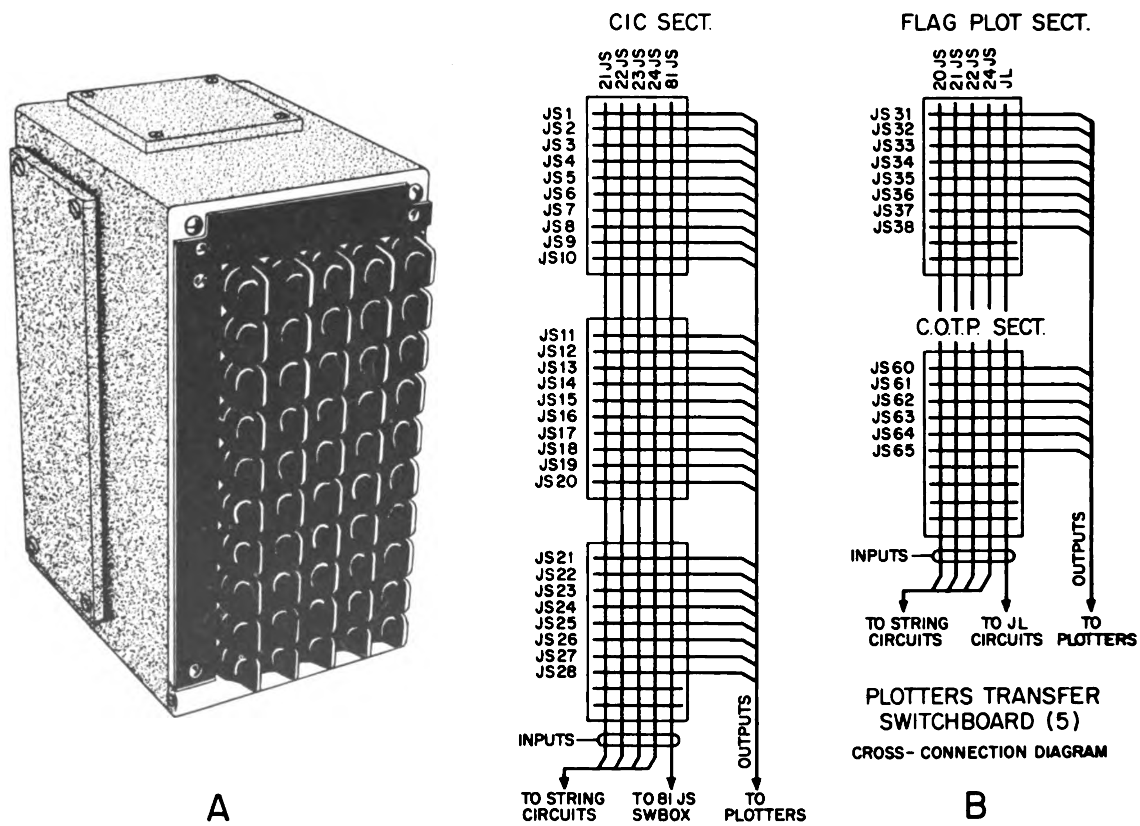



Figure 9-11.—Plotters transfer switchboard, type SB-82/SRR. (A) External view; (B) Wiring diagram.

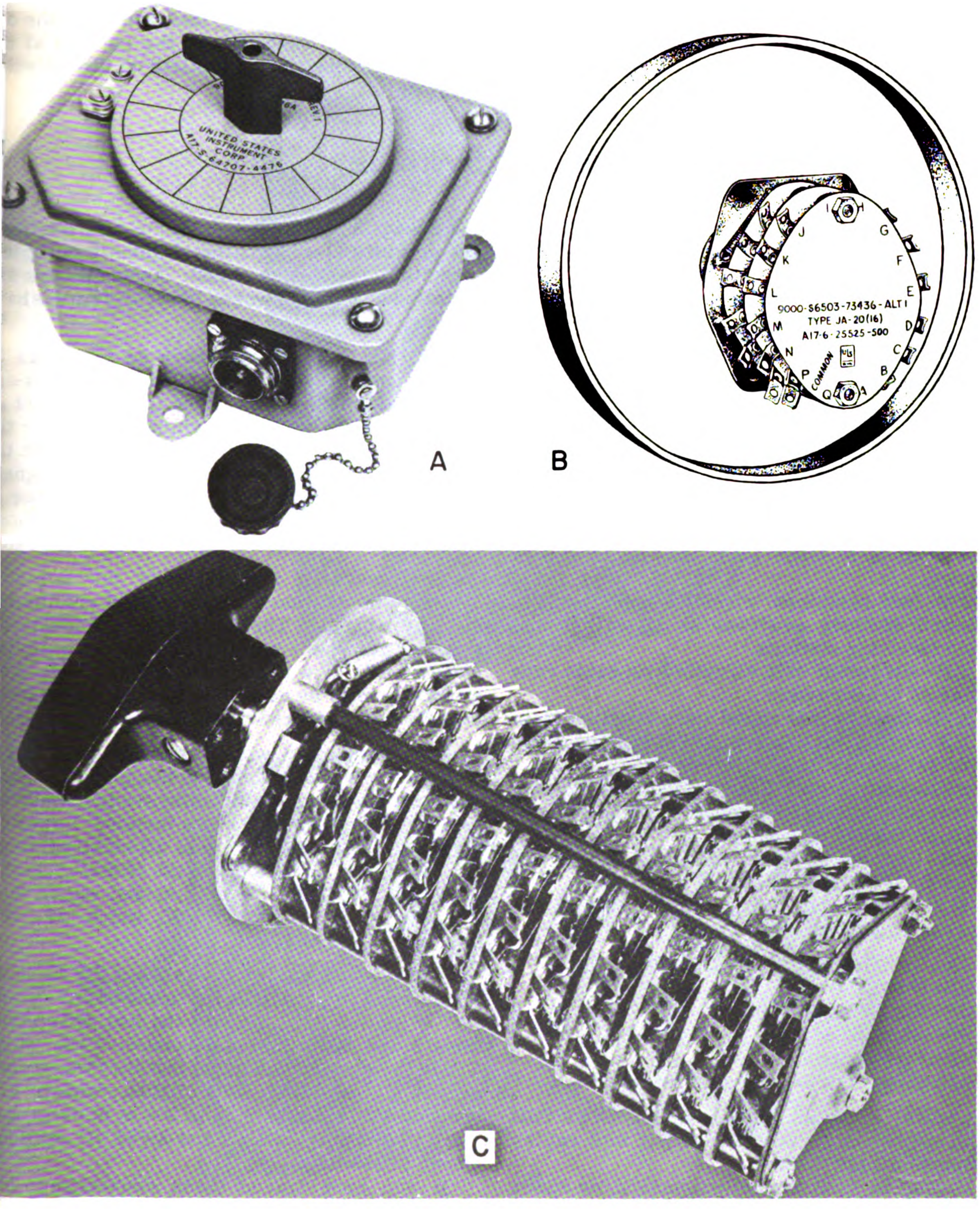



Figure 9-12.—Sound-powered telephone transfer switches. (A) Type A26A-16; (B) View of switch; (C) Type JA10C(IC).

with several secondary battery computers, the lines to each of the secondary battery mounts are connected to a transfer switch. This switch permits the connection of all the mount outlets to the proper outlets at the proper computer. Similarily, in ships equipped with several secondary battery directors, the lines to each secondary battery computer are connected to a transfer switch. Setting this switch to the desired director connects all the outlets at the computer to the proper outlets at the selected director.

# Call-Bell Systems

Call-bell systems provide a means of signaling between stations in a ship. These systems consist of circuits E and A.

## CIRCUIT E

Circuit E provides a means of signaling between stations on sound-powered telephone circuits and between outlets on voice tubes.

### DESCRIPTION

Circuit E in large ships may be divided as follows:

EM—Self-contained circuits with magneto call-bell stations provided at all calling and some receiving stations.

EP—Protected call circuits with cable runs protected behind armor.

EPS—Unprotected signal lines supplied from an EP circuit through separate protected fuses at the calling station.

EPL—Unprotected circuits supplied from an EP circuit through a protected local cut-out switch at the station called.

EX—Exposed call circuits with cable runs not protected behind armor.

In addition, circuit E has the following functional designations:

1E—Cruising and miscellaneous.
2E—Ship control.
3E—Engineering.
4E—Aircraft control.
5E—Fire control.
11E through 15E—Turrets I through V.

Therefore, a circuit that is designated as 3EP is an engineering call-bell circuit with cables protected behind armor.

Circuit E includes bells, buzzers, or horns installed at selected sound-powered telephone stations and at some voice tubes. Watertight and nonwatertight push buttons, or turn switches are provided at all signaling stations to complete circuits to the station called. Annunciators are installed at stations where several circuits have outlets.

The EM circuits may have as many as 32 ringing stations (fig. 9-13). These stations are of cast aluminum with all of the equipment on the cover, except for the terminal board for the connections. Assembled on the cover are the rotary selector switch, a hand-operated magneto generator, a howler unit, and an attenuator to control the volume of the howler. The telephone circuit may be of the string or switchboard type.

The operator simply turns the selector switch to the station to be called and cranks the generator handle. The howler (a modified sound-powered telephone receiver unit at the selected station) will give a high distinctive howl. The attenuator may be used to adjust the sound level of individual howlers at their respective stations.

The elementary wiring diagram (fig. 9-14) illustrates the simplicity of the circuit. Note that station 1 has no incoming leads connected to terminals 1 and 1W at its terminal board or strip. However, 1 and 1W at all other stations are connected to 2EMM31 and 2EM31. Trace 2EM31 and 2EMM31 to station one, where they are connected to N and NW, which are the howler connections.

At station 2 the terminals 2 and 2W have no incoming leads. Trace the leads from N and NW of station 2 to station 1 and find which terminals and leads they are connected to. Stop! Trace them now. You found that they were connected to 2EMM32 and 2EM32, which are connected to terminals 2 and 2W at station one. They are connected to 2 and 2W at all stations except at station 2.

If you have traced these connections you should be able to analyze some troubles when they occur.

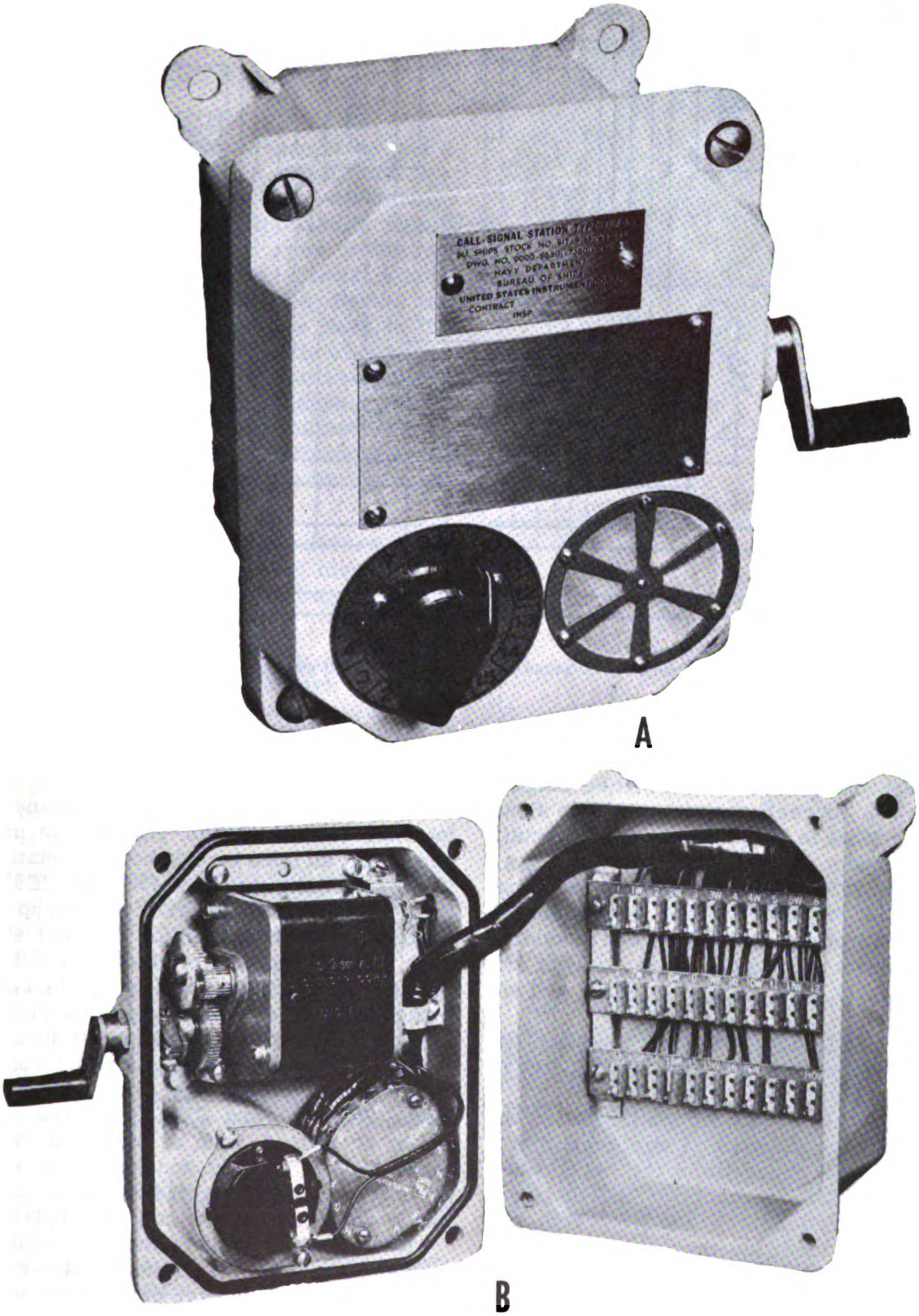



Figure 9-13.—Magneto ringing station. (A) External view; (B) Internal view.

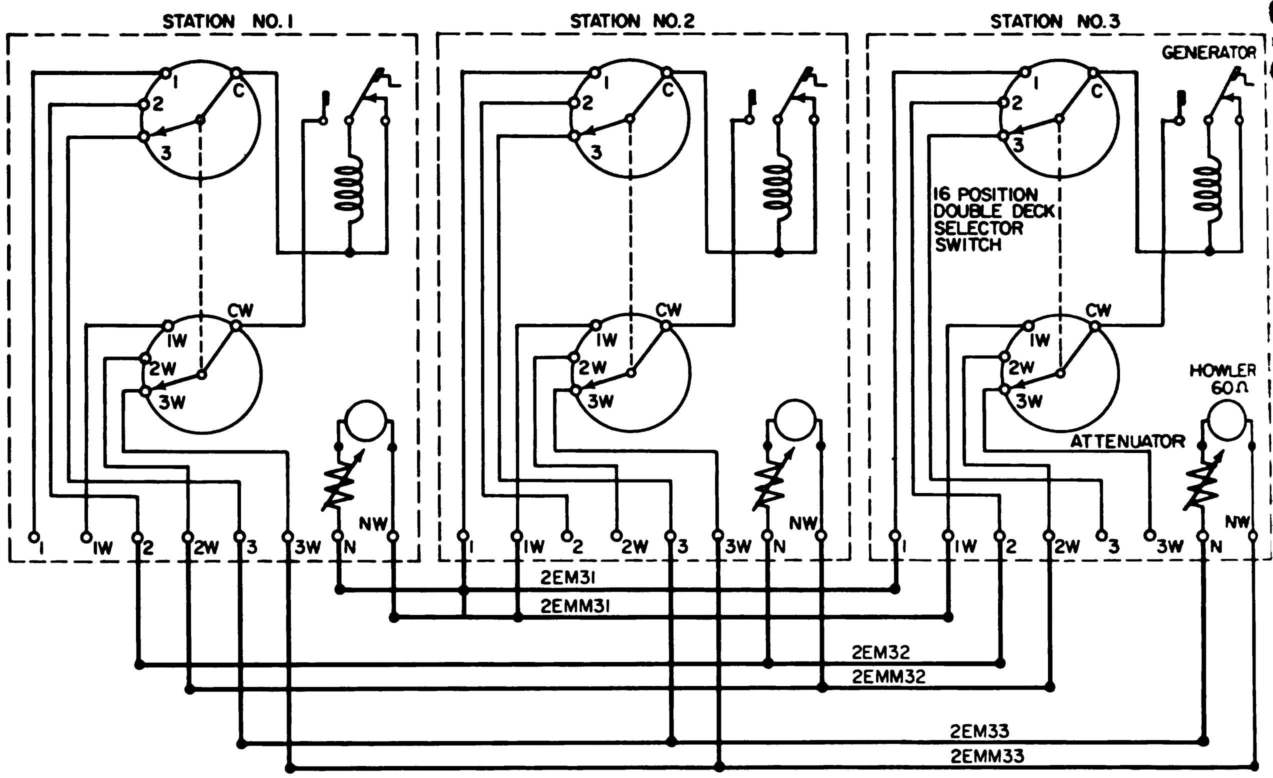



Figure 9-14.—Sound-powered magneto call system.

## TROUBLESHOOTING

Troubleshooting any circuit will be simplified if you ask yourself certain questions about the circuit.—What is the purpose of the circuit? What units make up the circuit? How can I check the individual units? What is the most likely cause of trouble? Where should I start? A careful study of the elementary and isometric circuit drawings will help you to analyze and locate trouble in your circuits quickly and effectively.

Problem: Station 3 is manned; however, the station's howler cannot be operated from any of the other stations.

By tracing the circuit for the howler on the elementary wiring diagram it was found that N and NW were the connections for the howler. Therefore at station 3 remove the incoming connections to terminals N and NW. Then use an ohmmeter to measure the resistance of the howler and attenuator which are connected to the leads N and NW.

You should read at least 60 ohms, the resistance of the howler unit. The attenuator is a variable resistor. If the resistance of the circuit is lower than 60 ohms, replace the howler unit.

If there is a good value of resistance for the internal circuit at the station, we must now check for an open circuit between station 3 and its connections to 2EMM33 and 2EM33. An isometric drawing will give you the approximate location of each connection box and station by deck, frame, and port or starboard. After checking the isometric diagram, go to the connection box closest to station 3. Open the cover of the box and inspect for loose connections or broken leads. If the leads are good and connections tight, use a megger to check for ground on leads 2EMM33 and 2EM33. If the circuit is clear of ground, then at station 3 ground the leads one at a time and check for continuity at the connection box. If there is an open wire, use a spare lead in the cable to replace it.

Now reconsider the internal continuity test at station number 3. If there had been an open wire, you would not have performed the external test previously described, but you should have proceeded to check the resistance of the howler.

[I]f the howler has the required ohmic value, [c]heck the attenuator, which should be open or [h]ave a loose or broken lead.

## CIRCUIT A

Circuit A is for the convenience of the ship's [o]fficers in calling pantry attendants and or[d]erlies. Calls are provided from all cabins; [s]taterooms, except those equipped with ship's [s]ervice telephones; and wardrooms to the re[s]pective pantries and orderlies. Circuit A calls [a]re provided also from all sick-bay berths and [i]solation wards to the attendant's desk in the [s]ick bay. Circuit A consists of bells or buzzers [a]t the orderly and pantry stations and nonwater[t]ight pushbuttons in the various cabins, state[r]ooms, and messrooms. Where a station is to [b]e signaled by more than one pushbutton, a drop[t]ype annunciator is installed in addition to the [b]ell or buzzer.

Three simplified call-bell circuits are shown in figure 9-15. These simplified circuit connections apply to circuit A as well as to circuit E.

The upper branch circuit, with one bell and one pushbutton in series with each other, is used to call a single station from one location.

The center branch circuit, with two pushbuttons in parallel with each other and in series with the bell, is used to operate one bell from two remote locations.

The lower branch circuit, with two bells in parallel with each other and in series with one pushbutton, is used to operate two bells from one location.

Note that the bells or signaling devices (fig. 9-15) are connected to the side of the line bearing the negative designation, EE. This arrangement is used on a-c circuits that have no polarity but in which one side of the line arbitrarily is designated as EE for convenience.

## ANNUNCIATORS

Call-bell stations that have several sound-powered handsets, each on a different circuit, are provided with annunciators to identify the circuit of the station that originates the call.

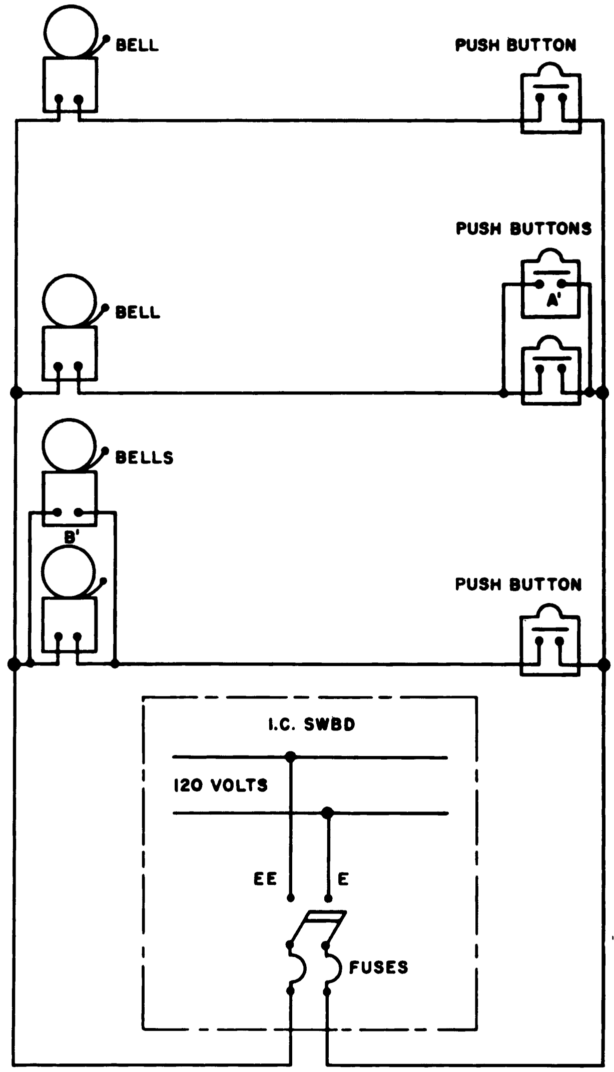



Figure 9-15.—Simple call-bell system.

Annunciators used with E-call circuits are of the drop type. The drop, or target, is embossed with the circuit letter and is held mechanically in the nonindicating position. When the circuit is energized by operating a pushbutton at the calling station, an electromagnet causes the target to drop to the indicating position. The drops are returned to their normal, or nonindicating, positions by a hand-operated reset button.

Annunciators used with A-call circuits are similar to those used with E-call circuits except that in A-call circuits the drop is embossed with the number of the stateroom, or location of the calling station, instead of the circuit letter.

A simple diagram for a 2-circuit, 4-drop annunciator is shown in figure 9-16. When a pushbutton is operated, the proper annunciator drops and the bell rings. The alarm bell rings only when the pushbutton is closed. One side of each drop and one side of an audible-signal relay are connected together so that when the external circuit is closed by the pushbutton, the current flows through the drop and the relay. The relay is energized and closes its contacts to the audible signal. The annunciator may be equipped with one or more relays as required by the number of associated circuits, but utilizing a common audible signal.

Schematic diagrams of an E- and an A-call-bell circuit are shown in figure 9-17A and B, respectively. Study these diagrams carefully because, as an IC3, you are expected to maintain call-bell circuits.

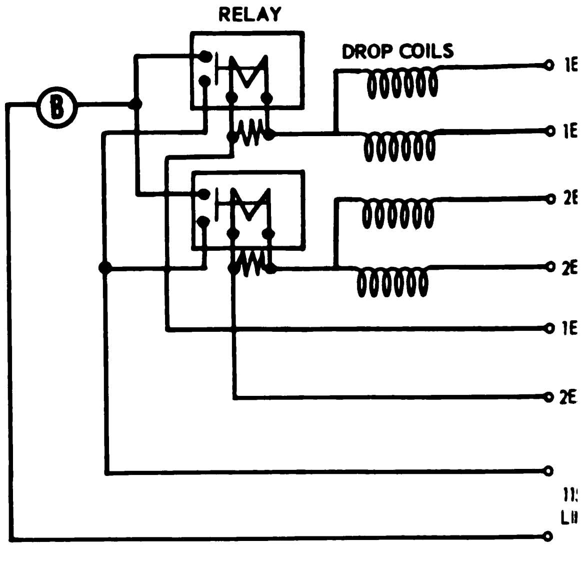


Figure 9-16.—Two-circuit, four-drop annunciator.

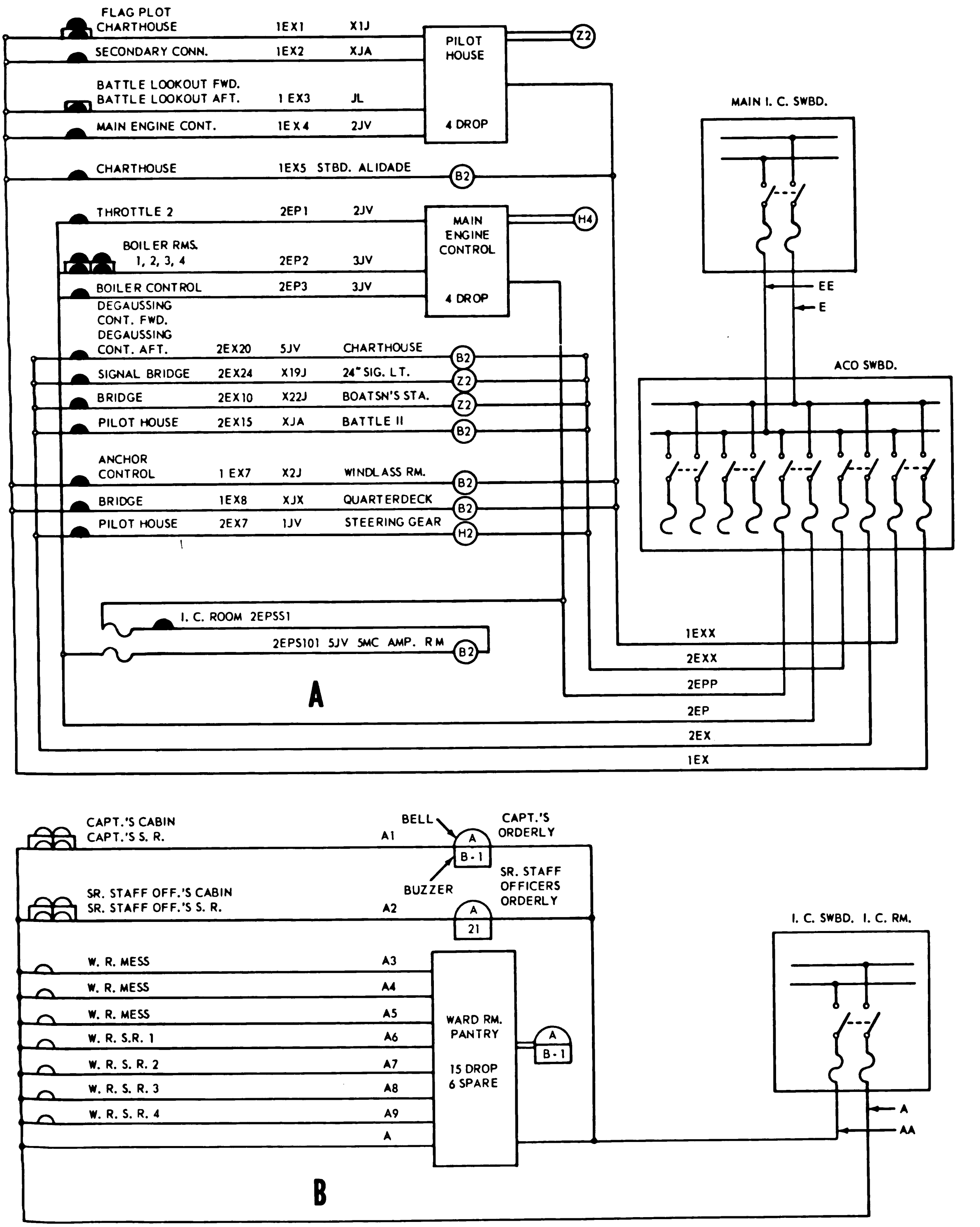



Figure 9-17.—E- and A-call-bell circuits.

# QUIZ

1. Name the three basic designs of sound-powered receiver and transmitter units.
2. List the principal parts of the cantilever receiver unit.
3. In the sound-powered handset, does the switch close both the transmitter and the receiver circuits?
4. Give two reasons why a switch is used in the sound-powered handset.
5. In the type-M headset, what circuit contains the switch?
6. What generally causes loss of sensitivity in a sound-powered unit?
7. What is the probable trouble when a sound-powered telephone fails to operate properly but is bound to be in good condition electrically?
8. In a sound-powered switch box, is the tie switch normally closed?
9. Give the uses of (a) the rotary type of selector switch and (b) the rotary type of transfer switch.
10. What circuits provide a means of signaling between sound-powered telephone stations and between voice-tube outlets?
11. For what purposes are "A" calls generally provided?
12. What is the purpose of an annunciator?

# CHAPTER 10

# PRINCIPLES OF THE GYROCOMPASS

## Introduction

A general knowledge of the physical characteristics and nomenclature of the earth and its effects on rapidly spinning bodies (gyroscopes) is necessary before considering the gyrocompass.

### THE EARTH

The earth is an oblate spheroid—that is, a spheroid flattened at the poles. Its equatorial axis measures about 7,927 statute miles and its polar axis, about which it rotates, measures about 7,900 statute miles.

#### EARTH'S AXIS

The earth's axis is an imaginary line drawn through the earth's center between the two geographical poles. The earth spins about this axis and makes 1 complete revolution every 24 hours.

#### EARTH'S ROTATION

The direction of the earth's rotation about its axis is west to east. The viewer (looking from space in the vicinity of the South Pole toward the South Pole) sees the earth rotate in a clockwise direction. Conversely, the viewer (looking from space in the vicinity of the North Pole toward the North Pole) sees the earth rotate in a counterclockwise direction.

#### HORIZONTAL EARTH RATE

The horizontal earth rate is the angular velocity (linear speed) of the earth about a horizontal north-south axis. The rate or velocity varies as the cosine of the latitude, being equal to the angular velocity of the earth itself at the equator and becoming zero at either pole. The earth's linear speed at the equator is approximately 900 knots.

#### VERTICAL EARTH RATE

The vertical earth rate is the angular velocity of the earth about a vertical axis. The rate or velocity varies as the sine of the latitude, being equal to the angular velocity of the earth itself at the poles, and becoming zero at the equator.

#### EARTH'S DIMENSIONS

The length of a statute mile is 5,280 ft; the length of a nautical mile is 6,080 ft. The geographical mile is the measure of 1 min of arc on the earth's surface at the equator. The Navy Hydrographic Office uses 6,087.078 ft as the length of the geographic mile.

The equator is an imaginary circle on the earth's surface everywhere equidistant from the two poles. At the equator the earth's circumference is approximately 21,000 nautical miles.

A meridian is an imaginary circle on the earth's surface drawn through the two poles and the observer's station.

The latitude of a position on the earth's surface is the arc of the meridian intercepted between the equator and that position. Latitude is designated north and south from the equator, which is 0° latitude, through 90° to the poles. Thus, a position on the earth's surface, north of the equator, having an arc of 40° is located at latitude 40° N. as shown in figure 10-1.

The longitude of a position on the earth's surface is the angular distance measured through 180° east or west of the prime, or zero, meridian. The prime meridian passes through the observatory at Greenwich, England.

The geographical or true north and south poles are located 90° north and south latitude, respectively.

The magnetic poles are located on the earth's surface where the dip of a magnetic needle is 90°. In the Northern Hemisphere the location of the earth's magnetic pole is approximately 71° north latitude and 96° west longitude. In the Southern Hemisphere the location of the magnetic pole is approximately 73° south latitude and 156° east longitude.

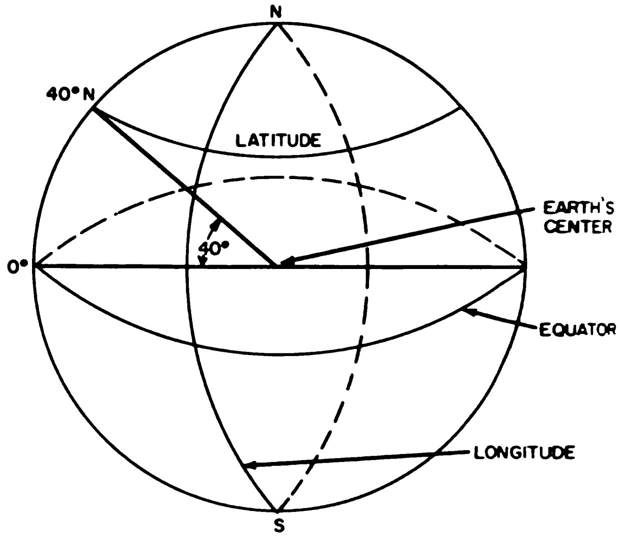


Figure 10-1.—Degree of latitude.

# Free Gyroscope

The operation of the gyrocompass depends upon certain properties inherent in rapidly spinning bodies. Therefore, it is essential to have a knowledge of the principles and behavior of the gyroscope that apply to the gyrocompass.

The gyroscope is a heavy wheel, or rotor, suspended so that its axle is free to turn in any direction. The rotor axle is supported by two bearings S, S' in a ring, as illustrated in figure 10-2. This ring is supported by means of studs and bearings H, H' in a slightly larger outer ring. The outer ring is mounted in the supporting frame by means of studs and bearings V, V'. The two supporting rings are called GIMBALS. The supporting frame is not a part of the gyroscope but merely supports it. The rotor and the two gimbals are balanced about their axes, which are mutually perpendicular and intersect at the center of gravity of the rotor. The bearings of the rotor and gimbals are considered to be completely free of friction. Actually there is always some friction, but it has been reduced to such an extent that it is considered nonexistent.

## THREE DEGREES OF FREEDOM

The gyroscope rotor has three degrees of freedom—(1) freedom to SPIN, (2) freedom to TURN, and (3) freedom to TILT. The three degrees of freedom permit the rotor to assume any position within the supporting frame (fig. 10-2). The rotor is free to spin about its own axle, spinning axis S-S', giving the first degree of freedom. The inner gimbal ring is free to rotate on its bearings about the horizontal axis, H-H', giving the second degree of freedom. The outer gimbal ring is free to rotate on its bearings about the vertical axis, V-V', giving the third degree of freedom.

## GYROSCOPIC PROPERTIES

When a gyroscope rotor is spinning rapidly, the gyroscope develops two properties that it does not have when the rotor is at rest. These two properties, which make it possible to develop the gyroscope into a gyrocompass, are (1) rigidity of plane and (2) precession.

### RIGIDITY OF PLANE

When the rotor of a gyroscope is set spinning with its axle pointed in one direction (fig. 10-3A), the rotor continues to spin with its axle pointing in the same direction, no matter how the frame

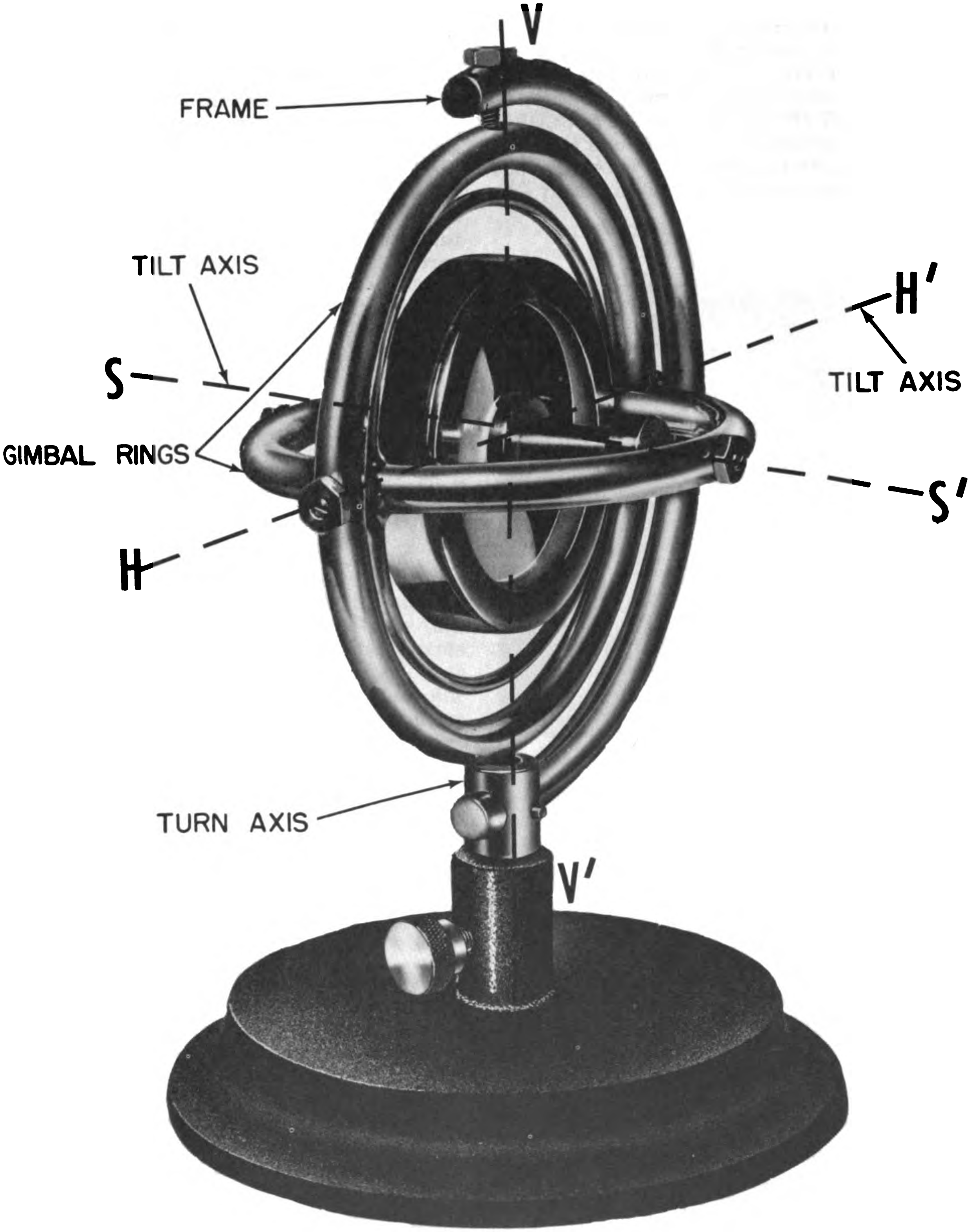
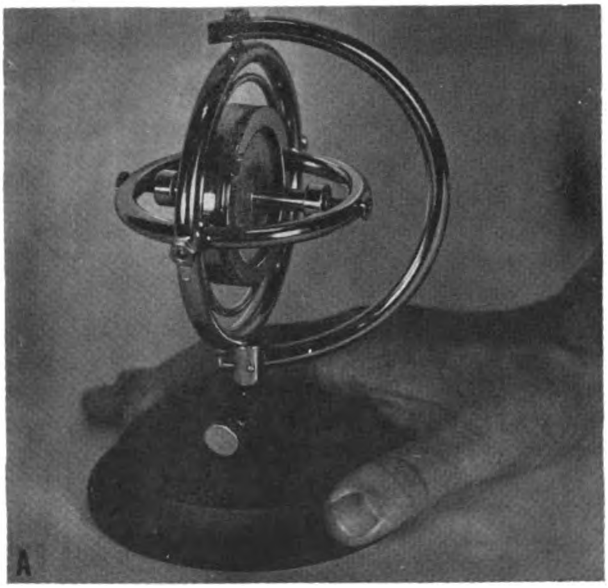



Figure 10-2.—The gyroscope.

of the gyroscope is tilted or turned (fig. 10-3B). As long as the bearings are frictionless and the rotor spins, no turning of the supporting frame can change the plane of the rotor with respect to space. This property of the gyroscope is known as RIGIDITY OF PLANE, GYROSCOPIC INERTIA, or STABILITY. It results from the fact that the rotating wheel of a gyroscope has high angular momentum and kinetic energy.



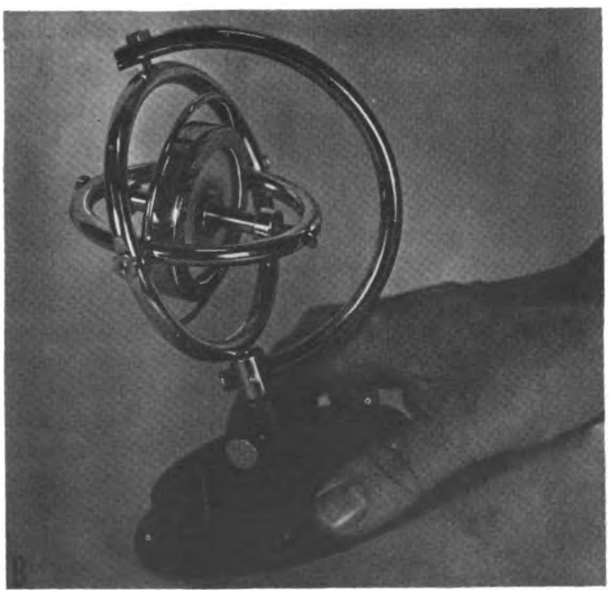



Figure.10-3.—Rigidity of plane of spinning gyroscope.

The reason for rigidity of plane is demonstrated by the spinning rotor with a vertical axle, shown in figure 10-4. The mass of the rotor is considered as concentrated at points a, b, c, and d around the circumference of the rotor. A momentary force, F, exerted on the axle attempts to change the direction of the path of points c and d—that is, point c tends to move upward and point d downward. Because of the very high kinetic energy, these points resist any attempt to change their paths or directions of motion. This is the reason for rigidity of plane. The energy and momentum of the rotor attempts to keep the plane of the rotor and the alinement of the axle fixed in space.

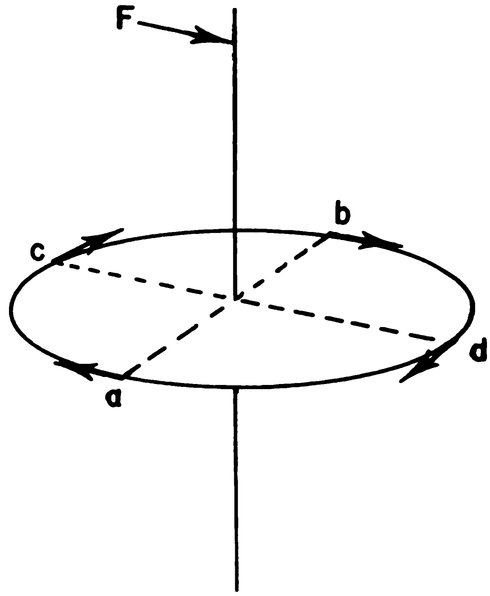



Figure 10-4.—Spinning rotor with a vertical axle.

A gyroscope can be made more rigid by (1) making the rotor heavier, (2) causing the rotor to spin faster, and (3) concentrating most of the rotor weight near the circumference. If two rotors with cross sections like those shown in figure 10-5 are of equal weight and rotate at the same speed, the rotor in figure 10-5B, is more rigid than the rotor in figure 10-5A. This condition exists because the weight of the rotor in figure 10-5B, is concentrated near the circumference. Both gyroscope and gyrocompass rotors are shaped like the rotor shown in figure 10-5B.

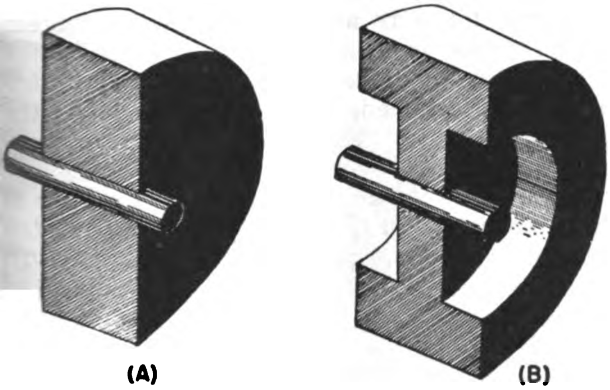



Figure 10-5.—Weight distribution in rotors.

## PRECESSION

Because of gyroscopic inertia (fig. 10-3), it is obvious that moving the outer supporting frame has no effect on the direction in which the axle of a spinning gyroscope points. To change this direction, it is necessary to apply a force to the gyroscope rotor or its axle. A horizontal force on one end of the axle (fig. 10-4) produces a turning effect which attempts to tilt the gyroscope about the axis ab. This turning effect is called TORQUE. If the rotor were not spinning, the axle would tilt in response to the applied force. When the rotor is spinning, however, its rigidity causes it to resist any attempt to tilt the axle about ab and instead, it turns about the axis cd. Conversely a torque attempting to turn the gyroscope about the axis cd is similarly resisted and results in a tilt about the axis ab. This rotation of a gyroscope about an axis perpendicular to the axis about which a torque is exerted is called PRECESSION. Precession takes place whenever any torque tends to tilt the axle of a spinning gyroscope rotor. The precession caused by the applied torque is always about an axis at right angles to the axis about which the torque is applied.

Precession is demonstrated by considering a rotor with a vertical axle having its weight concentrated at points a, b, c, and d (fig. 10-6). If a horizontal force, F, is applied to the axle of the gyroscope rotor in figure 10-6A, a downward force is exerted on point a and an upward force on point b. If the rotor were not spinning, point a would move down and point b would move up, thus tilting the rotor about the axis cd. However, a rotational force is exerted on points a, b, c, and d (fig. 10-6B) because the rotor is spinning. When an external force, F, is applied to the spinning rotor, the resultant torque of the forces applied to the points on the rotor is the vector sum of the forces X and X' (fig. 10-6C). It is obvious that the direction of the forces acting on point a is down and to the left and that the direction of the forces acting on point b is up and to the right. This resultant motion causes the plane of the rotor to tilt about axis ab. Note that the force applied in the direction of axis ab causes the axle to tilt about axis ab. Therefore, the axle precesses, or moves, at right angles to the applied force.

The direction of precession in response to an applied force depends on the direction in which the rotor is spinning. The axis of a free-spinning gyroscope tends to turn or precess in

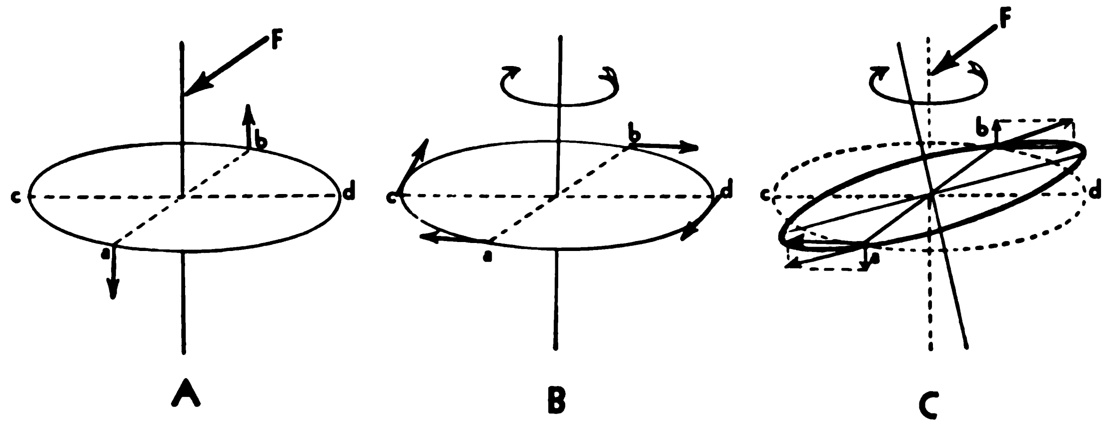



Figure 10-6.—Analysis of precession in a free gyroscope.

such a direction that it becomes parallel to the axis of the applied torque, by the shortest path, and with the rotation of the wheel in the same direction as the applied torque.

A simple way to determine the direction of precession is illustrated in figure 10-7. Consider the force that tends to change the plane of rotation of the rotor as it is applied to point A at the top of the wheel. This point does not move in the direction of the applied force, but a point 90° away around the wheel in the direction of rotation moves in the direction of the applied force. This is the direction of precession.

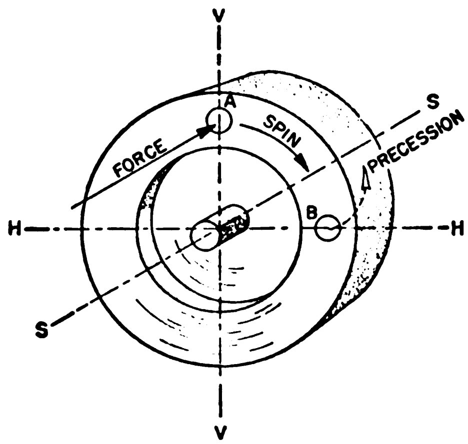



Figure 10-7.—Direction of precession.

Any force that tends to change the plane of the spin axis causes a gyroscope to precess. Precession continues as long as the force is applied if the direction of the force moves with the precession. Precession ceases immediately when the torque is removed. If the plane through which the force is acting remains unchanged, the gyroscope precesses until the plane of the rotor is in the plane of the force. When this position is reached, the torque is about the spinning axis and can cause no further precession.

If the plane in which the force acts moves at the same rate and in the same direction as the precession which it causes, the precession will be continuous. A force attempting to change the horizontal axis is provided by a weight that is suspended from the end of the spinning axle (fig. 10-8). As the gyroscope precesses about its vertical axis it carries the weight around with it so that a continuous force acts on the horizontal axis and precession continues indefinitely.

### FORCE OF TRANSLATION

Any force that attempts to change the angle of the plane of rotation of a gyroscope with respect to its original position produces a movement known as precession. A force operating through the center of gravity of the gyroscope does not change the angle of the plane of rotation but moves the gyroscope as a unit without changing its position in space. Such a force operating through the center of gravity is known as a FORCE OF TRANSLATION. Thus, the spinning gyroscope may be moved freely in space by means of its supporting frame, without disturbing the plane of rotation of the rotor. This condition exists because the force that is applied through the supporting frame acts through the center of gravity of the rotor and is a force of translation.

## Effect of Earth's Rotation

As explained previously, a free-spinning gyroscope can be moved in any direction without altering the angle of its plane of rotation. If this free-spinning gyroscope is placed on the earth's surface at the equator with its spinning axis horizontal and alined east and west an observer in space below the south pole would note that the earth rotates clockwise from west to east and carries the gyroscope along. As the earth rotates, rigidity of plane keeps the gyroscope wheel fixed in space and rotating in the same plane at all times. Figure 10-9 shows how this gyroscope would appear to the observer in space. Assume that the gyroscope is set spinning at 0000 hours with its spinning axis alined east and west and parallel to the earth's surface. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the axle of the gyroscope is alined with the original starting position. At 1200 the earth has rotated 180° while the gyroscope retains its original position. At 1800 the earth has rotated 270°

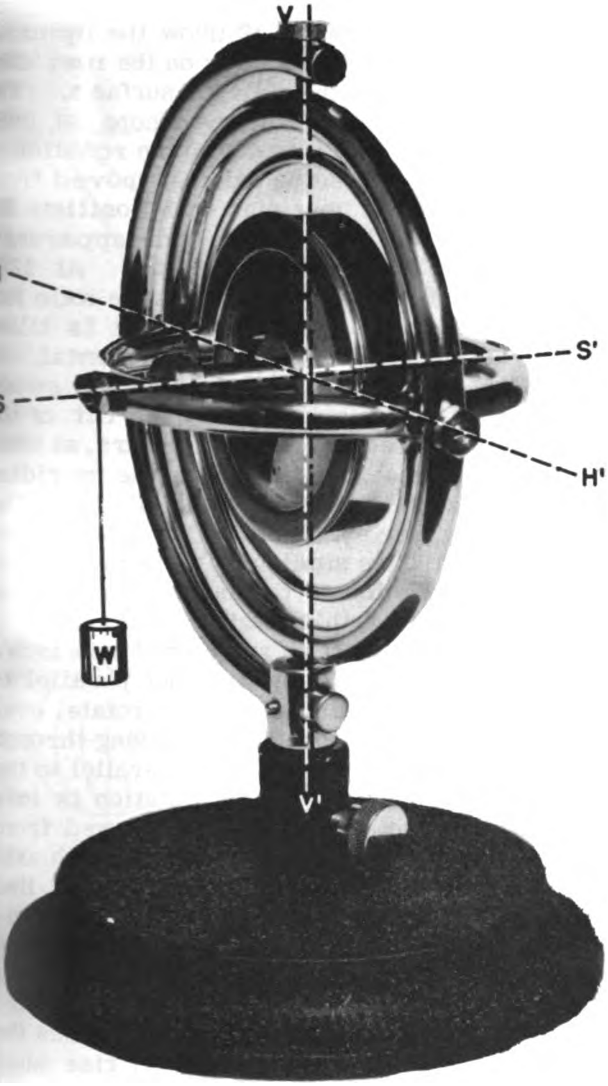



Figure 10-8.—Continuous precession.

while the gyroscope retains its original position. At 0000 the earth has rotated 360° and the gyroscope remains in its original position in space.

This rigidity of plane appears quite different to an observer on the earth's surface. As the earth rotates, the observer moves with it and the gyroscope wheel appears to rotate about its horizontal axis. Figure 10-10 shows how this gyroscope appears to the observer on the earth's surface beside the gyroscope. Assume that the gyroscope is set spinning at 0000 hours with its spinning axis horizontal and pointing west toward the observer. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the gyroscope axle apparently has tilted. To the observer, the axle points

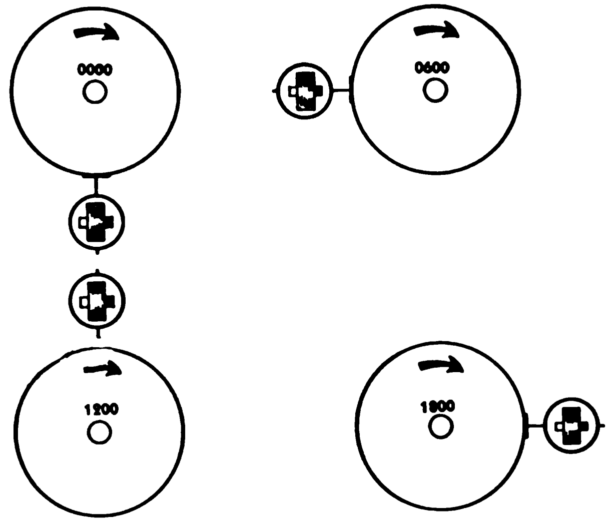



Figure 10-9.—Free gyroscope at the equator viewed from space.

straight down and is vertical to the earth's surface. At 1200 the gyroscope axle is horizontal again, but the axle points away from the observer. At 1800 the gyroscope axle is again vertical and points straight up. At 0000 the earth has rotated 360° and the gyroscope axle is back in its original position.

## APPARENT ROTATION OF THE GYROSCOPE

The rotation of the gyroscope axle as seen by the observer on the earth's surface is known as APPARENT ROTATION. Apparent rotation is caused by rigidity of plane which tends to maintain the plane of the gyroscope wheel parallel to its original position in space.

Now assume that the spinning gyroscope, with its spinning axis horizontal, is moved to the North Pole (fig. 10-11). To an observer on the earth's surface the gyroscope appears to rotate about its vertical axis. To an observer in space the gyroscope axle appears to remain fixed and the earth appears to rotate under it.

When the gyroscope axle is placed parallel to the earth's axis at any location on the earth's surface, the apparent rotation is about the axle of the gyroscope and cannot be observed. At any point between the equator and either pole, a gyroscope whose spinning axis is not parallel to the earth's spinning axis has an apparent rotation that is a combination of the apparent

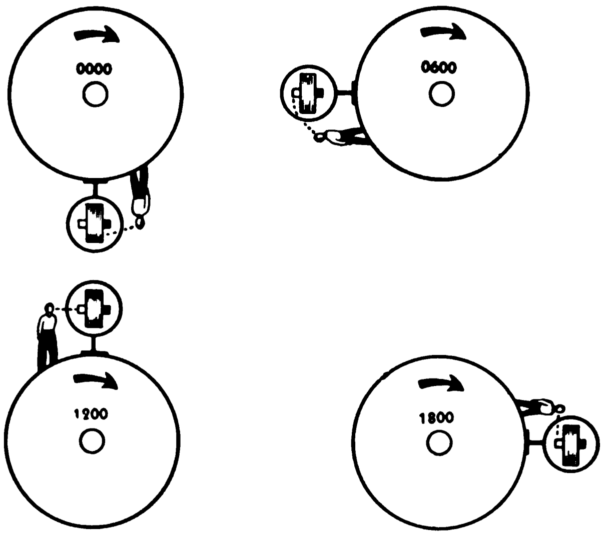



Figure 10-10.—Free gyroscope at the equator viewed from the earth's surface.

rotation at the pole and at the equator. This apparent rotation is about both the horizontal and the vertical axes. Apparent rotation is illustrated by placing a spinning gyroscope with its axle on the meridian and parallel to the earth's surface at 45° north latitude and 0° longitude, as shown in figure 10-12. As the earth rotates, the positions of the gyroscope at 0000, 0600, 1200, and 1800 show the apparent rotation about the vertical and horizontal axes. Both views are of the same gyroscope, but they are from different angles in order to show the movement about both axes. In both views the observer is above the earth's surface, but he is rotating with the earth. Both views should be considered together because they show the same movement although in different planes.

A and B of figure 10-12 show the spinning gyroscope at 0000. The axle is on the meridian and is parallel to the earth's surface. The apparent movement of the gyroscope at 0600 (C and D of fig. 10-12) is due to the rotation of the earth. The gyroscope axle has moved from alinement with the meridian to a position 45° east of the meridian, and the axle apparently has tilted 45° from the horizontal. At 1200 (E and F of fig. 10-12) the gyroscope axle has moved back to the meridian, but it is tilted now at an angle of 90° from the horizontal. At 1800 (G and H of fig. 10-12) the axle has swung 45° west of the meridian, and the tilt of the axle has decreased 45°. After 24 hours, at 0000 the next day, the axle is back on the meridian and is horizontal (A and B of fig. 10-12). The action of any free gyroscope at any latitude between 0° and 90° is similar. This apparent rotation is in relation to the earth's surface and is caused by the earth's rotation.

A gyroscope, if set on any part of the earth's surface with the spinning axle not parallel to the earth's polar axis, appears to rotate, over a 24-hour period, about a line passing through the center of the gyroscope and parallel to the earth's axis. This apparent rotation is in a counterclockwise direction when viewed from south to north. The path that the north axle describes in space is indicated by the line EAWB back to E (fig. 10-13). The line EN represents the amount of deflection between the gyroscope and the meridian at the start of the observation.

The effect of the earth's rotation causes the north end of the gyroscope axle to rise when east of the meridian and to fall when west of the meridian in any latitude. This tilting effect provides the means by which the gyroscope can be made into a north-seeking instrument.

# Gyrocompass

A free gyroscope, if set with its spinning axle in the plane of the meridian and parallel to the earth's axis, remains in that position because the apparent rotation produced is about the gyroscope axle. Thus, it becomes a direction-indicating device. Once set, it continues to point north as long as no disturbing forces cause it to precess out of the plane of the meridian. Such an instrument, however, is not useful as a compass because any slight friction sets up torques that cause it to precess away from the meridian. Except at, or near, the equator an excessive tilt in relation to the earth's surface is required to keep the gyroscope axle parallel to the earth's axis. Also, if the axle is set sufficiently level for the instrument to be useful as a compass in a north or south latitude, the earth's rotation causes it to turn away from the meridian, as explained in the preceding paragraphs.

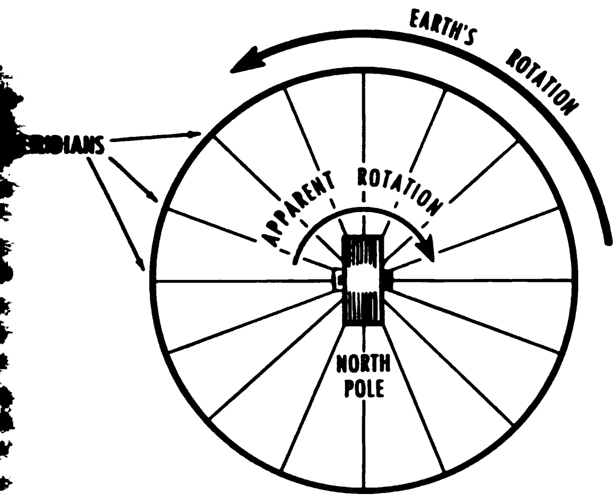



Figure 10-11.—Apparent rotation of a gyroscope at the North Pole.

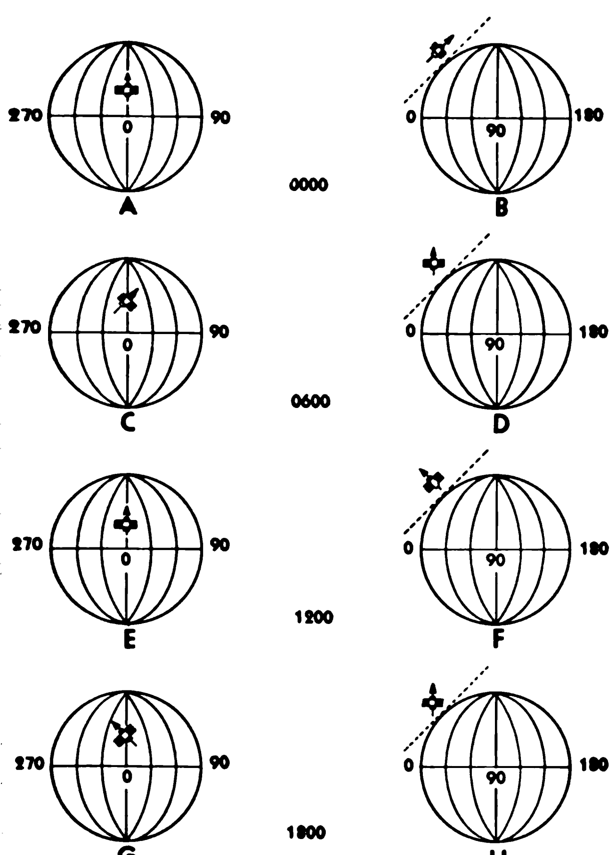



Figure 10-12.—Apparent rotation of a gyroscope at 45° N latitude.

The following conditions must be met to make a gyroscope into a gyrocompass that accurately indicates north at all times.

1. Torques of the correct magnitude and direction must be provided in order to precess the gyroscope so that the spinning axis is brought parallel to the meridian within a reasonable time after the wheel is set spinning. Correct torques also must be provided to cause precession about the vertical axis at the proper rate and in the proper direction to cancel the effect of the earth's rotation.

2. The axis of spin of the gyrocompass must be nearly level when parallel to the meridian, and a means must be provided to prevent it from oscillating across the meridian.

## NORTH-SEEKING GYROSCOPE

It is obvious from figures 10-10, 10-11, and 10-12 that the spinning axis of a free gyroscope tilts with respect to the surface of the earth when the earth turns and when the axle is not parallel to the earth's axis. For example, the gyroscope spinning axis that is east-west as the equator makes a complete revolution in a vertical plane in 24 hours. A force applied at right angles to the end of the spinning axis causes the gyroscope to precess—that is, if the spinning axis is east-west, a downward force on the end of the axle causes it to precess into a meridian. A gyrocompass operates on these principles.

A gyrocompass is simply a gyroscope with a means for exerting a force at right angles to the end of its axle whenever its axle tilts with respect to the surface of the earth. Because of the rotation of the earth, the axle tilts whenever it is not on the meridian. The axle is precessed automatically into a north-south direction.

The torques that are necessary to produce the power precession for converting the gyroscope into a north-seeking gyrocompass are provided by gravity. Two types of compasses which employ this principle are used by the Navy. They differ mainly in the manner in which they utilize the force of gravity to cause the desired precession. The NONPENDULOUS type of compass, manufactured by Sperry Gyroscope Company, Inc., uses a device called a mercury ballistic; whereas the PENDULOUS type of compass manufactured by Arma Corporation has more of the weight of the rotor and case

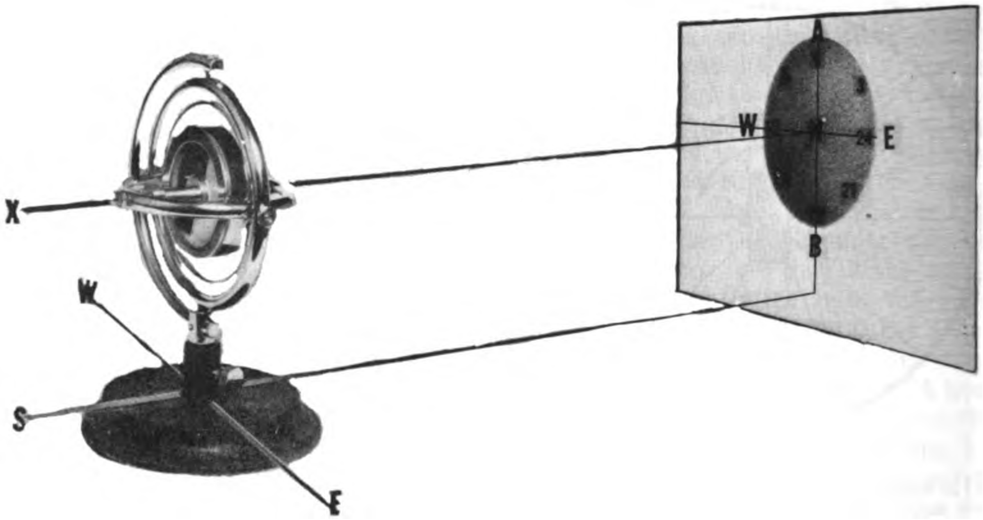



Figure 10-13.—Path of the spinning axle of a free gyroscope.

below the center of support, making it in effect pendulous.

The Sperry Gyroscope Mk 19 uses an electrolytic level to develop an electric signal, which is amplified and converted to torque electromagnetically. This method replaces the methods that use weight and gravity to produce a torque.

The Sperry Mk 19 Gyroscope is covered in IC2, NavPers 10556-A.

## SPERRY PRINCIPLE

In its simplest form, the mercury ballistic consists of two mercury-containing reservoirs, one mounted at each end of the rotor axle. The two reservoirs are connected by a pipe so that the mercury is free to flow from one reservoir to the other, as shown in figure 10-14.

When the axle is level (fig. 10-14A), each reservoir contains the same amount of mercury, each weighs the same, and each exerts the same downward force on its end of the axle. Therefore, no torque is produced about any axis. When the axle is tilted, even slightly (fig. 10-14B), mercury runs through the connecting tube from the higher container to the lower container. The amount of mercury in the two tanks is no longer equal. The lower tank is heavier because it contains more mercury. Therefore, the lower tank exerts more force against its axle than does

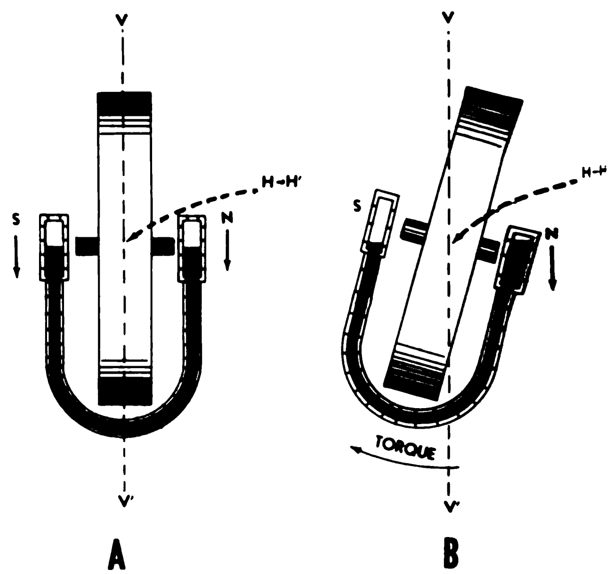



Figure 10-14.—Action of a mercury ballastic.

the upper tank, and produces a torque about axis H-H'. This torque, which seemingly tends to increase the tilt, instead, causes precession about the vertical axis, V-V'.

The rotor in a Sperry gyrocompass spins counterclockwise when viewed from the south end of the axle. When the north end is low, the excess mercury in the north tank exerts a downward pressure on the north end of the axle and causes precession to the east, or clockwise.

When the north end is high the excess mercury in the south tank exerts a downward pressure on the south end of the axle and causes precession to the west, or counterclockwise.

As you have learned, when the north end of the rotor axle is east of the meridian, the earth's rotation causes it to rise. When a mercury ballistic is added to the gyroscope, the elevation of the north axle produces a torque about the horizontal axis that causes counterclockwise, or westerly, precession. When the north end of the axle is west of the meridian, the earth's rotation causes it to drop. A low north axle causes the mercury ballistic to exert a torque about the horizontal axis that gives clockwise, or easterly, precession.

If this gyroscope with its mercury ballistic is set on the equator with the axle pointing to the east of the meridian and with the rotor spinning counterclockwise (A of figure 10-15) the north end of the axle tilts upward because the earth rotates under it. When this tilt occurs mercury flows from the north to the south tank, and the south tank becomes the heavier. The south tank applies a torque around the horizontal axis (B of figure 10-15). This torque results in a precessional motion around the vertical axis toward the meridian and the west. Because the earth is constantly turning, the gyroscope continues to tilt upward, more mercury flows to the south tank, and the torque around the horizontal axis gradually increases with a corresponding increase in the precession about the vertical axis (C and D of figure 10-15). This upward tilting continues until the gyroscope axle is on the meridian (E of figure 10-15). The south tank contains more mercury than the north tank, and the gyroscope is tilted upward its greatest amount. At this point the rate of precession is at its peak.

After the gyroscope axle crosses the meridian it begins tilting downward so that mercury flows from the south tank to the north tank. This transfer of mercury gradually reduces the torque about the south end of the axle with a corresponding gradual reduction in the rate of precession of the gyroscope about the vertical axis. When the gyroscope axle is once more level, it points to the west of the meridian, the mercury is distributed equally in both tanks, no torque is applied to either the north axle or the south axle, and precession ceases.

As the earth continues moving, the north end of the gyroscope axle tilts downward, mercury flows into the north tank, which applies a torque to the north end of the spin axis. Hence, the direction of precession is reversed and is now toward the east. The downward tilt of the spinning axis continues, and the torque and rate of precession increase. By the time the gyroscope axle reaches the meridian, it has attained its maximum rate of precession again, but it now has a downward tilt. After the gyroscope passes the meridian, the rotation of the earth starts the north end of the gyroscope axle tilting upward. As this action occurs the torque about the north axle gradually diminishes to zero and the precessional motion around the vertical axis slows down until the gyroscope axle is once more horizontal and precession ceases. When the gyroscope axle become horizontal, the axle points in its original starting position. Figure 10-16 shows that the path followed by the north axle of the gyroscope has the shape of an ellipse. The gyroscope continues these oscillations indefinitely as long as the wheel is spinning.

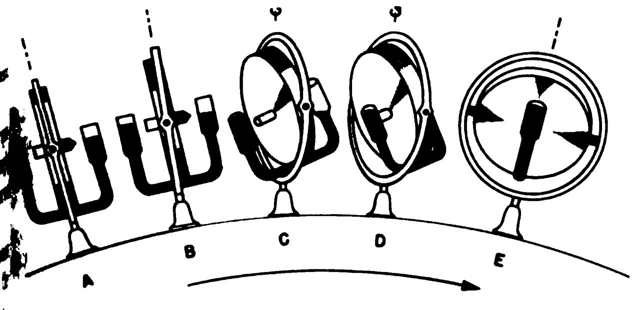



Figure 10-15.—Elementary Sperry gyrocompass at the equator.

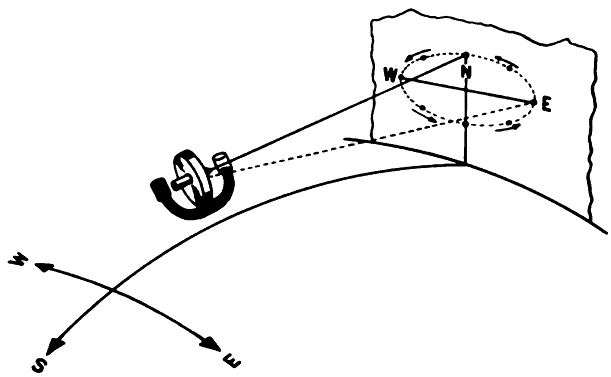



Figure 10-16.—Undamped period of the Sperry compass at the equator.

## ARMA PRINCIPLE

The Arma compass is north-seeking because it is given a force of precession by a pendulous weight. To understand how this compass operates, assume again that the gyroscope is on the equator and that its spinning axis is horizontal and points to the east of the meridian. Instead of having a mercury ballistic, the gyroscope has a weight, W, at the bottom of the rotor case, as shown in figure 10-17. The north end of the gyroscope appears to tilt upward because the gyroscope wheel maintains its plane in space as the earth revolves under it. Gravity attracts the weight toward the center of the earth, straight down, as shown in A through E of figure 10-17. This pull of gravity has the same effect as a torque about the horizontal axis.

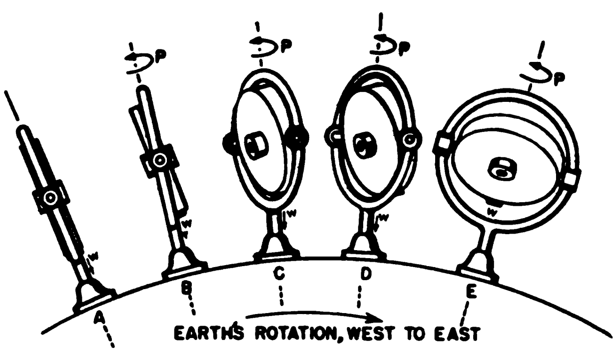



Figure 10-17.—Elementary Arma compass at the equator.

The mercury ballistic of the Sperry compass as shown in B of figure 10-15 applies a downward force on its SOUTH axle to cause precession to the west. Conversely, the weight W of the Arma compass has the same effect as a downward force on its NORTH axle to cause precession to the west. Because both types of compasses must precess in the same direction—that is, to the west—the rotors obviously must rotate in opposite directions to give this precession. The rotor of the Sperry compass rotates counterclockwise whereas the rotor of the Arma compass rotates clockwise when viewed from the south axle.

As the upward tilt increases, the torque, or pull of gravity, increases with the rate of precession to the west. When the gyroscope is on the meridian (E of fig. 10-17), the axis has reached the maximum in both tilt and the rate of precession. After the gyroscope has swung across the meridian, the tilt and the rate of precession diminish until the north end of the axle is at its farthest point west of the meridian and is again horizontal. At this point there is no precession because the weight is acting through the center of gravity of the rotor and therefore does not produce torque. However, the earth continues to rotate under the gyroscope. The north end of the axle drops below the horizontal, and, as the pendulous weight no longer hangs vertically down from the center of the rotor, a torque is again produced around the horizontal axis. The precession resulting from this torque is toward the east. The downward tilt and the rate of precession increase until they are at a maximum value, when the axle is again on the meridian. As the axle crosses the meridian, the downward tilt decreases because the earth rotates under the gyroscope. The angle of tilt and the rate of precession decrease and become zero when the rotor is at its point of farthest travel to the east and is in the horizontal. Now the gyroscope axle is horizontal once more at the point where the oscillation first started. Oscillations continue as long as the gyroscope wheel continues to spin. As in the Sperry compass, the north axis of the Arma compass moves along an elliptical path, as shown in figure 10-16.

Whatever the starting position may be, oscillations take place for both types of gyroscopes. The gyroscope precesses one way or the other until the axis is made level by the effect of the earth's rotation. The gyroscope then swings toward the meridian, crosses it, continues to the other side, becomes level again, swings back to the starting position, and continues the oscillations indefinitely.

## PERIOD OF OSCILLATION

The time required for one complete cycle of this movement of the gyroscope wheel is called PERIOD OF OSCILLATION. The time is conveniently expressed in minutes. For a given wheel at a particular spot on the earth's surface the period is the same regardless of the angle through which the wheel oscillates.

The period of a north-seeking gyroscope is determined by the (1) size and shape of the rotor, (2) rotor speed, (3) torque developed by the mercury ballistic or pendulous weight, and (4) latitude. Arma and Sperry have built compasses with an undamped period of 85 minutes at 40.7° north latitude. An undamped period of 85 minutes is long enough to prevent the compasses from oscillating in response to disturbances such as rolling and pitching of the ship, which have very short periods by comparison.

A graph representing the oscillations of a north-seeking gyroscope with a period of 85 minutes is shown in figure 10-18. Such a graph is known as an undamped curve. The original displacement of the gyroscope axle is 30° east of the meridian. In 21 1/4 minutes the axle reaches the meridian; after 42 1/2 minutes it is 30° west; at 63 3/4 minutes it is again on the meridian; and after 85 minutes it is back at its starting position, 30° east. The cycle is then repeated and continues indefinitely.

A gyrocompass with an undamped period of 85 minutes in one latitude has a different period in any other latitude. The nearer the gyrocompass is to the equator the shorter is the period; the farther away the gyrocompass is from the equator, the longer is the period. This is true because the tilt of the axle caused by the earth's rotation when the axle is not on a meridian is greatest at the equator. With zero tilt at the north pole there is no restraint to keep the gyrocompass axle from apparently turning about the vertical axis. Maximum tilt at the equator causes maximum restraint and maximum directive effort to cause the gyrocompass to precess toward the meridian.

To be useful as a compass, a north-seeking gyroscope must be made so that its axle settles in a position that is parallel to the meridian and to the surface of the earth, or nearly so. At any location except at the equator the north end of a level gyroscope normally is moved to the east or west by the effect of the earth's rotation. If a gyroscope is started with its axle level and pointed north in a north latitude, the rotation of the earth causes the north end of the axle to turn slowly toward the east and rise. Conversely, if a gyroscope is started with its axle level and pointed north in a south latitude, the rotation of the earth causes the north end of the axle to slowly turn toward the west and fall. It must, therefore, be made to precess to the west in a north latitude and to the east in a south latitude at the proper rate to cancel this effect of the earth's rotation. The rate of precession required is so slow that only a small angle of tilt is necessary in any latitude.

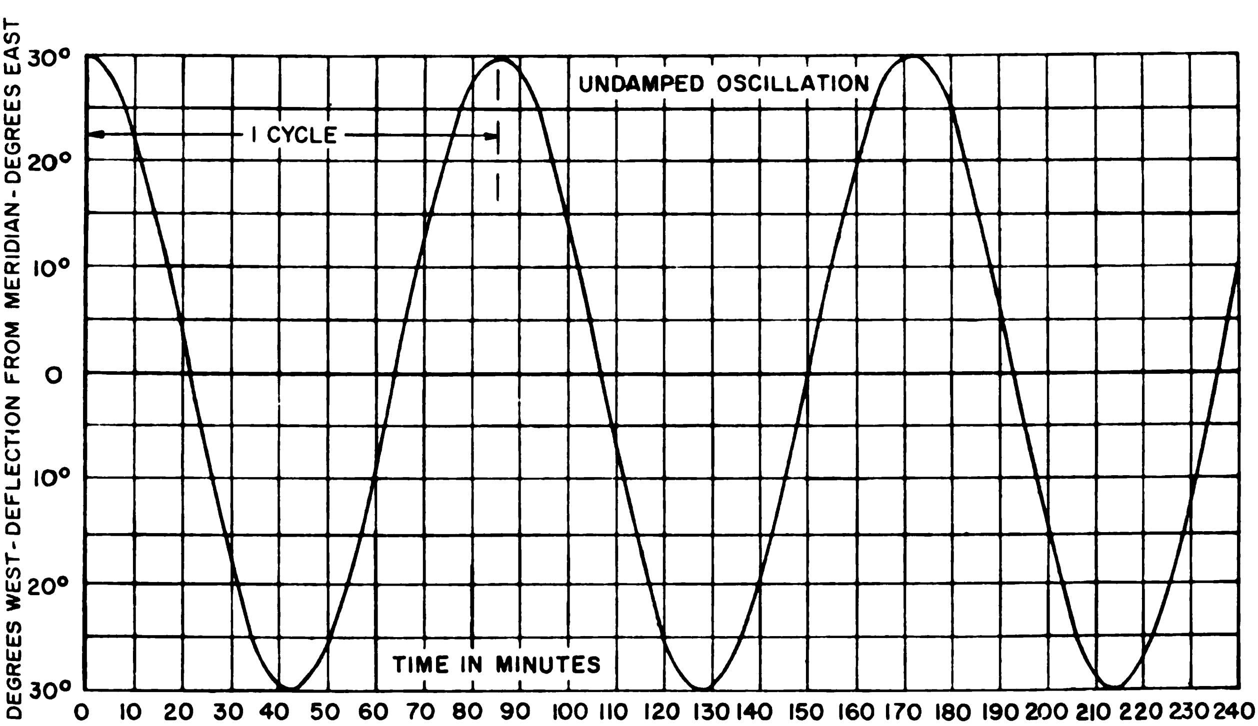



Figure 10-18.—Oscillation curve of an undamped compass.

## DAMPING THE OSCILLATIONS

The north-seeking gyroscope can never settle in the desired position as long as it oscillates across the meridian. Therefore, some means must be provided to suppress, or damp, the oscillations by reducing the size of successive swings past the meridian until the swinging is stopped. When damped, the north-seeking gyroscope (1) settles with the tilt that is necessary to cancel the effect of the earth's rotation and (2) gives a continuous indication of true north. The time required for effective damping in either make of compass is about 4 hours.

### SPERRY METHOD

Oscillations are damped in the Sperry gyrocompass by employing a portion of the torque produced by the action of gravity upon the mercury ballistic to remove some of the tilt given the rotor axle by the rotation of the earth.

In the previously described mercury ballistic, the tanks are attached directly to the bearings at the ends of the shaft. In the actual compass the ballistic is pivoted on studs and bearings on an outside ring, called the PHANTOM RING, in such a way that its only point of contact with the gyroscopic element is through a connecting arm, or link, which bears against the bottom of the case in which the rotor spins (fig. 10-19). The rotor case corresponds to the inner ring of a gyroscope and holds the bearings on which the axle turns.

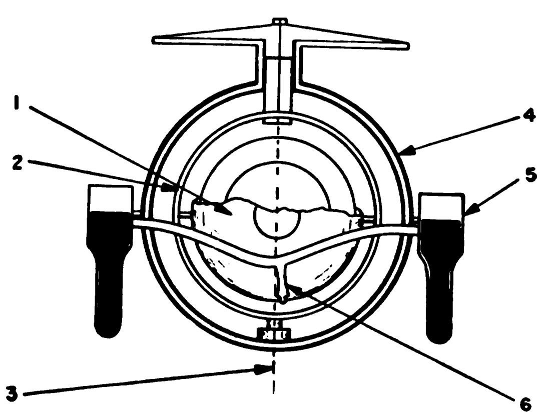



Figure 10-19.—Elements of the Sperry compass.

If the point of connection between the mercury ballistic and the rotor case is in the line of the vertical axis the only torque that can be exerted by the mercury ballistic is about the horizontal axis, and the resulting precession is only about the vertical axis. Thus, the compass would oscillate only back and forth across the meridian. However, if this point of connection between the ballistic and the rotor case is set a fraction of an inch to the east of the vertical axis (fig. 10-19) the force exerted by the mercury ballistic is applied about both the horizontal and the vertical axes, and torque is exerted about both the axes. Precession then results about both the vertical and the horizontal axes. Precession about the horizontal axis is much slower than precession about the vertical axis because the point of connection is offset from the vertical axis only a small amount.

With the compass displaced east or west of the meridian, if it is pointing 30° E of the meridian and level (point A, figure 10-20), the earth's rotation will cause the north axle to rise. When the north end rises it causes a transfer of mercury to the south tank. Gravity action on this excess of mercury in the south tank causes torques to be exerted about both the horizontal and vertical axes. The torque about the horizontal axis causes precession of the north end of the gyrocompass axle to the west about the vertical axis. The torque about the vertical axis causes precession of the north end of the gyrocompass axle downward about the horizontal axis. At this time the precession about the horizontal axis opposes apparent rotation about the horizontal axis. The precession about the vertical axis will cause the compass to precess to the meridian. However, the compass cannot remain on the meridian (point B, figure 10-20), because

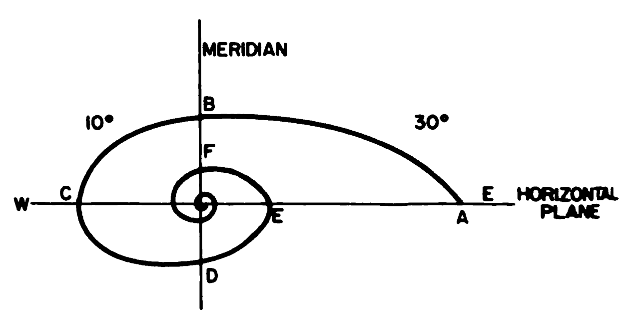



Figure 10-20.—Path followed by the North axle of a damped Sperry compass.

this time it has its maximum tilt and there-re maximum rate of precession about the ver-cal axis. As the gyro precesses past the merid-n, the direction of apparent rotation about the rizontal axis and the direction of precession out the horizontal axis are now both down-ard. This action causes the gyro to become vel (point C, figure 10-20). When the axle comes level, precession ceases as there are torques being applied by the mercury bal-stic. If the proper (correct) torques have been plied, the compass would be only 10° W of the eridian, reducing the oscillation by 66 2/3 rcent. However, as the earth continues to tate, the compass will not remain level. pparent rotation about the horizontal axis uses the north axle to tilt downward. This tion causes a transfer of mercury to the north nk. Gravity action on this excess of mercury in e north tank will produce torques about both the orizontal and vertical axes. The torque about e horizontal axis will cause precession about e vertical axis, the north end moving toward e east. The torque about the vertical axis ill cause precession about the horizontal xis, the north end moving upward, again pposing apparent rotation about the horizon-al axis. The precession about the verti-al axis will cause the gyro to precess to he meridian (point D, figure 10-20). However, t cannot remain in the meridian because at his time it has maximum tilt, therefore maxi-num rate of precession, causing the gyro to recess past the meridian. Now that the north xle is again east of the meridian, the apparent otation about the horizontal axis and the direc-ion of precession about the horizontal axis both ause the north axle to become level (point E, igure 10-20) more quickly. At this time the compass would be approximately 3 1/3° east of he meridian. This damping action would con-inue for approximately 2 1/2 oscillations, and he compass would then settle in the meridian.

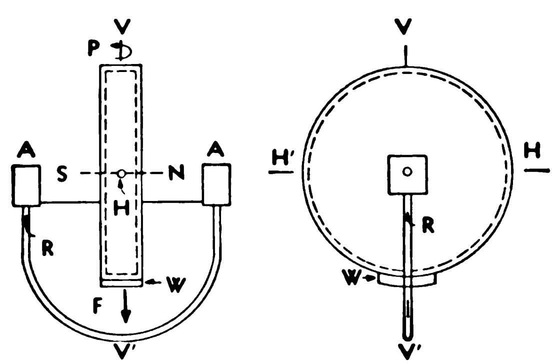
## ARMA METHOD

In the Arma compass the oscillations are reduced by slowing down the rate of precession during each swing away from the meridian so that, in the time required for the axle to become level and start to swing back, the compass does not travel very far.

The damping arrangement used in the Arma compass consists of a fluid ballistic, as shown in figure 10-21. Two tanks, partly filled with a light oil, are secured to the rotor case in line with the north-south rotor axle on opposite sides of the rotor. The tube that connects the tanks has a small opening so that the oil flows slowly from one tank to the other. Unlike the action of the Sperry mercury ballistic the action of the Arma damping is delayed because of the small opening in the tube. The effect of this damping lags behind that of the pendulous weight.

If the north end of the gyroscope axle is elevated, the pendulous weight exerts a downward force on the high, or north, axle. At the same time oil begins to (1) flow from the north tank to the south tank and (2) exert a small force on the low, or south, end. Because of the small opening in the tube, the flow of oil is not effective for some time. If the tilt is maintained long enough, however, sufficient oil accumulates in the south tank to reduce the effect of the pendulous weight on the high end of the axle. The longer the tilt is maintained, the greater is the amount of oil in the south tank and the smaller is the net force exerted by the pendulous weight on the north axle.

If the tilt is reversed and the south axle is elevated the excess oil in the south tank acts on the high end of the axle. The small opening in the tube prevents the oil from flowing immediately into the north tank. Hence, for a short time after the tilt is reversed the weight of the oil in the south tank adds to the force exerted by the weight on the high south axle.




S, N —SPINNING AXIS
V, V′ —VERTICAL AXIS
H, H′ —HORIZONTAL AXIS
A, A —OIL TANKS WITH PIPE CONNECTION
R —RESTRICTED OPENING IN OIL LINE
W —WEIGHT OR PENDULOUS CHARACTERISTIC
F —GRAVITATIONAL FORCE

Figure 10-21.—Damping arrangements of the Arma compass.

In A of figure 10-22, the axle has just been tilted with the north end up, and the oil has not had sufficient time to run into the south tank in any great amount. In B of figure 10-22, the tilt has been maintained long enough for a large amount of oil to flow into the south tank, and the resultant force is greatly reduced. In C of figure 10-22 the tilt has just been reversed and there is still excess oil in the south tank. This excess oil adds to the pendulous weight and results in an increased force. In D of figure 10-22 the south axle has been tilted up for some time and the oil has built up in the north tank so that the effect of the weight has been reduced. The length of the arrows indicates the magnitude of the force that is being exerted.

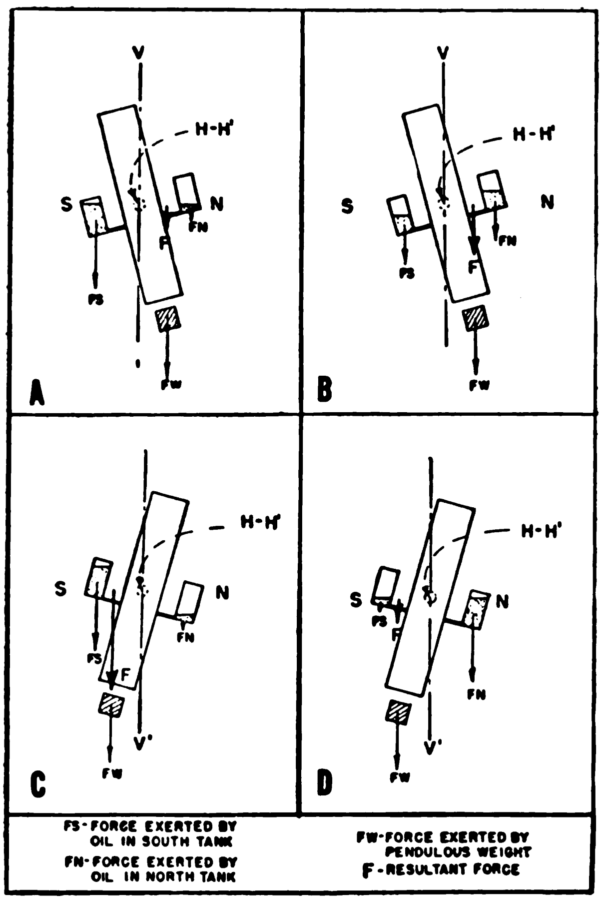



Figure 10-22.—Action of Arma damping tanks.

Starting with the compass displaced 30° to the east of the meridian and level (point A, figure 10-23) the earth's rotations will cause the north axle to rise. This causes the pendulous weight to become elevated, the north axle up. This will produce a torque about the horizontal axis causing precession about the vertical axis to the west. However, due to the elevation of the north axle, it will cause the north tank to be elevated. This will cause a transfer of oil to the south tank. This transfer of oil to the south tank will be very slow because of the restriction in the connecting line and will not have much effect at the beginning. However, as time goes on the oil accumulating in the south tank produces a torque about the horizontal axis opposing the torque produced by the pendulous weight making the net torque less than that produced by the pendulous weight above. The rate of precession will be less because there is now less torque causing precession. The north axle of the compass will continue to rise as long as it remains east of the meridian so that the pendulous weight will always exert enough torque to cause it to reach the meridian (point B, figure 10-23). However, it cannot remain on the meridian because at this time it has maximum tilt, therefore maximum rate of precession. As the north axle of the compass crosses the meridian to the west, the earth's rotation will now cause the north axle to fall. This action further reduces the effect of the pendulous weight. As oil has been transferring to the south tank all this time because of the elevation of the north axle, a point is soon reached at which the torque produced by the oil ballistic is exactly equal and opposite to the torque produced by the pendulous weight. At this time the net torque about the horizontal axis is zero (point C, figure 10-23). Therefore precession to the west ceases. However, the north axle of the compass (being west of the meridian) continues to fall due to the earth's rotation further reducing the torque produced by the pendulous weight. The torque produced by the oil ballistic is now greater than that produced by the pendulous weight and causes

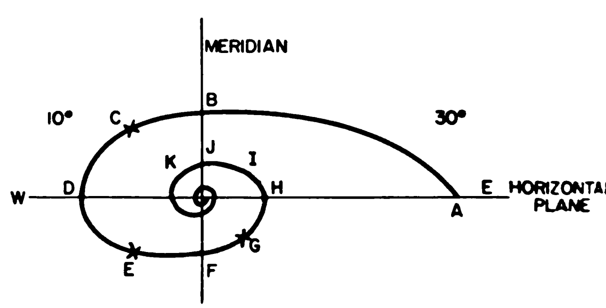



Figure 10-23.—Path followed by the north axle of a damped Arma compass.

·ecession to the east even though the axle has ›t yet become level. As the north axle becomes vel (point D, figure 10-23) there is still an :cess of oil in the south tank due to the re- riction in the oil line. This excess of oil in .e south tank causes it to continue to precess the east. However, the north axle continues fall due to the rotation of the earth, elevating .e south axle. The pendulous weight now pro- ıces a torque about the horizontal axis that .so causes precession to the east. At this me the oil ballistic and pendulous weight are certing torques that are aiding each other. owever, as the south axle is now elevated, oil ill be transferring to the north tank until a ɔint is reached where there is equal oil in ɔth tanks (point E, figure 10-23). However, :ecession continues to the east because of the ›rque produced by the pendulous weight. The ɔuth axle being elevated causes oil to continue › transfer to the north tank. This action pro- ıces an excess of oil in the north tank, causing torque about the horizontal axis opposing that ›rque produced by the pendulous weight. How- ver, as long as the north axle remains west of ıe meridian, it will continue to fall, producing nough torque to cause it to reach the meridian ›oint F, figure 10-23). At this time, there is ıaximum tilt and maximum rate of tilt, there- ›re, it cannot remain on the meridian. The orth axle of the compass is now east of the ıeridian and will rise due to the earth's rota- .on further reducing the effect of the pendulous eight. As oil has been accumulating in the orth tank during this time, a point is soon eached at which the torque produced by the oil allistic is exactly equal and opposite to that roduced by the pendulous weight. The net ɔrque about the horizontal axis is now zero nd precession to the east ceases (point G, igure 10-23). The north axle continues to rise ue to the earth's rotation further reducing he effect of the pendulous weight. The oil allistic is now producing a greater torque han the pendulous weight and causes precession o the west even though the north axle is not yet evel. When the north axle becomes level (point I, figure 10-23) there is still an excess of oil n the north tank because of the restrictor in he connecting line which causes the compass o continue to precess to the west. As the north ıxle becomes elevated due to the earth's rota- ion, it raises the pendulous weight to the north vhich produces a torque about the horizontal ıxis that also causes precession to the west. The torque produced by the pendulous weight and the oil ballistic now aid each other. However, as the N-axle is now elevated, oil will transfer to the S-tank. A point is soon reached at which there is equal oil in both tanks (point I, figure 10-23). Precession continues to the west due to the pendulous weight. However, oil continues to transfer to the south tank which now produces a torque about the horizontal axis opposing the torque produced by the pendulous weight. The north axle will continue to rise as long as it remains east of the meridian. As it reaches the meridian it has maximum tilt and therefore maximum rate of precession and therefore cannot remain on the meridian (point J, figure 10-23). This action continues for about 2 1/2 oscillations at which time the compass has settled and is on the meridian.

Damped period of oscillation for Arma is 105 min.

Damped period of oscillation for Sperry is 85 min.

Because of the restriction of the flow of oil, the effect of the damping tanks always lags behind the effect of the pendulous weight. This lag makes the oil ballistic useful as a damping device because the ballistic permits the weight of the oil to act at just the right time to oppose the oscillations away from the meridian.

The oscillation curve of an undamped compass compared to the oscillation curves of a damped Sperry and Arma compass are shown in figure 10-24. Note that the damped period for both compasses is somewhat larger than the undamped period and that the damped period of the Arma compass is larger than that of the Sperry.

The amount by which each successive swing past the meridian is reduced by the damping device is not the same for all swings. In the Arma compass it is less on the first swing than on the following swings. In the Sperry compass it is greater on the first swing than on succeeding swings. The average amount by which successive oscillations are reduced is called the percentage of damping or the damping factor. It is about 70 percent for both Sperry and Arma compasses.

## ERRORS

As discussed in the preceding paragraphs, a free-spinning gyroscope can be made to seek

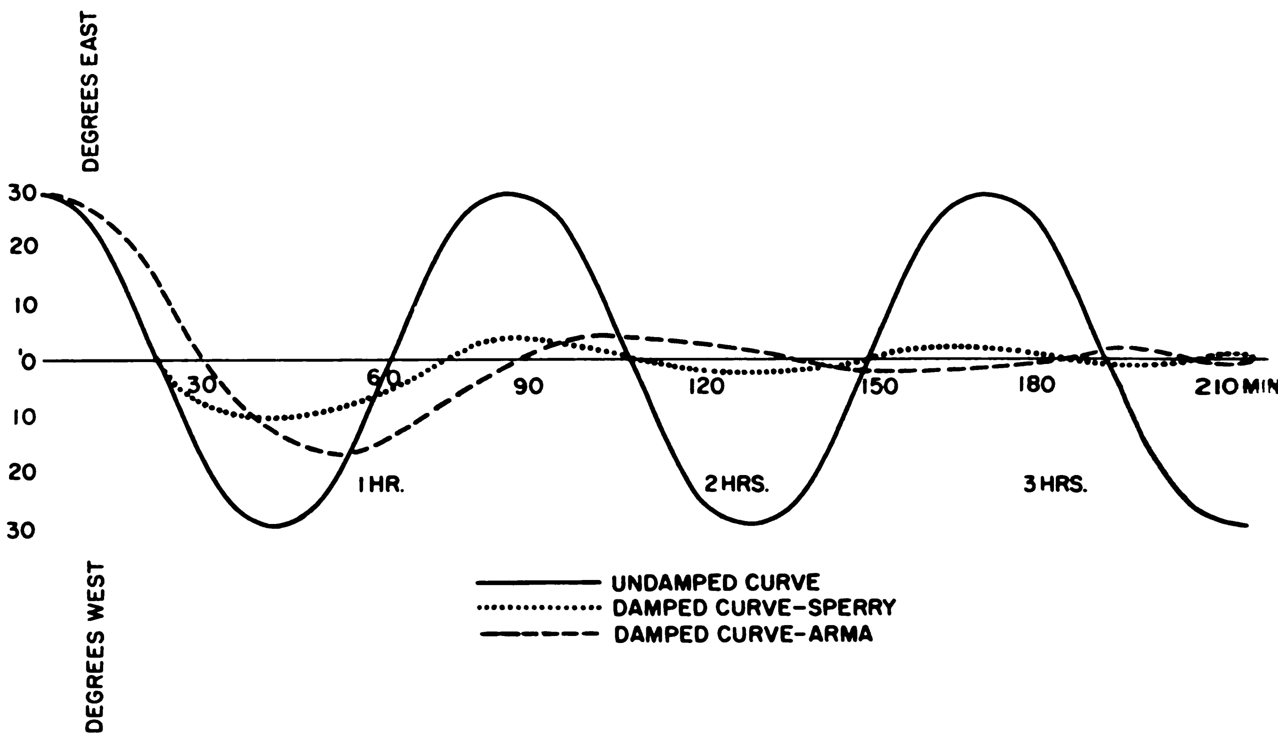



Figure 10-24.—Oscillation curves of undamped and damped compasses.

and remain in the meridian by using either the Sperry nonpendulous or the Arma pendulous method. These two compasses function perfectly on land for indicating the true north. A gyrocompass installed aboard ship is subjected to many disturbing forces that affect its ability to seek and hold the meridian. Therefore, it is necessary to consider roll and pitch, changes of course and speed, and actual course and speed over the surface of the ocean. Unless these motions are compensated for, they tend to produce errors in the gyrocompass. Such errors are called constant-motion, oscillating, and quadrantal. These errors and methods of correcting them are explained in more advanced I.C. training courses.

## QUIZ

1. What are the two properties of a spinning gyroscope?
2. What are the three methods of increasing the kinetic energy of the rotor of a gyroscope?
3. What is precession?
4. What is the force of translation with respect to a gyroscope?
5. What causes apparent rotation of a gyroscope with respect to the surface of the earth?
6. What makes the Sperry gyrocompass north-seaking?
7. In what direction does the rotor of the Sperry compass rotate when viewed from the south end of its axle?
8. (a) If a Sperry gyrocompass has a damped period of 85 minutes and is started with its north axle 5° west of the meridian, how long does it precess before it reaches the meridian? (b) How long would this gyrocompass precess before it reaches the meridian if it were started with its north axle 37° east of the meridian?

How much time is normally required for effective damping of the (a) Sperry compass? (b) Arma compass?

Does the damped Sperry compass precess about both its vertical axis and its horizontal axis?

11. If a Sperry compass is started with its north axle displaced 45° east of the meridian, how far west of the meridian does it swing on its first oscillation?

12. What means is used to damp the Arma compass?

# CHAPTER 11

# MAGNETIC AMPLIFIERS

## Introduction

Amplification of voltage and power can be accomplished by means of the magnetic amplifier, which employs as the controllable element an iron-core saturable reactor. The magnitude of the impedance of the saturable reactor depends upon the range of flux change that occurs in its core. This action, in turn, depends upon the magnitude of the control current. If the control current is varied a small amount, the power delivered to a load is varied through a much wider range. Herein lies the action of amplification.

The magnetic amplifier has certain advantages over other types of amplifiers. These include (1) high efficiency (90 percent); (2) reliability (long life, freedom from maintenance, reduction of spare parts inventory); (3) ruggedness (shock and vibration resistance, overload capability, freedom from effects of moisture); and (4) no warmup time. The magnetic amplifier has no moving parts and can be hermetically sealed within a case similar to the conventional dry-type transformer.

Also, the magnetic amplifier has a few disadvantages. For example, it cannot handle low-level signals; it is not useful at high frequencies; it has a time delay associated with magnetic effects; and the output waveform is not an exact reproduction of the input waveform.

The magnetic amplifier is important, however, to many phases of naval engineering because it provides a rugged, trouble-free device that has many applications aboard ship. These applications include throttle controls on the main engines; speed, frequency, voltage, current, and temperature controls on auxiliary equipment; fire control, servomechanisms, and stabilizers for guns, radar, and sonar equipment; and pulse-forming, sweep-multivibrator circuits for radar and loran equipment.

### EARLY TYPES OF SATURABLE CORES

Early saturable reactors employed ordi transformer silicon-steel cores. The amp ing qualities of these devices were not satisfactory because of the relatively saturation flux density and high hysteresis

To introduce the concept of controllin magnitude of the current through a loa means of the self-induced voltage in a rea (fig. 11-1), apply a 60-cycle, 117-volt so having a sine-waveform across a series cuit containing a variable inductance (the trolled element) and a fixed resistor (the lo

The circuit (fig. 11-1A), although no accurate analogy of magnetic amplifier act represents the control of the magnitude of current by utilizing the induced voltage inhe in the reactor, L.

Lenz's law states that the induced em any circuit is always in such a direction a oppose the effect that produces it. Because current in an a-c circuit is always chang the opposition of the induced voltage is c tinuous. Increasing the induced voltage in series circuit comprising r and L will red the magnitude of the circuit current and ca it to lag behind the source voltage by an creasing angle (fig. 11-1B). This action duces the circuit power factor.

The obvious advantage of controlling circuit current with adjustable inductance the absence of appreciable heat loss in control element. The obvious disadvantage low circuit power factor.

Magnitude of the inductance may be vari in a number of ways. For example, doubli the number of turns will quadruple the i ductance. (Inductance varies as the square the number of turns.) Also, increasing t permeability of the core will increase t ductance. (Inductance varies directly with rmeability.)

The latter action may be accomplished in a mber of ways. For example, if the reactor re is air, the permeability, $\mu$, will be unity. a laminated silicon-steel core is gradually serted into the coil, the permeability will crease (fig. 11-1C) toward the point of maxi- um $\mu$. The coil impedance will increase d the circuit current and power factor will crease.

A review of magnetism and magnetic circuits in *Basic Electricity*, NavPers 10086, will help in the understanding of the rest of the chapter. Another way to vary the permeability of the silicon-steel core of the reactor is to introduce a d-c control voltage (dotted battery) in series with the circuit (fig. 11-1A). Increasing the d-c voltage will increase the d-c ampere turns and H (the ampere turns per centimeter are approximately equal to H). Hence, the flux density, B (fig. 11-1D) will increase with H and the d-c control voltage.

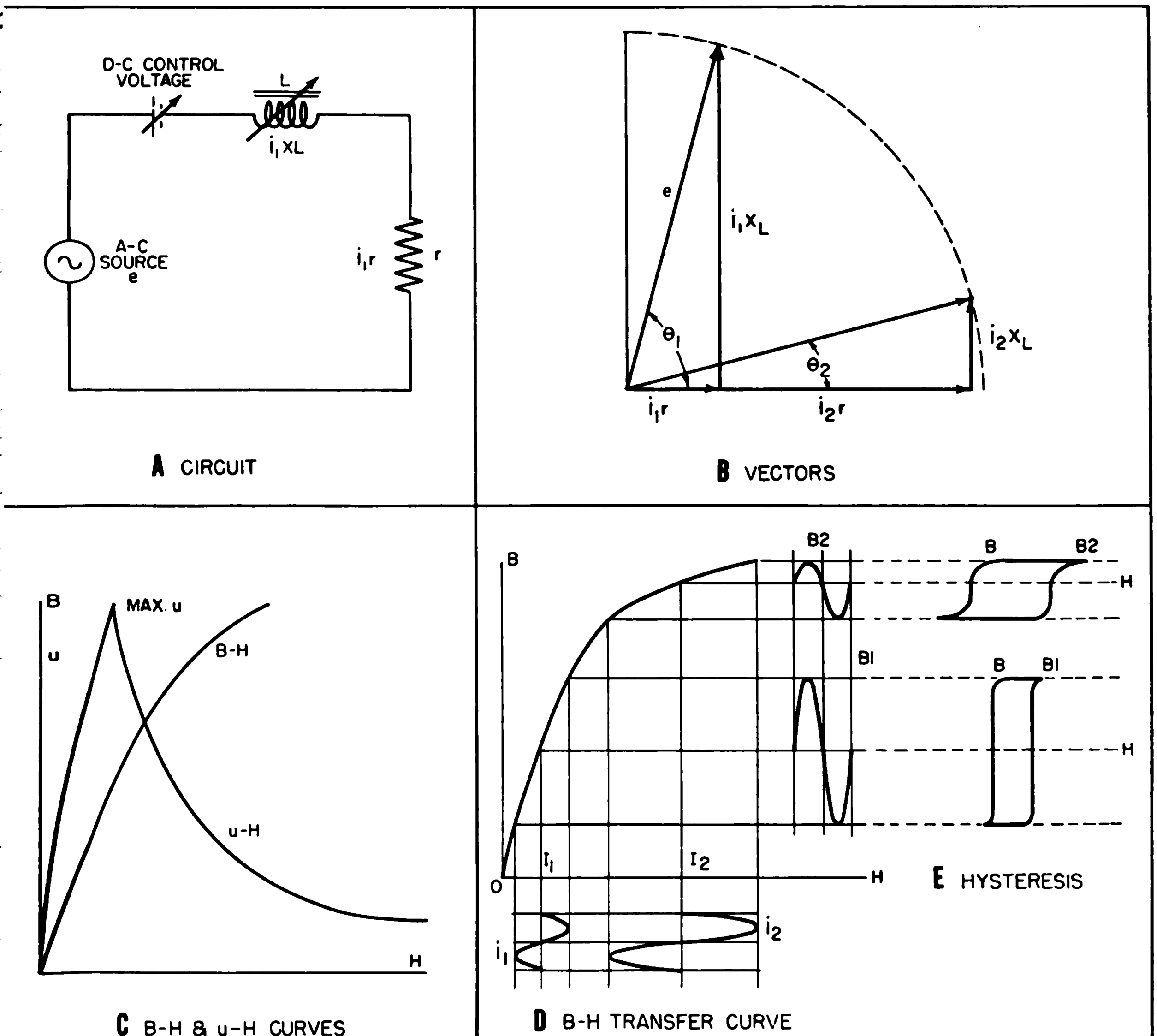



**Figure 11-1.—Load current-controlled by variable inductance.**

The permeability ($\mu = B/H$) decreases to the right of the point of maximum, $\mu$ (fig. 11-1C) as the d-c control voltage (and H) continue to increase.

The effect of these actions on the load current (a-c component) is represented by projecting the load current curve, i1 (fig. 11-1D) to the B-H curve and transferring the projection to the flux density curve, B1. Thus, with low values of d-c control voltage and direct current, $I_1$, the associated flux excursions in the reactor core are relatively large (curve B1). The resulting induced voltage across the reactor is high and the load current, curve $i_1$, has low amplitude.

Voltage $i_1r$ across the load for the condition of large flux change in the coil is relatively small (fig. 11-1B), and the voltage, $i_1X_L$, across the coil is relatively large. The circuit current lags the source voltage by a relatively large angle, $\theta_1$, and the circuit power factor is low.

Increasing the d-c control voltage and direct current from $I_1$ to $I_2$ will partially saturate the core so that smaller flux excursions (curve B2) will occur with correspondingly reduced magnitude of induced voltage and increased load current (curve $i_2$). The voltage, $i_2r$, across the load for the condition of small flux change in the coil is increased (fig. 11-1B) and the voltage, $i_2X1$, across the coil is decreased. The angle, $\theta_2$, by which the circuit current lags the source voltage is decreased, and the circuit power factor approaches unity.

With increased values of d-c control voltage and flux density, the cycle of magnetization is reduced (fig. 11-1E) from B1 to B2.

The load current (a-c component) in this example, is relatively insensitive to small changes in d-c control current. Also, the series reactor is never driven very far into saturation so that its impedance never drops to a very low value. For a given value of control current, the full cycle of the corresponding hysteresis loop is completed for each cycle of source voltage. Thus, the gain of the circuit (ratio of a-c load power change to d-c control power change) is relatively low.

To obtain greater circuit gain, certain changes must be made. The reactor core is driven into saturation periodically. This action allows the load current to flow for a controlled portion of each cycle. Before saturation is reached, the flux change prevents current flow through the load for another controlled portion of each cycle. The result of operating the r actor core in the region of saturation fo portion of each cycle will increase the circ gain materially. This action is described la in this chapter.

The evolution of a practical magnetic amp fier has resulted from the recent developm of high quality steels, gapless construction the magnetic circuit, special low-leakage rec fiers, and self-saturating magnetic circui The improvement in processing magnetic m terials and the successful development of dr disk or metallic rectifiers have contribut principally to the wide use of this device an amplifier. High quality steels have i creased the power-handling capacity. The dr disk rectifiers convert either the entire outp or part of the output from alternating curre to direct current. Variations in the contr current level, like the variations in the gr voltage of a thyratron, produce correspondi variations in the output.

## MATERIALS SUITABLE FOR MAGNETIC AMPLIFIER CORES

Various types of nickel-iron alloys th have more suitable magnetic properties th previous ones for use as core materials fo saturable reactors have been developed an are commercially available. These material are the (1) high permeability alloys and (2 grain-oriented alloys.

High permeability materals, such as Permalloy A, Mumetal, 1040 alloy, and equivalent have low and intermediate values of saturatio flux density but relatively narrow and stee hysteresis loops. These materials are use extensively as the cores in low-level inpu amplifier stages.

Grain-oriented materials, such as Orthonol, Deltamax, Hypernik V, Orthonik, Permeron and equivalents, have higher values of saturation flux density and more rectangular-shape hysteresis loops (fig. 11-2A) than the high permeability materials. Grain-oriented materials are referred to as square-loop materials because of the flat top and bottom o the hysteresis loop. A conventional loop is shown in figure 11-2B. These materials are used as the cores in high-level output amplifier stages in which maximum permeability occurs close to saturation flux density, resulting

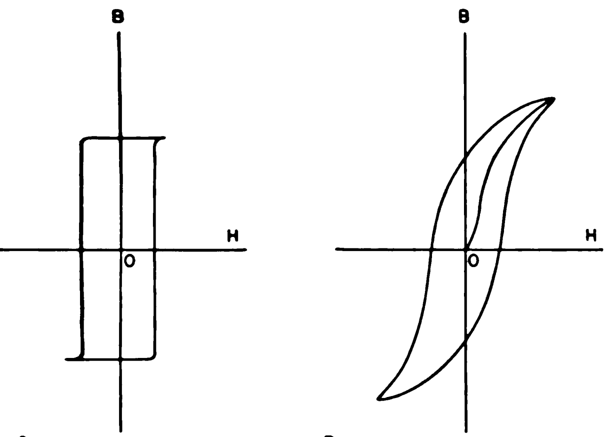



Figure 11-2.—Hysteresis loops.

in a substantial increase in the power-handling capacity for a given weight of core material.

In the manufacture of saturable cores, the characteristics of the grain structure of the material can be altered considerably by rolling and annealing.

A great improvement in the magnetic properties of some materials is obtained by cold-rolling the material before it is annealed. The cold-rolling process develops an orientation of the grain in the direction of rolling. If a magnetizing force is applied to the material so that the flux is in the direction of the grain, a rectangular hysteresis loop is obtained. In some materials cold-rolling produces almost infinite permeability up to the knee and almost complete saturation beyond the knee.

# Basic Half-Wave Circuit

A description of a simple half-wave circuit 'ig. 11-3A) will be given as an example of the perating principles in general of the magnetic mplifier.

## WINDINGS

The magnetic amplifier contains a magnetic :ore made of a square-loop material upon which two windings are placed. The load, or 'gating" winding, L, is connected in series with a rectifier, the load, and an a-c power supply. A second or "control" winding, C, is connected in series with a rectifier, the control signal source, and the same a-c source. The two windings have a 1:1 turns ratio. The magnetic amplifier in this circuit acts like an electrically operated contactor that gates (turns on) the load circuit periodically. A control voltage applied to the closing circuit of the contactor closes the contactor, which completes a circuit to the load. This action can be repeated periodically, for example, by introducing an a-c control voltage in series with a half-wave rectifier and the contactor closing coil.

The action of the control winding of the magnetic amplifier may be compared to that of the closing coil of the contactor. The action of the load winding may be compared to that of the contactor's main contacts. The latter action is that of introducing a high impedance (main contacts open) for a controlled portion of each half cycle and then removing this impedance (main contacts closed) and allowing current to flow through the load during the remaining portion of the half cycle.

## POLARITIES

In a previous study we found that transformers have polarity markings (fig. 11-4). The solid arrow at the source is marked minus at the head and plus at the tail to represent arbitrarily the positive half cycle of active source voltage. The electron flow is from the negative terminal of the source into the dotted end of the primary and returning to the positive end of the source.

The solid arrow in the secondary of the transformer has the same polarity as that of the source because the secondary is the source for the load.

The dotted (dashed line) arrow in the primary winding represents the induced voltage in the primary for the first half cycle of applied voltage and has the same polarity markings as the source voltage and the secondary voltage arrows.

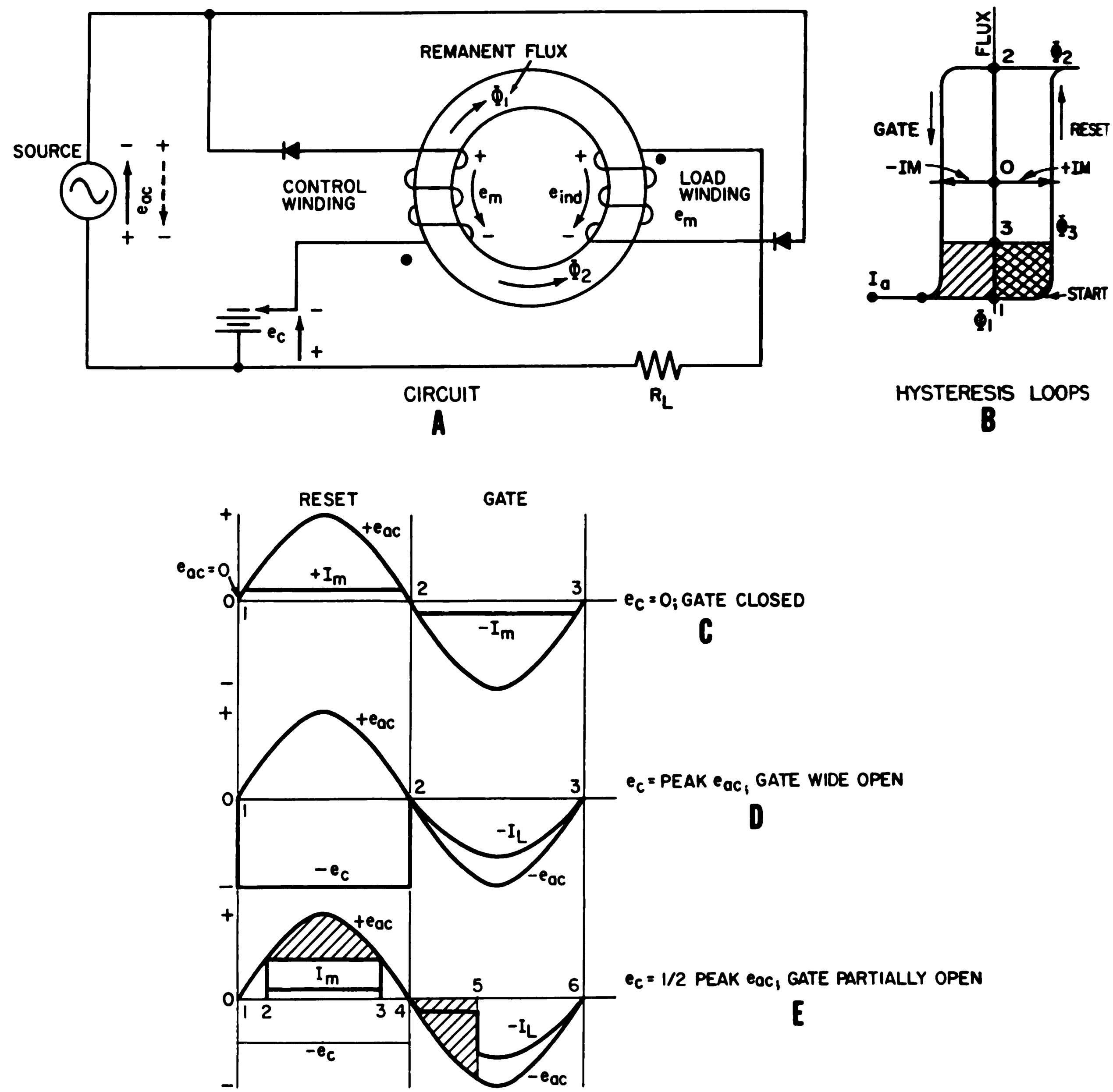



Figure 11-3.—Basic half-wave magnetic amplifier.

The direction of electron flow through the load is represented by a solid arrow, the polarity of which is opposite to that of the other three arrows. This reversal of markings is characteristic of load voltages with respect to source voltages. For voltages across loads, the arrow head is on the positive side and the tail is on the negative side. For voltages originating in generators, transformers, batteries, etc., the arrow head is on the negative side and the tail is on the positive side.

In the example of figure 11-3A, the solid arrow at the source indicates the direction of electron flow through the circuit during the positive half cycles of applied voltage, $e_{ac}$. The polarity markings (dots at one end of the windings) are indicative of the way the turns are wound on the core. The dotted ends of the

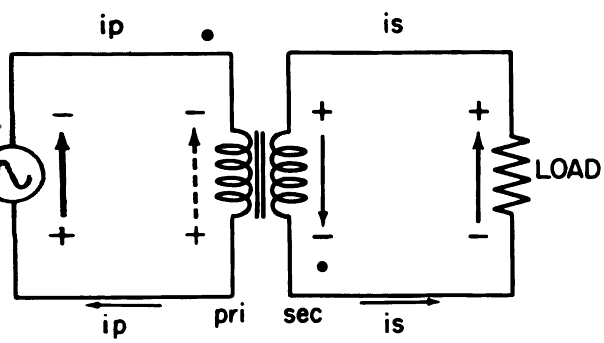



Figure 11-4.—One-half cycle of applied voltage $e_{ac}$.

ndings of a core are assumed to always have particular instantaneous polarity with respect the undotted ends of the windings. Also, the tted ends of two or more windings on a ommon core are considered to have the same stantaneous polarity with respect to each her. For example, in figure 11-3A, if the ltage applied to the control winding is of polari- at some instant to cause current to flow NTO the dot-marked end of that winding, the duced voltage of the other winding will be of polarity (at the same instant) such as to ause current to flow OUT of the dot-marked nd of that winding. The control voltage, $_c$, is assumed to be a direct voltage. The ectifier arrowheads are pointed in the di- ection of electron flow. This direction is pposite to conventional commercial usage.

## FUNCTION OF RECTIFIERS

Rectifiers are placed in the load and con- rol circuits to prohibit current flow in the ontrol circuit during the gating half cycle and n the load, or gating, circuit during the reset alf cycle. The magnetic amplifier is not an mplifier, in the sense of a step-up trans- ormer. Voltages generated by mutual induc- ion (transformer action) between the control nd load windings exist in these windings, but hey have only a small effect on the amplifier operation under the established conditions.

During the first half cycle (solid arrow of source) of the applied voltage, the direction of the INDUCED voltages in both windings is INTO, or positive, at the polarity-marked ter- minals. In the load windings this action is in the forward direction of the rectifier and against $e_{ac}$. Thus, the rectifier in the load circuit prevents current flow through the load and is subjected to an inverse voltage equal to the difference between $e_{ac}$, and the mutually induced voltage in the load winding. The time interval corresponding to the first half cycle, is called the "reset" half cycle. The reset action is described later.

## ANALYSIS WITH ZERO D-C CONTROL VOLTAGE

As mentioned previously, figure 11-3 is used in the analysis of the action of the basic half-wave magnetic amplifier. Figure 11-3A, represents the basic circuit. Figure 11-3B, represents the square-type hysteresis loop for the core material used in this circuit. Figure 11-3C, D, and E, represents the waveforms of current and voltage for three conditions to be considered. The symbol representing a quantity is common to all parts of the figure. For example, the magnetizing current, $I_m$, is represented in figure 11-3B, C, and E. The hysteresis loop is enlarged for clarity and is not drawn to the same scale as parts C, D, and E.

### RESET HALF CYCLE

The first condition to be described is with the control voltage, $e_c$, at zero. At the be- ginning of the reset half cycle, the core is as- sumed to possess a residual or negative satura- tion remanent flux level, $\Phi_1$ (fig. 11-3B). The direction of this flux is indicated by the arrow, $\Phi_1$, in figure 11-3A. As $e_{ac}$ increases from 0 in a positive direction (indicated by the solid arrow at the source (fig. 11-3A) and by the part of the sine curve, point 1 to point 2 (fig. 11-3C), the current in the control winding es- tablishes an mmf represented by half the width of the hysteresis loop, $+i_m$ (fig. 11-3B). The applied voltage establishes an mmf that acts in a direction to oppose the residual core flux, $\Phi_1$, and therefore to demagnetize the core. The amount of change of flux will depend upon the MAGNITUDE of the applied voltage across the control winding and the TIME INTERVAL dur- ing which this voltage is applied.

In this example, the first half cycle of ap- plied voltage is assumed to reverse the core magnetism and to establish its flux density at essentially the positive saturation level, $\Phi_2$ (fig. 11-3B). This action is called reset.

As $e_{ac}$ increases from 0 in a positive direction in the vicinity of point 1 (fig. 11-3C), there is no change in core flux until the current increases to the value of $+I_m$, corresponding to one-half of the width of the hysteresis loop. Thus, with no flux change, the current rises abruptly and is limited only by the resistance of the circuit and the low value of $e_{ac}$. When the current reaches the value, $+I_m$, the core flux starts to change from the $\Phi_1$ level toward the $\Phi_2$ level (fig. 11-3B). The accompanying self-induced voltage opposes $e_{ac}$ and limits the current to a constant small value during the flux excursion from the level $\Phi_1$ to $\Phi_2$.

This flux change continues during the time interval between point 1 and point 2 (fig. 11-3C). As it continues, the induced voltage continues to vary in magnitude with $e_{ac}$ and to oppose $e_{ac}$ in such a manner that $I_m$ remains constant over the half-cycle interval.

### GATING HALF CYCLE

The next half cycle is called the "gating" half cycle. It starts at point 2 (fig. 11-3C), at which time the polarity of the applied voltage reverses. The direction of $e_{ac}$ for this half cycle is indicated by the dotted arrow (fig. 11-3A). During this time interval, the rectifier in the control circuit blocks the flow of control circuit current. However, the rectifier in the load circuit permits current from the source to flow in that circuit. This current will magnetize the core in a negative direction—that is, in a direction to change the flux from the $\Phi_2$ level to the $\Phi_1$ level. The applied voltage is assumed to be of the correct magnitude to cause the core to be magnetized to the $\Phi_1$ level (fig. 11-3B). A condition of equilibrium is indicated.

The large flux change from the $\Phi_2$ level to the $\Phi_1$ level causes a self-induced voltage in the load winding, L, and a mutually induced voltage in the control winding, C. The self-induced voltage in the load winding opposes $e_{ac}$. The mutually induced voltage in the control winding also opposes $e_{ac}$. The rectifier in the control circuit is subject to an inverse voltage equal to the difference between $e_{ac}$ and the mutually induced voltage in the control winding. Because of the maximum flux change in the core, maximum impedance is presented by the load winding to the circuit containing $R_L$ throughout the gating half cycle, and therefore $e_{ac}$ will appear across the load winding and not across $R_L$. For this condition, the curre[nt] through the load is limited to a very sma[ll] magnetizing component that is negligible com[-]pared to normal values of load current. Th[e] gate is closed.

## ANALYSIS WITH MAXIMUM D-C CONTROL VOLTAGE

The second condition described is for th[e] condition that $e_c$ is equal to the peak value o[f] $e_{ac}$. At point 1 (fig. 11-3D), the remanen[t] magnetism is again at the $\Phi_1$ level (fig. 11-3B).

### FIRST HALF CYCLE

The applied voltage, $e_{ac}$, rises from 0 t[o] maximum during the first 90° of the cycle but has no effect on the core flux because the control voltage, $e_c$, has a magnitude equal to the maximum value of $e_{ac}$, and the polarity opposite to that of $e_{ac}$. Thus, the rectifier prevents the flow of battery control current during the time that $e_c$ is greater than $e_{ac}$. Because there is no voltage across the control winding (the rectifier is essentially an open circuit), no flux change can occur from point 1 to point 2 (fig. 11-3D). Figure 11-3B, does not apply. Thus, no change in flux occurs during the reset half cycle for this assumed condition.

### SECOND HALF CYCLE

When $e_{ac}$ reverses its polarity (solid to dotted arrow), the rectifier in the control circuit continues to block the flow of current in that circuit. In the load circuit the polarity of $e_{ac}$ during the gating interval, points 2 to 3 (fig. 11-3D), is such as to tend to drive the core further into negative saturation (point $I_a$, fig. 11-3B). Because the core is already saturated, no further flux change occurs, and $e_{ac}$ appears across $R_L$ because the loading winding offers no impedance to $I_L$.

The full value of load current flows, and its magnitude is $e_{ac}/R_L$. The gate is wide open. The condition is analogous to a thyratron tube that has no grid bias. The tube fires when the plate is only slightly positive, and conduction occurs immediately and continues for essentially the full half cycle. The waveform of this current, $-I_L$, is illustrated in figure 11-3D.

## ANALYSIS WITH PARTIAL D-C CONTROL VOLTAGE

The third condition assumes that $e_c$ is approximately half peak of $e_{ac}$. During the reset half cycle, voltage is applied to the control winding during the time interval from point 2 to point 3 (fig. 11-3E). The magnitude of this voltage is $e_{ac} - e_c$. This voltage will be less than the peak value of $e_{ac}$, but greater than zero; and a new set of conditions will be established.

### FIRST HALF CYCLE

The reset cycle is just beginning. During the interval 1 to 2 (fig. 11-3E), $e_c$ is greater than $e_{ac}$, and the rectifier opposes any current flow in the control winding. During the interval 2 to 3, $e_{ac}$ exceeds $e_c$, and magnetizing current flows in the control winding. As mentioned previously, the extent of the change in core flux will depend on the time interval and magnitude of the voltage applied across the control winding within the half cycle. Because the time interval is very short, and the net voltage applied to the control winding is much less than $e_{ac}$, the core flux level is assumed to change from $\Phi_1$ to the level along the line through $\Phi_3$ (fig. 11-3B). During the interval 3 to 4 (fig. 11-3E), $e_{ac}$ is again less than $e_c$, and the rectifier prevents any further flow of control current. As in the previous examples, the rectifier in the load circuit prevents any current flow in that circuit during the reset half cycle.

### SECOND HALF CYCLE

When $e_{ac}$ reverses, magnetizing current flowing through the load winding changes the core flux from the level through point 3 to the level through point 1 (fig. 11-3B). This change is assumed to take place during the interval 4 to 5 (fig. 11-3E). The impedance of the load winding is high during this interval, and current flow through the load is restricted to the magnetizing current. However, at point 5 the core becomes saturated, and no further flux change occurs. The impedance of the core drops to zero, and current $e_{ac}/R_L$ flows through the load during the interval 5 to 6. The load voltage is in phase with $e_{ac}$ and has the same waveform as that of $e_{ac}$ for this part of the cycle.

### ENERGY CONSIDERATIONS

The area of the portion of the hysteresis loop traversed is a measure of the energy required to complete that particular cycle of magnetization. It may be divided equally by the y axis.

For condition 1 (fig. 11-3C), the entire right-hand area of the loop shown in figure 11-3B, is proportional to the area under the $+e_{ac}$ voltage wave (which is proportional to the energy supplied), and the left-hand area is proportional to the area under the $-e_{ac}$ voltage wave.

For condition 2 (fig. 11-3D), the area in both half cycles is zero (no flux change occurs), and the load, $R_L$, absorbs the entire applied voltage, $e_{ac}$. No energy is supplied to the control windings.

For condition 3 (fig. 11-3E), the right-hand shaded area of the hysteresis loop (fig. 11-3B) is proportional to the shaded area under $+e_{ac}$ (fig. 11-3E), and the left-hand shaded area of the hysteresis loop is proportional to the shaded area of $-e_{ac}$. In this case the magnitude of $(e_{ac} - e_c)$ applied to the control winding determines how far the core flux is carried from negative saturation toward positive saturation, and consequently, how much of the gating half cycle will be nonconducting.

For condition 3, the energy supplied to the control winding is partially reduced. The corresponding area is reduced from the total area under $+e_{ac}$ for condition 1 to that indicated by the shaded portion under the $+e_{ac}$ curve in figure 11-3E. The flux change is not carried to level $\Phi_2$ on the hysteresis loop, but to some point part way up the loop (level $\Phi_3$), as determined by the shaded area under the $+e_{ac}$ curve.

In other words, the time in the gating half cycle at which the core saturates (the firing angle) is determined by the shaded area under the $+e_{ac}$ curve or the amount of energy supplied to the control winding during the reset half cycle. Thus, as $e_c$ is reduced in magnitude, the voltage, $e_{ac} - e_c$, applied to the control winding increases, and the core flux is carried further toward positive saturation during the reset half cycle.

This action increases the firing angle and delays the time in the gating half cycle when the core saturates and the load winding becomes conducting. Thus, the average load current and load voltage are reduced. They both vary with the control voltage.

By way of contrast with the relative-low-circuit power factor of the example in figure 11-1, the power factor of the circuit of the example in figure 11-3 is unity for all values of d-c control voltage between zero and maximum.

# Conclusion

## REACTORS

A reactor is simply a coil connected in an a-c circuit. The flux changes direction as the current reverses, and the opposition (impedance) to this change varies with the frequency and the amount of flux produced by a given current. Thus, if the frequency of the applied voltage is held constant, the iron-core coil having greater inductance will have greater impedance than an air-core coil. Notice however, that if the voltage applied to the iron-core is great enough to drive the core beyond saturation, the excess voltage will "see" an impedance equivalent to that of an air-core coil. Thus, the current flowing in an iron-core coil will increase slowly with an increase in applied voltage until saturation of the core is reached. Thereafter, with an increase in applied voltage the current flow will increase rapidly.

## SATURABLE REACTORS

A saturable reactor is a reactor in which the "degree" of saturation of the magnetic core material may be independently controlled. The reactor shown in figure 11-5A, has an output winding and a control winding. The function of the control winding is to control the degree of saturation of the core and thereby control the power delivered through the output winding to the load.

As the current supplied to the d-c control winding increases, the impedance of the a-c output winding decreases and the a-c load current increases (fig. 11-5B). Note that the polarity of the d-c control current may be either positive or negative without altering the effect.

Because the core flux in the reactor is proportional to the ampere turns of the reactor windings, it follows that by winding many turns on the control winding and only a few turns on the output winding, a small control current can be made to control a large output current.

If the polarity of the d-c control current is not changed, the core-saturating mmf produced by the control winding will be always established in the same direction ($\Phi_d$, fig. 11-5A). The mmf produced by the a-c output winding, however, reverses its direction during each half cycle of the a-c supply voltage. The a-c mmf then opposes the d-c mmf one-half of each cycle and during this half cycle tends to desaturate the core. If this effect were eliminated by eliminating the "desaturating half cycle" of the output current, the change in control current required to produce a given change in output current would be considerably less; the "gain" or amplification would be increased.

## MAGNETIC AMPLIFIERS

A magnetic amplifier may be regarded as a device using saturable reactors either alone or in combination with other circuit elements to secure amplification or control. A self-saturating magnetic amplifier has one or more rectifiers inserted in the output circuit to eliminate the "desaturating" half-cycle of output current. The load current is an alternating or a pulsating direct current. Figure 11-5C, shows a simple half-wave, self-saturating magnetic amplifier.

Further refinements of the self-saturating magnetic amplifier are shown in figure 11-5D. In this amplifier the output winding is divided into two equal sections and a bias winding is added. The output sections are arranged so as to produce alternate half-wave pulses through the output windings.

The mmf produced by the d-c bias winding, as shown by the arrows in the core, is in a direction opposite to that of the core-saturating

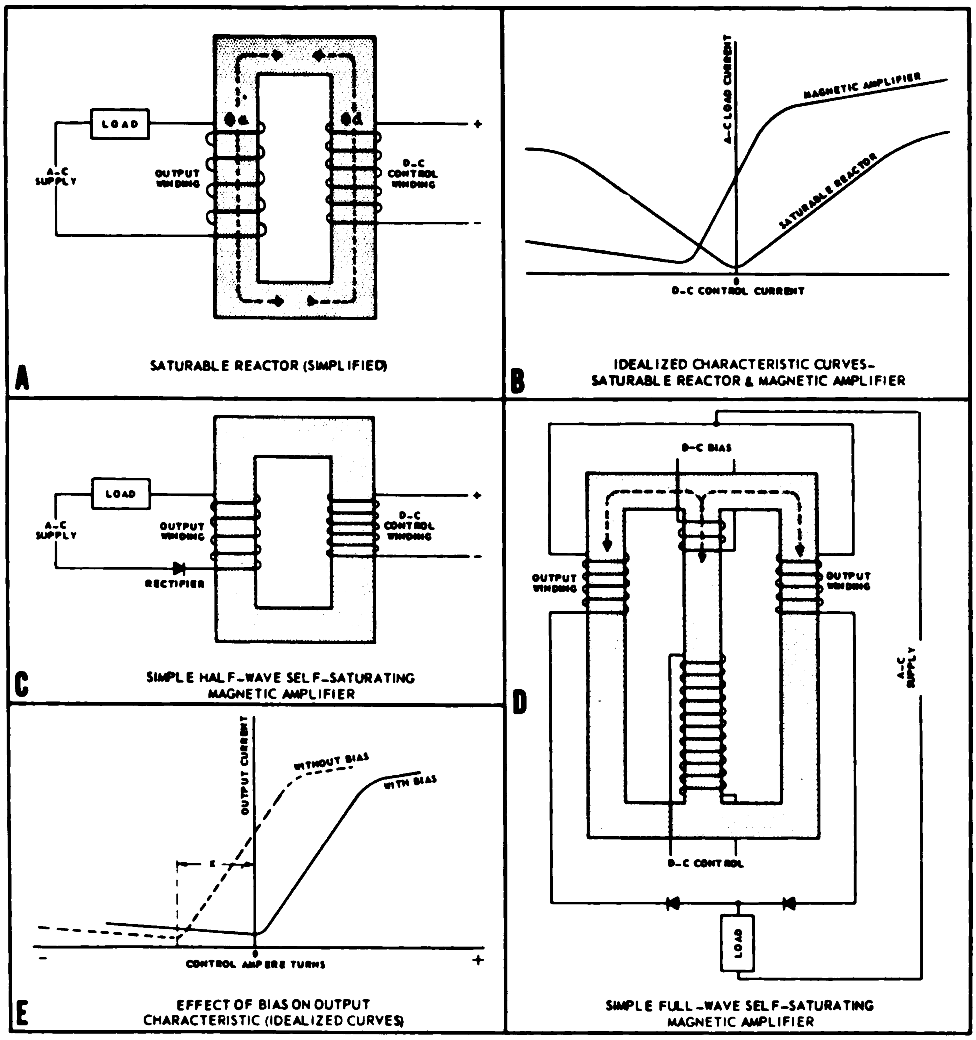



Figure 11-5.—Summary of principles of operation.

mmf produced by the output windings. The effect of this opposition is to reduce the output current (fig. 11-5E), corresponding to zero control current and to shift the output curve toward "cutoff". Because each output winding conducts on alternate half cycles, the flux in one output leg is building up while the flux in the other output leg is decaying. (The flux decays because the rectifier acts like an open switch when the source voltage is in a direction opposite to that of the rectifier.) The center leg is the common return path for the flux of each outer leg.

The result of an increasing flux in one outer leg and a decreasing flux in the other outer leg is to maintain the flux in the center leg at a constant level at the fundamental frequency of the supply voltage. Thus, no change in flux will occur in the center leg, and no voltage will be induced in the control winding at the fundamental frequency of the supply voltage.

Improved output characteristic of the amplifier is shown graphically by the upper curve of figure 11-5B. Note that in comparison to the saturable reactor, the output current is now sensitive to the polarity of the control current.

From the characteristic curve for the magnetic amplifier (fig. 11-5B), it may be noted that the output current is relatively high when the control current is zero. This effect is undesirable in certain applications. Compensation for this effect is made by the addition of a bias winding supplied from a separate fixed d-c voltage source with a polarity that will decrease the output current.

The effect of the bias signal is to desaturate the core and to shift the characteristic curve to the right by applying "X" ampere turns in the negative direction (fig. 11-5E). Note that the shape of the characteristic curve is not changed by the addition of the bias signal.

Some amplifiers are biased so that the output is a maximum when the control signal is zero. A "negative" control signal may then be used to reduce the output current. This mode of amplifier operation appears less frequently in magnetic amplifier equipment.

## FEEDBACK

Magnetic amplifiers are usually provided with several control windings, each of which has an appreciably different number of turns. The winding used as the control signal winding depends upon the signal current available and the impedance level of the signal source. The other windings may be used as additional turns for the control winding, as bias windings, or as feedback windings.

The effect of feedback in magnetic amplifiers is much the same as that in other types of amplifiers. In a self-saturating magnetic amplifier, no positive feedback (or only a very small amount) is used because the amplifier is likely to become unstable. When negative feedback is used, the power amplification and the response time are decreased, and the linearity of the control characteristic is improved.

In certain types of magnetic amplifier systems, a negative feedback signal is obtained from the output of the system and fed back to the first stage of amplification. In the first stage amplifier, the feedback signal is magnetically compared with a reference signal so that the net control signal, which is called the ERROR SIGNAL, is the difference between the reference signal and the feedback signal. Thus, if the reference signal produces 10 core-saturating ampere turns, and the feedback signal produces 9 core-desaturating ampere turns, the error signal will be 1 core-saturating ampere turn. The feedback ratio is said to be "10 to 1."

If the reference signal is held constant, and, if for some reason the output of the system changes, the error signal will change in a direction that will restore the output to its original value so that it is always maintained proportional to the reference signal. When the magnitude of the reference signal is changed, the magnitude of the output signal will change proportionally, and the system will regulate about the new value of reference signal.

## CONVENTIONAL SCHEMATIC REPRESENTATION

The schematic representations of three simple magnetic amplifier circuits are illustrated in figure 11-6. Note that the type of core on which the coils are wound is shown above each of the three schematics. Each coil is placed adjacent to the core on which it is wound. The coils and cores around which a dotted line has been drawn are usually enclosed and "potted" in a single "can"; the internal coil connections are not accessible.

The diagram shown in figure 11-6A, is an electrical schematic representation of the circuit shown pictorially in figure 11-5C, Figure 11-6B, is a combination of two single cores potted in a common enclosure. The windings shown on each individual core are drawn so that, with relation to their common core, the magnetic effect of each winding is in the direction of the conventional current flow (opposite to electron flow) through the winding. This relation is shown by the arrows adjacent to the windings of figure 11-6B. (The arrows are not usually drawn as a part of the schematic.) The direction of the rectifiers in the figure is that of conventional current flow (opposite to the

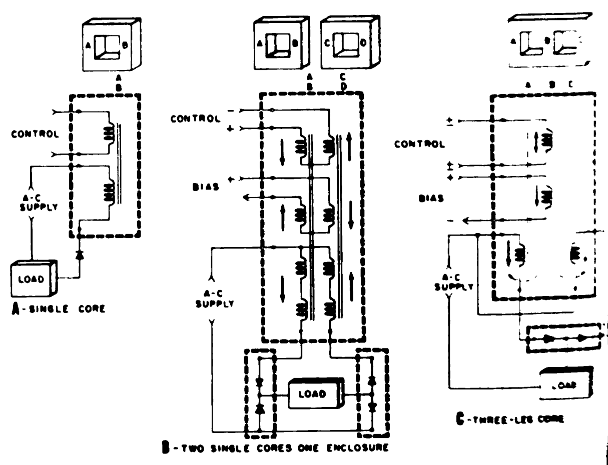



Figure 11-6.—Schematic representation of magnetic amplifier circuits.

rections represented in the analysis of magtic amplifier action, figure 11-3).

The conventional current flow through the tput windings, as indicated by the arrows, is ways in the same direction as the conventional tput rectifier arrows.

Being a self-saturating magnetic amplifier, is is the direction that saturates the core and creases the output current. All windings nose current flow is in this direction are atmpting to increase the output current.

Conversely, all windings whose current flow in the opposite direction, such as the bias inding in figure 11-6B, decrease the output rrent.

Figure 11-6C, is the schematic diagram of a hree leg" reactor circuit. Two of the threere legs are shown schematically; windings on e center legs are placed between the two legs nown as closely spaced parallel lines. The agnetic effect of the bias windings on the cenr leg is in a direction opposite to that of the urrent flow through the load windings. This ffect may be visualized by following the arrows round the core, as shown by the dotted arrows figure 11-6C, (also, see fig. 11-5D, of which nis schematic is a representation).

An analysis of the magentic amplifier circuit hown in figure 11-6B, reveals the following eatures:

1. On alternate half cycles of the a-c supply, he output windings alternately conduct.
2. The direction of current flow through the utput winding is opposite to that of the bias rinding. (The bias current flows in a direction hat partially desaturates the core.)
3. The direction of current through the output windings is the same as that of the control vindings. Both currents tend to mutually assist each other in partially saturating the core, decreasing the impedance, and overcoming the desaturating effect of the bias current. Both control and output currents can be said to be "positive"; whereas, the bias current can be termed "negative".
4. With larger positive control current, output current increases and, vice versa, decreases with decreased control current.

These features, while common to many magnetic amplifier circuits, are not necessarily used in every application.

## CORRECTIVE MAINTENANCE

When there is a casualty to a magnetic amplifier circuit, deenergize the circuit and tag it as previously described in chapter 6. Check all switches and contacts for dirt and loose connections. After inspecting the connections, check the individual components. When a winding is suspected, deenergize the circuit, then ground the winding with a tool having an insulated handle. This action will discharge any stored or static charge on the circuit. After disconnecting the unit from all other equipment in the circuit, check the suspected winding for continuity and resistance, using a suitable range on the ohmmeter.

When checking the metallic rectifiers, ground and disconnect as in the case of the winding of the magnetic amplifier. A comparative resistance check (forward compared to backward) will indicate whether or not the rectifying material has shorted out. Place the leads of the ohmmeter across the terminals of the rectifier and you will read either a high (back) resistance or a low (forward) resistance. Reverse the ohmmeter leads to get the alternate reading. The high resistance should be at least eleven times the low resistance.

# QUIZ

1. The magnitude of the impedance of the saturable reactor depends upon the magnitude of change of what quantity in the core?
2. State five advantages of the magnetic amplifier over other types of amplifiers.
3. State four disadvantages of the magnetic amplifier.

Refer to figure 11-1 for questions 4 through 7.

4. What quantity in the winding of variable reactor, L, is utilized to control the magnitude of the load current?
5. If a laminated silicon-steel core is gradually inserted into the coil, what will be the effect on (a) permeability, (b) impedance, (c) circuit current, and (d) power factor?

6. With low values of d-c control voltage and current, what will be the relative magnitude of the (a) flux change in the core, (b) induced voltage in the reactor winding, (c) load current, $i_1$, and (d) circuit power factor?
7. With relatively large values of d-c control voltage and current, what will be the relative magnitude of the (a) flux change in the core, (b) induced voltage in the reactor winding, (c) load current, $i_2$, and (d) circuit power factor?
8. Name two general classes of nickel-iron alloys that have been developed for use as core materials for saturable reactors.
9. Describe the general shape of the hysteresis loops for Orthonol, Deltamax, Hypernik V, Orthonik, Permerson, and equivalents.

Refer to figure 11-3 for questions 10 through 17.

10. How is the load or gating winding connected with respect to the a-c source, the load, and rectifier?
11. How is the control winding connected with respect to the a-c source, the control signal source, and rectifier?
12. Are the rectifier arrowheads pointed in the direction of conventional current flow or electron flow?
13. To what two quantities is the magnitude of core flux change in the reset half cycle proportional?
14. For the condition $e_c=0$: (a) What is the ra of flux change during the reset half cy (b) What is the range of core flux cha during the gating half cycle? (c) Wha the relative magnitude of the impeda presented by the load winding to the curcuit?
15. For the condition $e_c=e_{ac}$ peak: (a) W relative magnitude of control winding c rent will flow during the reset half cy (b) What relative flux change occurs du the reset half cycle? (c) What relative m nitude of load current flows during the ga half cycle?
16. For the condition $e_c=1/2\ e_{ac}$ peak: (a) does no current flow in the control winc until $e_{ac}$ exceeds $e_c$? (b) What is the re tive change of flux in the reset half cyc (c) Why does the load current suddenly r at point 5 (fig. 11-3E)? (d) What is the lation between the right-hand shaded a of the hysteresis loop and the shaded a under the $e_{ac}$ voltage curve?
17. What is the power factor of the load circ for all values of load current?
18. What is the effect of an increasing flux one outer leg (fig. 11-5D) and a decreas flux in the other outer leg on (a) the flux the center leg and (b) the voltage indu in the control winding at the fundamen frequency of the supply voltage?

# CHAPTER 12

# NEW INSTALLATION EQUIPMENTS

## Closed Circuit Television

New equipments are constantly being added those now in use aboard ships. Some new ems are a modification of equipment that has een in use for some time, and other items are ompletely new. Because the I.C. Electrician ill be expected to maintain these equipments, e are going to include basic descriptions of ome new equipments. Technical information n circuit operation will appear in more adanced I.C. Training Courses in this series.

So that you may have a better understanding f closed circuit television, we will first list nd define some of the terms and expressions iat will be used in the discussion.

BLACK LEVEL.—In television, a voltage epresenting the color black. Usually it is not reater than 80 percent of the maximum teleision signal amplitude.

BLANKING.—The process of applying negaive voltage to the control grid of the cathodeay tube to cut off the electron beam during the etrace or flyback period.

BLANKING WAVEFORM.—The signal introluced into the complex video signal at or above he black level, used to blank out video signals luring the retrace or flyback time.

D-C RESTORER.—A circuit used to reinsert he d-c component of the video signal lost during mplification.

PICTURE ELEMENT.—In a television sysem, the smallest portion of a picture or scene hat is individually converted into an electrical signal.

PICTURE SIGNAL, ALSO CALLED THE VIDEO SIGNAL.—The electrical pulses resulting from scanning of successive elements of a visual scene by a scanning device.

RASTER.—The illuminated rectangular area scanned by the electron beam in a picture tube, visible when the brilliancy control is turned up with no signal.

STREAKING.—In television, a broad streak following an outline representing a sharp change in shade from light to dark or vice versa. The streak is intermediate in shade and is caused by inability of the system to reproduce the change as rapidly as necessary.

SYNC.—A short form of the word, synchronizing, which means to cause two elements of a system to coincide in speed, frequency, relative position, or time.

SYNC GENERATOR.—Electronic equipment designed to produce the driving, blanking, and synchronizing pulses necessary to the operation of a television system.

SYNC WAVEFORM.—The waveform, as shown on an oscilloscope, produced by the sync generator.

SYNCHRONIZING SIGNALS.—Electrical pulses used to keep a television or facsimile receiving system in step with the transmitting system, so that the picture or scene will be reconstructed properly.

TARGET VOLTAGE.—The voltage that is applied to the electrode that collects electrons in a Farnsworth television dissector (pick up) tube. Also, the fluorescent screen in a tuning-eye tube.

TURRET.—A revolving plate sometimes mounted at the front of a television camera and carrying two or more lenses.

Closed circuit television is the name given to a system in which a TV camera is directly connected to one or more TV receivers. Thus, an action taking place in one compartment can be viewed at one or more locations at the time the action is taking place. An underwater TV camera may be lowered over the side, in place of a diver, to survey underwater damage. When closed circuit TV is used in this manner, conditions can be simultaneously examined by all interested parties without relying on the conclusions of one man. Closed circuit TV has an obvious advantage in extremely cold water. A submarine can, as shown by the *Nautilus*, use underwater cameras in a closed circuit TV system to examine ice conditions while cruising under the polar ice.

Regardless of the application, sufficient illumination must be provided. The TV camera light requirement is similar to the light requirements of a home movie camera in taking indoor home movies. Figure 12-1 shows the block diagram of a complete transmitter for a closed circuit TV system.

### CAMERA UNIT

The vidicon pickup tube, V101, is the heart of the camera unit. The vidicon is similar to a cathode-ray tube that uses electromagnetic deflection to focus the beam to a spot and to move the spot over the light sensitive surface.

The camera unit picks up the scene to be transmitted from a film or directly from the scene of action as it occurs. The scene is focused by a suitable lens system onto the mosaic of the vidicon tube. The mosiac consists of many thousands of tiny silver globules on a sheet of ruby mica, each globule treated with caesium vapor to make it photosensitive.

A scene focused on these globules will charge up the individual globules in the mosaic to a value that depends upon the brightness of the individual small picture areas of the scene.

The electron beam of the vidicon tube is made to sweep from left to right across the scene at a relatively high speed that is governed by the horizontal line scanning circuits. At the same time a vertical-field scanning circuit causes the beam to move from top to bottom of the scene 30 times per second (frame frequency). This combination of the horizontal and vertical scanning circuits results in 525 lines per frame.

As the electron beam in the vidicon tube strikes a given picture element in the mosaic, it releases an electric charge corresponding in strength to the brightness of that portion of the scene. As the electron beam moves onto a new picture element, the released electric energy assumes a new value corresponding to the new picture element brightness. This electric energy is collected by a terminal in the camera tube and is then fed to a suitable wide band video-frequency amplifier. This amplifier is composed of three stages, V102, V103A, and V103B, and is mounted in the camera housing. V103B is operated as a cathode follower to provide a low impedance input to the coaxial cable that carries the signal to the video amplifier located in the camera control unit.

### LENS SYSTEM

The lens system is not shown on the block diagram. However, most closed circuit TV cameras are equipped with a three-turret lens system. Some lens systems have provisions for remotely changing lenses (moving the turret or adjusting the lens focus. The instruction book for the camera unit will contain tables that show which lens to use in order to produce an image that just fills the mosaic of the camera tube. The image produced at the TV set will then fill out the raster on the picture tube screen. All lens adjustments should be made in strict accordance to the manufacturers' instructions.

### VIDEO CHASSIS

The signal from V103B in the camera unit is brought to V201B in the video chassis through a 50-ohm coaxial cable. The video signal is amplified by V201B, V201A, V202A, V203A, and V204A. A variable capacitor in the cathode circuit of V201A provides a means of adjusting the operating condition of the stage to prevent streaking of the picture caused by excessive target voltage. The cathode resistor of V202A is bypassed with a variable capacitor to allow some control over the aperature (lens opening) without adjusting the lens system. The lens aperature mentioned is an electrical aperature and is not to be confused with the physical aperature. A peaking coil in the plate circuit of V202A improves the high frequency response. The output of V202A is applied to the grid of V203A. The bias of V203A is set through a panel-mounted gain control. The setting of this control establishes the gain of the amplifier.

V203B is a triode connected as a diode to operate as a d-c restorer. The plate of V203B is directly connected to the control grid of V204A to establish the black level of the picture signal. The plate circuits of V204A and V204B are common. A blanking waveform (from the sweep chassis) is applied to V204B.

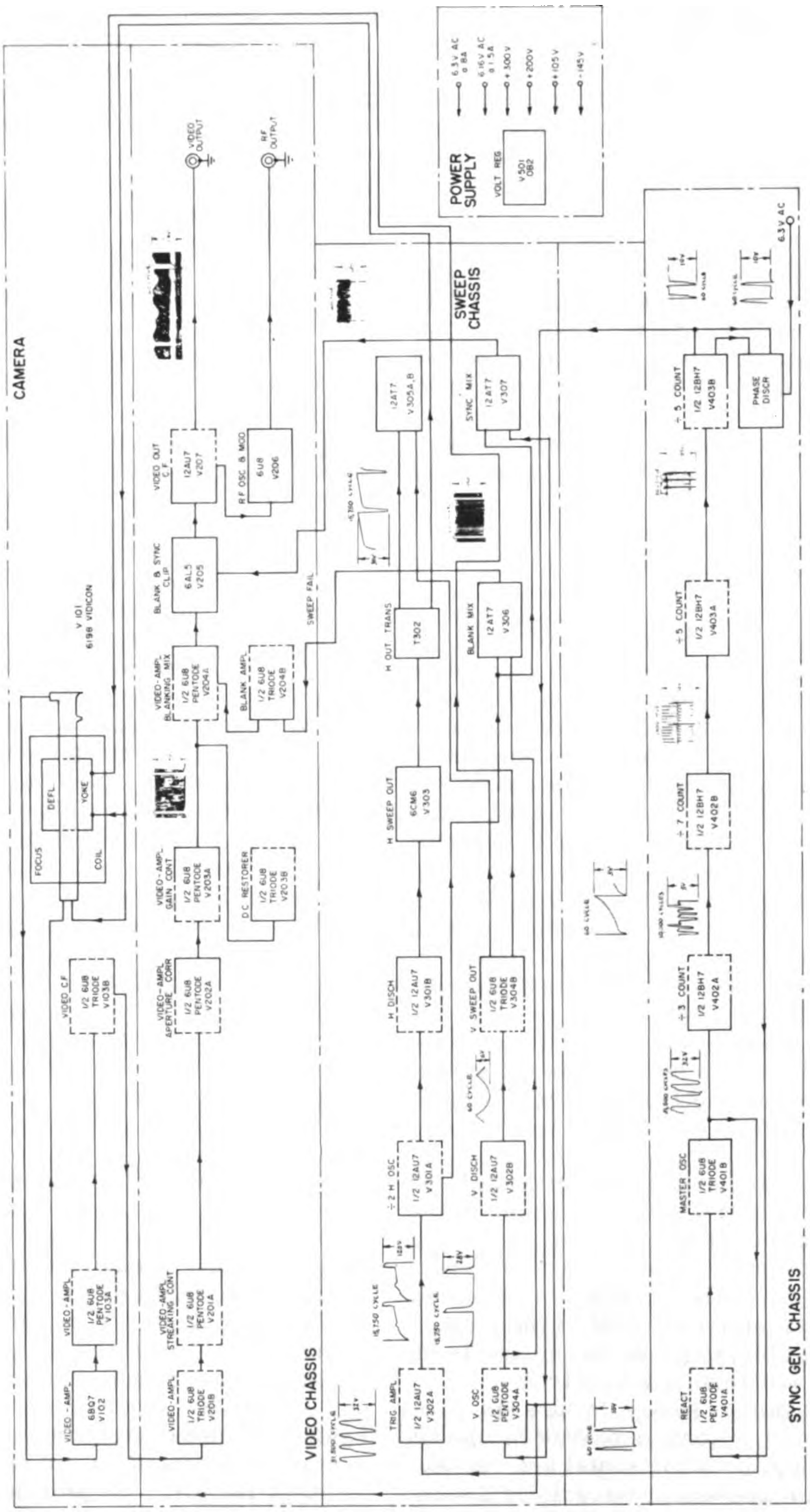



Figure 12-1.—Closed circuit TV.

V205 is a dual diode that performs two functions: it clips the negative blanking peaks of the video signal, and clips the negative sync peaks. The clipped output of one diode is coupled to the grids of the dual-triode, cathode-follower stage, V207. A video monitor can be connected to the jack marked, VIDEO OUTPUT, to observe the quality of the picture.

When the picture is to be supplied to one or more standard TV sets, the output of V207 is used to drive the modulator section of V206. This section modulates an r-f oscillator that may be tuned over the range between 54 and 88 mc. Thus, a standard TV set can be tuned to an unused channel ((either 2, 3, 4, 5, or 6) and the r-f oscillator can be tuned to the same channel) in order to view the scene being picked up by the camera.

## SWEEP CHASSIS

The master oscillator, V401B, in the sync generator chassis (described later) supplies a 31.5-kc signal to the grid of V302A. The output of this stage triggers the horizontal blocking oscillator, V301A. V301A divides the master oscillator frequency by a factor of two and drives V301B. The horizontal blocking oscillator, V301A, rate is set by the H. HOLD (horizontal hold) control on the panel. The amplitude of the horizontal discharge waveform, V301B, is controlled by the H. SIZE (horizontal size) control on the panel. The output of V301B is applied to V303, and the plate load for V303 is the horizontal output transformer, T302.

The horizontal sweep output signal from T302 is carried to the camera deflection yoke over a coaxial cable. A horizontal centering voltage is obtained from a H. CENT. (horizontal centering) potentiometer.

A stable 60-cycle vertical trigger pulse from the sync generator output stage is applied to the vertical blocking oscillator, V304A. through a germanium diode and capacitor (not shown in figure 12-1). The diode prevents the blocking oscillator from feeding back to the sync generator. The vertical blocking oscillator rate is set by the V. HOLD (vertical hold) control.

Protection against sweep failure is provided by V305A,B. Normal operation of this stage requires that both horizontal and vertical sweep signals be present at the grid of V305A. Should either or both of these signals fail, the vertical sawtooth waveform, which should appear at the plate of V305A, will not be present. No positive d-c voltage will appear at the grid of V305B, and, because a high fixed cathode bias is applied to the grid, V305B cuts off and a relay in its plate circuit opens. When the relay opens, a set of contacts on the relay applies -145 volts to the No. 1 grid of the vidicon and cuts off the tube. In this manner, the vidicon mosaic is protected from damage due to bombardment by a stationary electron beam.

An output is taken from the cathode of V304A (the vertical blocking oscillator) to drive V302B. The V. SIZE (vertical size) and V. LIN. (vertical linearity) controls act together to control the vertical sweep amplitude. The signal from the cathode of V304A is also applied to the vidicon tube cathode to provide a blanking signal of the correct amplitude and duration.

The camera deflection yoke voltages for the vertical sweep are taken from the plate circuit of V302B and from the cathode of V304B. V304B is driven by the plate signal from V302B.

The dual triode stage (V306) accepts inputs at the horizontal and vertical rates to provide a combined horizontal and vertical blanking in output, which is applied to the video amplifier chassis. The combined horizontal and vertical blanking signal is added to the amplified video signal in the video amplifier.

The sync mixer, V307, is a dual-triode stage with the control grids driven by the cathodes of V304A and V301A, which provide horizontal and vertical pulses, respectively. These pulses are mixed in the triode sections of V307 and added to the video signal in the video amplifier chassis. A capacitor and resistor (not shown in figure 12-1) differentiate the vertical sync pulse. Any positive overshoot on the vertical pulse is clipped by a germanium rectifier (not shown).

## SYNC GENERATOR CHASSIS

V401B is a triode master oscillator connected in an extremely stable circuit. V401A is a pentode used as a variable reactance across the tank circuit of V401B. The variable reactance feature is used to correct small variations in the oscillator frequency so that the counter output will always correspond to the line voltage reference signal frequency when the sync generator is operated in the line LOCK position.

Negative 31.5-kc pulses are fed from the oscillator circuit, V401B, to trigger V402A, which is a conventional blocking oscillator stage. The circuit time constants are chosen to control the rate at which the blocking oscillator fires. The firing rate is controlled so that V402A conducts on every third incoming trigger pulse (negative in polarity) reaching its cathode. Thus the incoming master oscillator pulses (31,500 cps) are divided by three and the V402A output frequency is 10,500 cps. A jack (not shown in figure 12-1) connected to the cathode of V402A provides a means of observing, with an oscilloscope, the 10,500-cps spikes on the 31.5-kc signal.

V402B is another blocking oscillator. The time constants of its circuitry control the rate at which V402B fires and are arranged so that the tube conducts on every seventh input trigger pulse of the 10,500-cps output from V402A. The output of V402B is 1500 cps (10,500/7). The 10,500-cps signal with 1500-cps spikes may be examined, with an oscilloscope, at a jack (not shown) connected to the plate circuit of V402A.

The 1500-cps output of V402B is applied to the control grid of V403A, a blocking oscillator that conducts on every fifty pulse from V-402B. Thus, the input frequency (1500 cps) is divided by five to give 300-cps pulse output. This output frequency is applied to V403B, which is a blocking oscillator that divides the 300-cycle input frequency by five to get 60-cps output pulses. The 60-cycle output of V403B is applied to two resistors (not shown) to give a positive-going pulse across one resistor and a negative-going pulse across the other resistor. The positive-going pulse is the vertical timing pulse to the sweep chassis, and the negative-going pulse is the vertical timing pulse to the phase detector network.

The difference in phase between the output pulses and a 60-cycle reference signal are rectified by separate germanium diodes (not shown), which have their outputs connected in parallel. The amplitude and polarity of the rectified voltage are such that when the voltage is applied to the control grid of the reactance tube, V401A, it will shift the master oscillator frequency in the direction required to eliminate the phase difference.

### POWER SUPPLY

The power supply furnishes +200 volts d-c at 220 ma, -145 volts d-c at 15 ma, 6.3 volts a-c at 8 amps, and 6 to 16 volts a-c at 1.5 amps. Part of the current from the +200-volt supply is applied to V501, a voltage regulator tube, which furnishes +105 volts regulated to the sync generator and video amplifier sections. Because the focus coil in the camera is connected in series with the regulated supply voltage, the focus coil current is regulated.

The accelerating and focusing anodes of the vidicon tube require +300 volts at 5 ma. Not shown in the power supply block is the voltage-doubler circuit that provides the +300 volts from the +200-volt supply.

The output of the terminal marked, 6-16 volts a-c, in the power supply block is made variable to permit adjusting the heater voltage of the vidicon and preamplifiers in the camera to 6.3 volts regardless of the camera cable length.

### CONCLUSION

The foregoing description will be greatly amplified in the training course for IC2. We have purposely avoided schematic diagrams and circuit operating theory because you should have more technical knowledge and more on-the-job training before you begin the study of difficult circuits.

After reading this section two or three times you should be able to see that a closed circuit TV camera unit is composed of (1) a camera tube that converts light into electrical signals, (2) amplifiers that build the extremely low camera output up to a usable signal for driving the modulator that amplitude modulates the RF oscillator, (3) trigger generators and blocking oscillators that are necessary to get the correct number of lines per picture and the correct number of frames per second, and (4) a power supply.

When you have these facts in mind you should not have a great deal of difficulty when you study the theory of opèration.

## Optical Landing System

The Fresnel lens optical landing system is primarily an electro-optical system installed along the flight deck of an aircraft carrier to provide a bar of light that indicates, to the incoming pilot, the correct glide path angle. The relative vertical position of this bar of light, as indicated by its alignment with horizontal lights, shows the pilot whether he is above, below, or on the ideal glide path.

Three lens assemblies are installed along the edge of the flight deck at varying distances from the aircraft carrier stern. The lights of only one lens assembly are activated for any one incoming aircraft. Thus the system compensates for differences in specified glide angles for different types of aircraft, weather, tactical conditions.

# Optical Principles

So that you may have a better understanding of the Fresnel lens, we will list and define some of the optical terms that will be used and then discuss some elementary principles of optics and lenses.

CONVEX LENS – A lens with one surface curved outward. If the other surface is flat, it is called a plano-convex lens; if both surfaces curve outward, it is called a double-convex lens.

FOCAL LENGTH.–The distance between the optical center of a lens and its principal focus point at which light rays coming from an infinite distance meet.

PRINCIPAL FOCUS POINT.–The point where light rays passing through a lens parallel to the principal axis converge and meet.

FOCUS.–Influencing a ray of light so that it converges to a spot of the desired size.

OPTICAL CENTER.–The point on the principal axis that has the property that no ray passing through it is deviated in direction.

PRINCIPAL AXIS.–A straight line passing through the center of curvature of the surfaces of the lens.

VIRTUAL IMAGE.–An image that appears to be coming from a new point at which no actual real image appears.

Figure 12-2 shows an ordinary convex lens. A convex lens will produce a virtual image on the same side of the lens as the object, if the object is placed inside the principal focus of the lens and the observer is on the opposite side of the lens from the object. A virtual image is formed when light passing through an optical system, from a point on an object, appears to be coming from a new point at which no actual real image is formed. A screen placed at the point where the virtual image appears will not show a picture of the object. This principle is illustrated in figure 12-2. The object DB is inside the principal focus point F2, the virtual image is D'B', and the observer is at Z. To obtain the position and size of the image formed by the lens, select a point, B, on the object DB. Of the rays emerging from this point select two, one of which is parallel to the principal axis of the lens while the other passes through the optical center of the lens.

The optical center of a lens is a point on the principal axis of the lens, located so that the rays passing through this point do not change direction. In figure 12-2 the ray passing through the optical center of the lens will form ray BC. The ray parallel to the principal axis of the lens will enter the lens at point E and will not be refracted because it enters the lens perpendicular to the surface of the lens. But the same ray, upon leaving the lens at point A, will be refracted from the normal, N, by an angle, r (called the angle of refraction) and will pass through the principal focus point, F1.

The intersection of these two rays, BC and AF1, will determine the location of image B' of point B from which these rays came. In a like manner, other points on the object, DB, can be located, giving the image, D'B'. The image formed in this manner, is virtual, erect, and magnified.

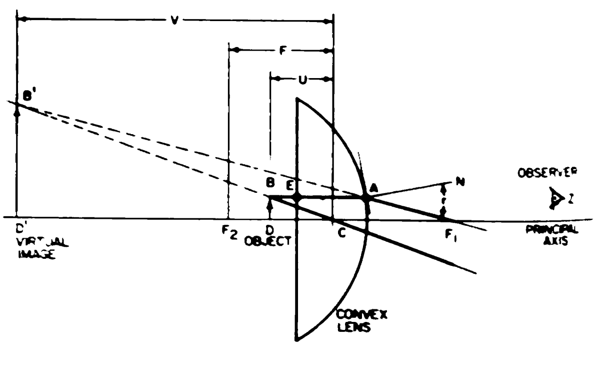



Figure 12-2.–Spherical lens.

## FRESNEL LENS PRINCIPLES

The Fresnel lens differs from the convex ens in that one surface consists of a number of stepped, concentric zones, as shown in figure 2-3. One advantage of the Fresnel lens construction is its thinness and the resultant light weight. In the regular convex lens at the left of figure 12-3, all zones have the same locus (the center of the curvature), and the resultant lens is thick in the middle. In the Fresnel lens the slope of each and every facet is independent of all the others, so there need not be any change in thickness.

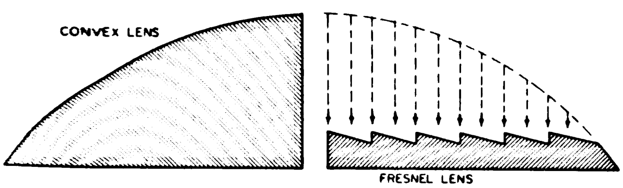



Figure 12-3.—Regular and Fresnel lens.

The change in thickness in an ordinary lens causes an effect called spherical aberration that is illustrated in figure 12-4. When this effect (fig. 12-4A) is present, the rays of light parallel to the principal axis of a convex lens pass through the zones near its edge, and cross the axis nearer the lens than those which pass through its center. Therefore, the reflected rays do not form a perfect cone of light and do not meet at the focal point (the point when least blurring occurs). In the Fresnel lens (fig. 12-4B) the spherical aberration effect is not present because each facet is independent of all others. By designing the lens around a suitable radius, astigmatism, which is the inability of an optical system to bring all rays from a point on the object to a sharp focus at the image, can be eliminated.

Focal length (the distance between the optical center of a lens and its principal focus point at which light rays coming from an infinite distance meet) is an important lens characteristic. The Fresnel lens is made of lucite, and its focal length varies appreciably with temperature because of the variation in dimensions and density of lucite with temperature.

Such changes may be eliminated by maintaining the lens at a fixed temperature or by automatically adjusting the lamp-to-lens distance as the temperature varies. In the Fresnel lens optical landing system, focal length variation is minimized by maintaining the lens at a constant temperature within a small allowable tolerance.

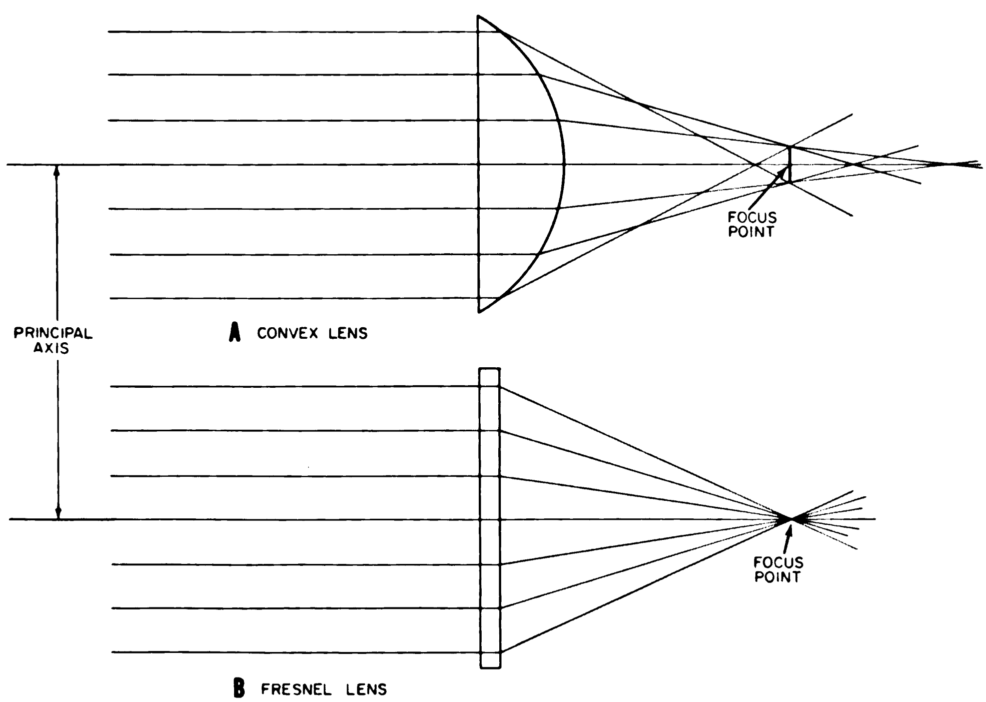



Figure 12-4.—Spherical aberration.

### LENTICULAR LENS PRINCIPLES

A lenticular lens is a form of double convex lens. In the Fresnel lens optical landing system it is made up of several long convex, cylindrical lenses side by side, as shown in figure 12-5. Each individual, long convex lens has the same short focal length. There are two results of this construction. One, because of the short focal length, the viewing area of the object is widened (spread out). Two, if the object is composed of a multiple light source with spacing between the lights, it will appear to an observer on the other side of the lens, as a continuous band of light filling the width of the lens regardless of the position of the observer in the azimuthal range of view (45 degrees) of the lens.

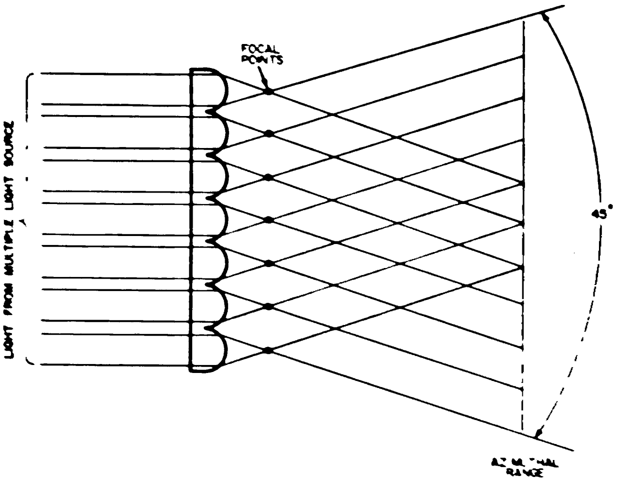



Figure 12-5.—Lenticular lens.

The lenticular lens is colored during the fabrication process, so it acts as its own yellow filter. There are two advantages to this process: (1) a separate light filter and its consequent light attenuation are eliminated, and (2) reduction of sun glare from the face of the Fresnel lens box by virtue of the facets in the lenticular. If a smooth filter cover were used with the lenticular, the sun reflection could eliminate the image.

### APPLICATION OF LENSES TO THE OPTICAL LANDING SYSTEM

In carrier operations it is necessary that aircraft stay close to a specified glide angle that has been chosen for the type of aircraft and in consideration of weather and tactical conditions. The glide angle is the angle between the pilot's line of sight and the horizontal plane. The optical landing system establishes this glide angle for the pilot and provides a path for the pilot to follow to maintain the correct glide angle.

### CONCLUSION

Five cells of the Fresnel lens deck edge assembly are arranged, as shown in figure 12-6. Each cell consists of a lenticular lens, a Fresnel lens, and a light source. The five cells are arranged, one above the other, along the circumference of a circle whose radius is 150 feet. As an observer moves from line of sight EO towards AO (fig. 12-6), he sees a common virtual image, 12 inches wide and approximately 6 inches high, appear to move smoothly from location U to location P. Assume that the correct glide angle is CO. Then a pilot who is on the correct glide angle will see the bar of light at position S in the line with the row of datum lights (to be described later) on either side of the bar of light. If, on the other hand, the pilot is on a flight path whose glide angle was too steep (for example, AO), the bar of light would appear above the line of datum lights at point P. If the pilot is on a glide angle that is too shallow, (for example, EO), the bar of light would appear below the line of datum lights at point U. In either case (too high or too low) the pilot would correct his glide angle so that the bar of light is positioned in line with the datum lights.

# Fresnel Lens Optical Landing System

The functional block diagram for the Fresnel lens optical landing system is shown in figure 12-7. The seven main assemblies in this system are (1) the Fresnel lens deck edge assembly (3 required), (2) the power panel, (3) the remote control panel (2 required), (4) the dimmer

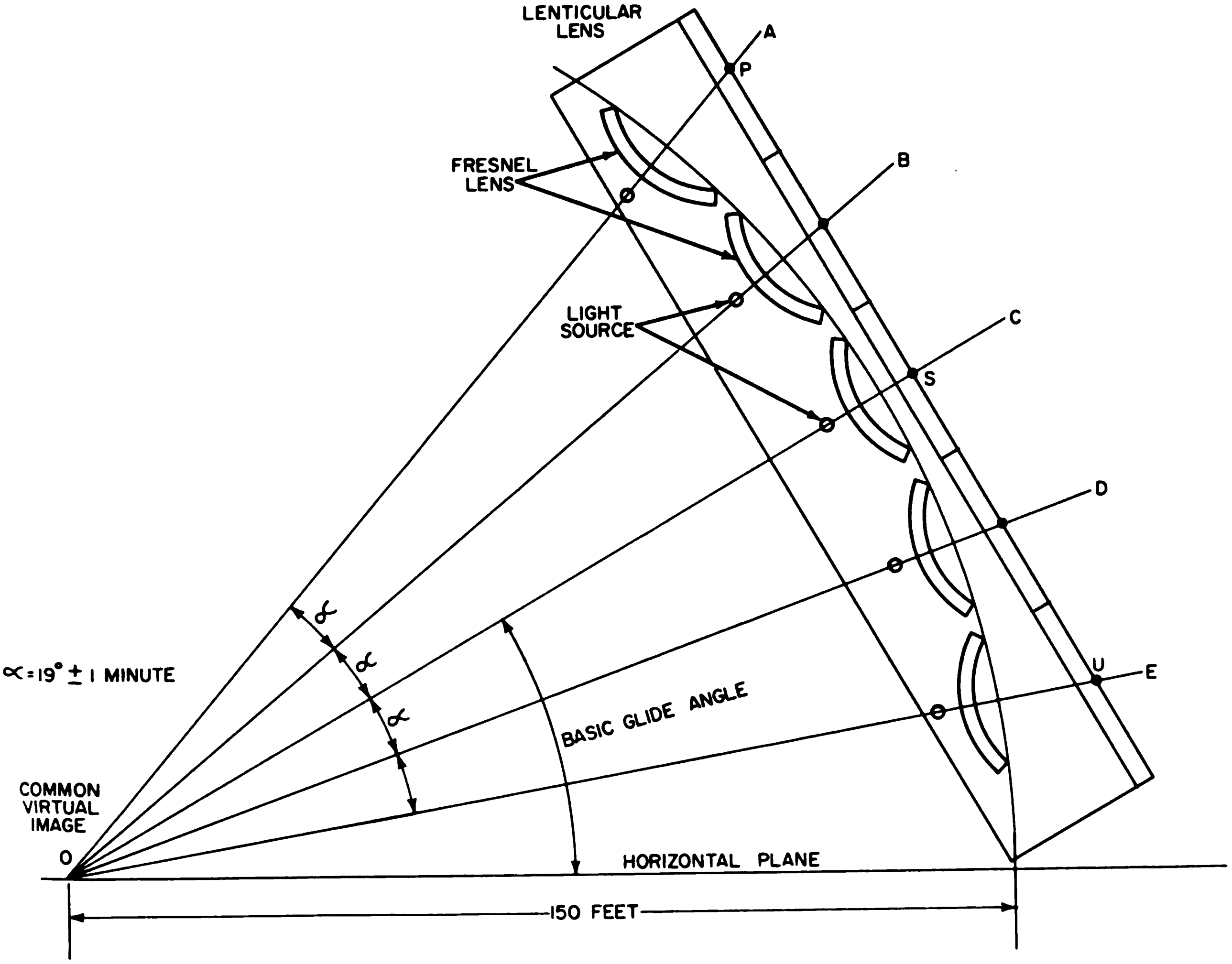



Figure 12-6.—Fresnel lens box.

control unit station, (5) the computer, (6) the servo amplifier enclosure, and (7) the transformer enclosure.

Each of the main assemblies consists of various subassemblies that are accessible for maintenance and repair. The servo amplifiers in the system use magnetic amplifiers rather than vacuum tubes for greater ruggedness, reliability, and efficiency.

## DECK EDGE ASSEMBLIES

Each of the three identical deck edge assemblies (fig. 12-8), consists of the following subassemblies: (1) source light and lens assembly, (2) datum light assemblies (2 required), (3) wave-off light assemblies (2 required), (4) cut light assemblies (2 required), (5) lens box drive mechanism, (6) inboard and outboard junction boxes, and the (7) background screen.

## SOURCE LIGHT AND LENS ASSEMBLY

The five cells produce a common vertical image of the light source in a fixed location 150 feet behind the Fresnel lens. The image, as seen from the front of the Fresnel box, is 12 inches wide and approximately 6 inches high when viewed from a distance greater than 600 feet. The total aperature in the Fresnel box through which the image may be seen is 12 inches wide by 48 inches high and has a theoretical vertical field angle of one degree, 32 minutes.

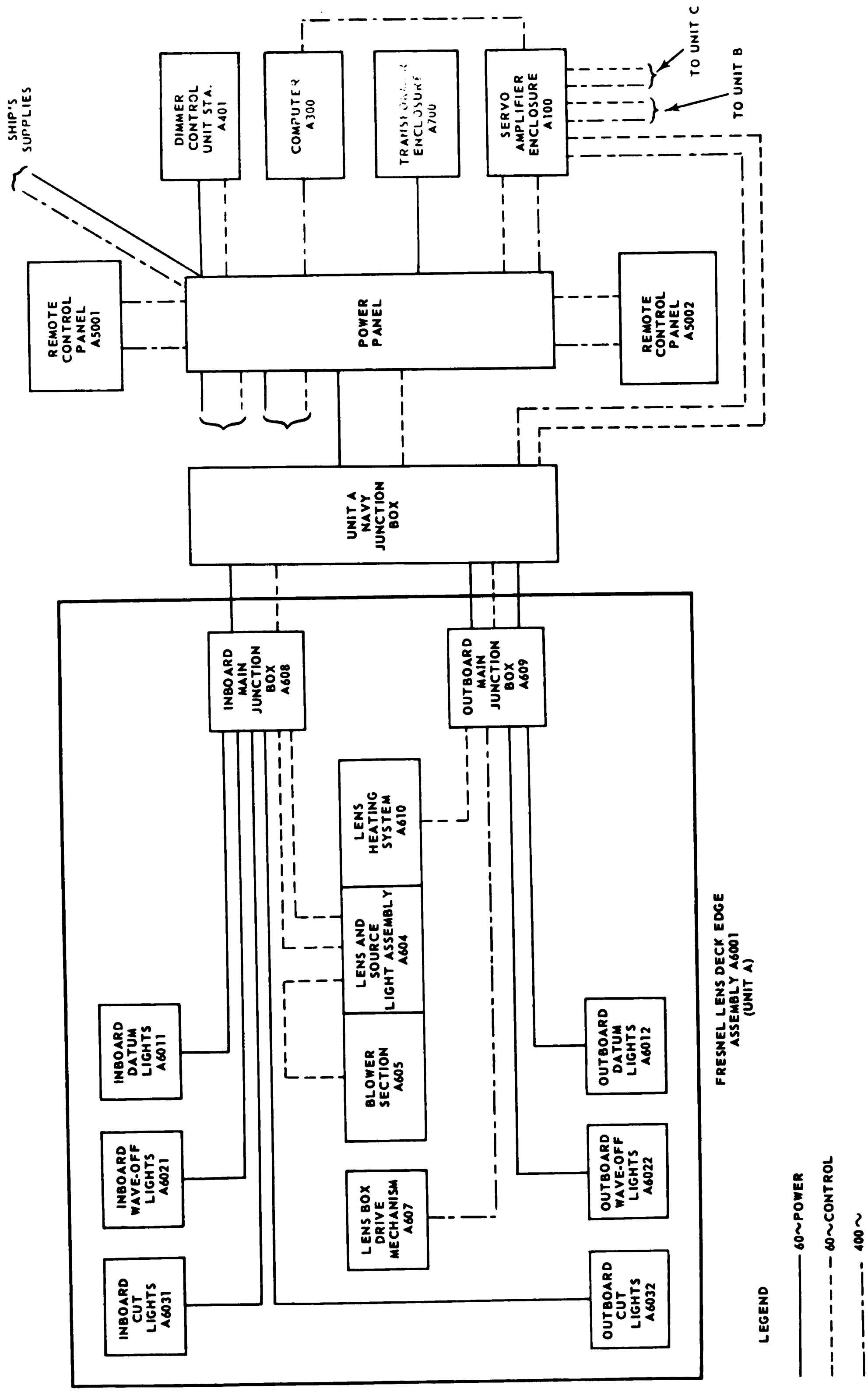



Figure 12-7.—Optical landing system.

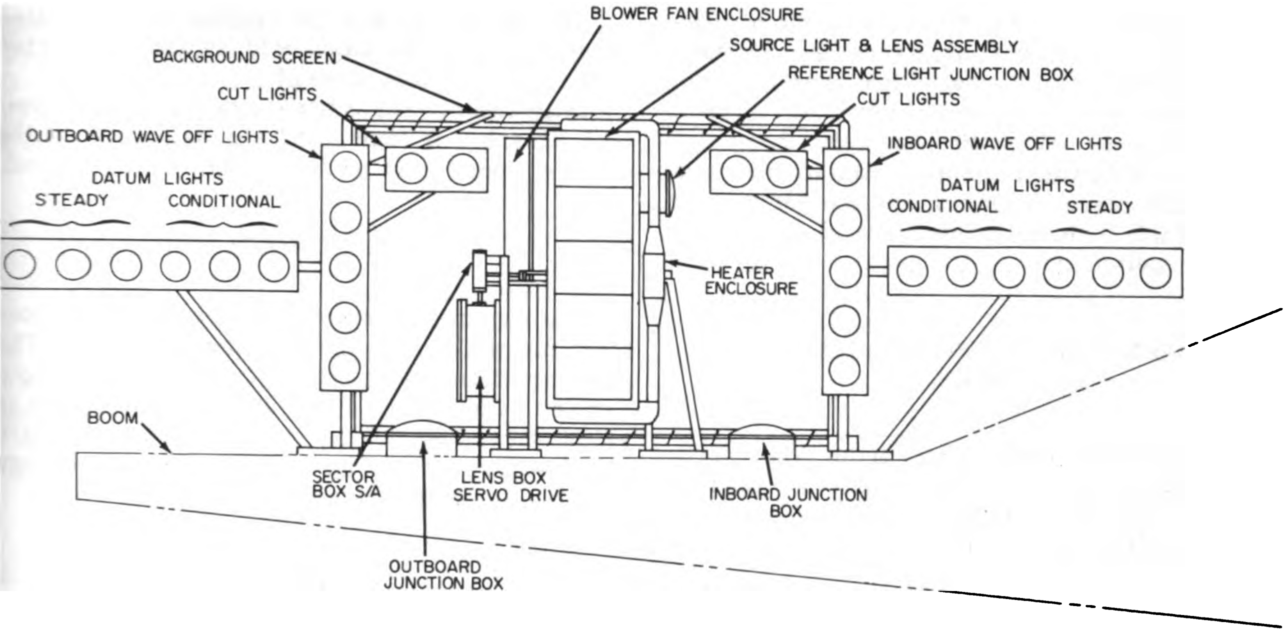



Figure 12-8.—Deck edge assembly.

The interior of the box is divided into five separate cells by the use of horizontal baffles and is painted black so that light from the source lights cannot be reflected from the interior surface to the Fresnel lens. Each cell is ventilated by a fan mounted on the outboard side of the box. An air filter adequately filters the air entering the cell.

## DATUM LIGHT ASSEMBLIES

Two identical datum light assemblies (fig. 12-8) are mounted one on either side of the Fresnel box. The lamps are aligned with the horizontal center line of the aperature in the Fresnel box. The assembly is mounted such that the center axis of its beam is parallel to the carrier's landing axis and is in a fixed position 5 degrees above the plane of the flight deck. Each lamp has a green filter mounted in front of the lamp lens.

## WAVE-OFF LIGHT ASSEMBLIES

Provisions for waving off the incoming pilot must be provided in case some condition should arise that would make a landing hazardous. This provision is met by two identical wave-off light assemblies (fig. 12-8) that are mounted one on either side of the Fresnel box, perpendicular to the datum light assemblies, parallel to the Fresnel box housing, and with the center lamp level with the datum light assemblies. The assembly is installed with the center axis of the main beam 5 degrees above the flight deck plane and parallel to the landing axis of the carrier. Each lamp has a red filter in front of the lamp lens.

## CUT LIGHT ASSEMBLIES

The cut lights are provided so that the officer in charge of landing operations can signal the pilot to cut off the engine of the airplane. Two identical cut light assemblies (fig. 12-8), are mounted, one on each side of the Fresnel lens box and level with the top wave-off lamp. The assembly is installed with the center axis of the main beam 5 degrees above the flight deck plane and parallel to the landing axis of the carrier. Each lamp has a green filter mounted in front of the lamp lens.

## LENS BOX DRIVE MECHANISM

The lens box drive mechanism is mounted in two enclosures on the outboard support structure of the Fresnel box (fig. 12-8). One enclosure houses the lens box servo drive, and the other houses the sector box subassembly. The lens box servo drive consists of one 50 watt, 115-volt, 400-cycle, 2-phase, low-inertia servo motor; one d-c tachometer generator whose rated output is 45 volts per 1000 rpm; one 400-cycle type synchro control transformer; one servo limit circuit chassis; and the servo gear train, which includes a mechanical limit stop and limit switches.

## INBOARD AND OUTBOARD JUNCTION BOXES

All electrical connections from other parts of the system are brought to outboard junction boxes. Connections between units of the deck edge assembly are made in inboard junction boxes.

## BACKGROUND SCREEN

The background screen serves to block out objects behind the deck edge assembly that might confuse the pilot. It is supported by the complete assembly.

## POWER PANEL

The power panel (fig. 12-7) is the power switchboard for the entire system. Physically, it is an aluminum box approximately 59 inches wide, 70 inches high, and 28 inches deep. Screens over openings at the top and bottom of the enclosure provide for natural draft ventilation.

Operation of the wave-off and cut lights may be accomplished at the power panel by connecting a hand held (pickle) switch to the proper terminals on the power panel.

## REMOTE CONTROL PANEL

Two remote control panels (fig. 12-7) provide for remote control of some of the power panel functions such as the brightness of the various lights, selection of the Fresnel lens deck edge unit for a specific type of plane, on-off switching of the various lights, indication of trouble in all the various lights (except the datum lights) and in the stabilization system.

The wave-off and cut lights are operated by buttons on the hand-held switch connected to the remote control panel.

Only one remote control panel can be in control at any one time, and the selection of the remote panel is made at the power panel.

## DIMMER CONTROL UNIT

The dimmer control rack (fig. 12-7) houses four magnetic amplifier dimmer units. The dimmer units are of three different power output ratings. One unit is rated at one kw, one unit is rated at two kw, and the remaining two units are rated at three kw. The maximum output voltage is 120 volts at 60 cycles.

## COMPUTER

The computer is a part of the stabilizing system that maintains the light beam at a fixed angle to the horizontal, regardless of the pitch and roll of the carrier. In operation, the computer receives roll and pitch information from a gyro stable element. This information is converted by the servo systems into rotation of the reference light and lens assembly (fig. 12-8). This rotation compensates for the roll and pitch and maintains the basic angle at a fixed value. The response of the system is such that it will follow a pitch of the carrier of ±5 degrees in a period of 7 seconds and roll motion of ±12 degrees in a period of 8 seconds, both within 10 minutes of angle.

A provision for setting fixed basic angles of the light beam with respect to the deck is incorporated into the stabilization system. This is the glide path for approaching aircraft, and angles can be set at 1/3-degree steps between the limits of three and six degrees. Pitch and roll stabilization is a dynamic correction around the basic angle.

The computer houses six assemblies: the pitch and roll receivers, the pitch and roll compensator, the basic angle receiver (each mounted on its own aluminum plate), and two computer limit switch chassis.

## PITCH AND ROLL RECEIVERS

The roll and pitch receivers are identical units. Each receiver consists of one 10-watt, 5-volt, 400-cycle, two-phase, low-inertia rvo motor; one d-c tachometer generator; two 0-cycle synchro transformers; the various ars; the limit stop; and the limit switches in e servo gear train.

### PITCH AND ROLL COMPENSATOR

The pitch and roll compensator is a mechani-l differential mounted on an aluminum plate. ne unit consists of three mechanical dif-rentials, three synchro transmitters, and the sociated gears.

### BASIC ANGLE RECEIVER

The basic angle receiver is an electrical fferential unit mounted on an aluminum plate. ne receiver consists of three synchro dif-rential transmitters, one synchro torque re-iver, and the gears. Figure 12-9 shows the sic angle receiver.

### COMPUTER LIMIT SWITCH CHASSIS

Each limit switch chassis consists of a ansformer, a single pole, double-throw relay, d two capacitors.

### SERVO AMPLIFIER ENCLOSURE

The servo amplifier enclosure (fig. 12-7), ouses five identical magnetic servo amplifiers. ach amplifier has a rated power output of 150 atts at a rated input of 115 volts, 400 cycles d consists of a two-speed servo signal mixing rcuit, a magnetic preamplifier, a magnetic ower stage, and error indicating circuitry.

The servo amplifier receives 2-speed and 6-speed signals from the synchro control ansformers. The purpose of the mixing cir-uit (in the servo amplifier) is to add only a mall portion of the 36-speed signal to the 2-peed signal. In this manner, the low-speed gnal is operative for large errors, but the gh-speed signal becomes effective near zero rror for a more accurate null.

The mixed, two-speed servo signal, to-ether with the stabilizing signal from the chometer, is the control signal to the magnetic reamplifier. The preamplifier is a fast response bridge type composed of two-toroidal magnetic cores, 5 diodes, balancing resistors, and a supply transformer. The preamplifier output is the control signal for the power stage. The output magnetic amplifier is a full-wave doubler consisting of four toroidal magnetic cores, 8 diodes, balancing resistors, 2 capacitors, and a power transformer. The power stage output controls the servo motor in the servo drive chassis. A portion of the mixed synchro input signal is acted upon by the error-indicating circuit to provide an error indication on a meter at the remote control units. The error-indicating circuit consists of two transformers, two diodes, and the meter zeroing resistors.

### TRANSFORMER ENCLOSURE

The transformer enclosure houses three step-down auto transformers and three step-down isolation transformers. The step-down auto transformers with taps around the 70 percent point permit the dimmers to operate at 100 percent of its rated power. For example, in a particular step the datum lights require approximately 70 percent of rated voltage and about 58 percent of full power. However, this 58 percent of rated power is approximately 100 percent load on the datum light dimmer. Therefore, if the dimmer was forced to deliver 100 percent of its rated power at 70 percent of its rated voltage, it would need to deliver (100/70)100=143 percent of its rated current. The dimmer cannot do this; therefore, a stepdown transformer with the proper turns ratio is connected between the dimmer and the lights. The current demand on the dimmer then will exceed its rated current.

The three isolation-type, step-down transformers serve a double purpose. They provide the necessary power matching and, in addition, provide 115/60-volt, step down for the next step operation because the reference lamps are operated five in series of 12 volts per lamp. There are three such reference light lines. Therefore, the transformers must be the isolation type because full line voltage on the secondaries would destroy the reference lamps.

### CONCLUSION

The foregoing discussion was intended solely to acquaint you with the terminology of the

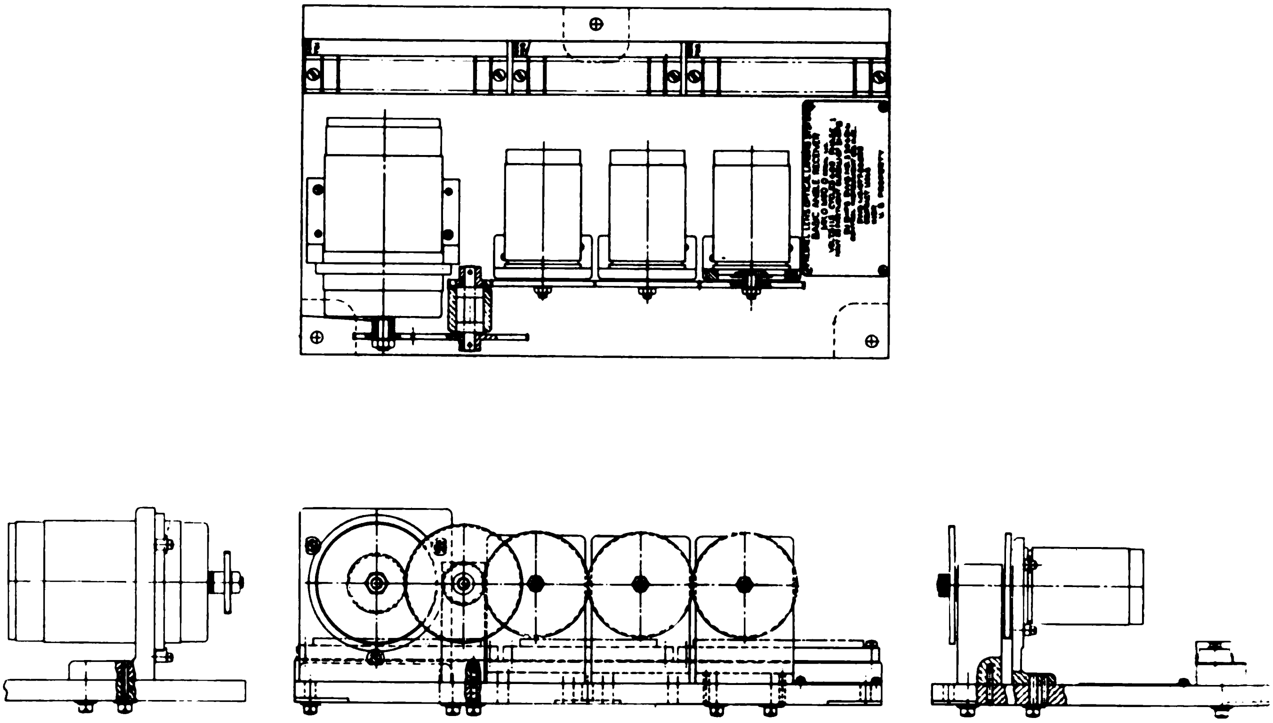


Figure 12-9.—Basic angle receiver.

Fresnel lens optical landing system. Obviously, the only place you would encounter such a system is aboard an aircraft carrier.

The optical landing system uses a combination of lights to inform the incoming pilot if he is on the proper glide path in order to engage the cable of the arresting gear; to wave him off for another try if he is not on the proper glide path; and to signal him to cut the engine to idling speed at the proper instant. Thus the system takes over some of the functions of the landing officer but the lights for wave-off and cut are manually operated by a hand held switch.

The following training courses in the I.C. series will give complete technical descriptions of the electrical components and the system.

# Underwater Log

An electromagnetic underwater log system is used to measure, indicate, and transmit speed and distance data relative to water. The complete system consists of a rodmeter, indicator-transmitter, and sea valve.

The sea valve (fig. 12-10) is mounted to the hull and houses the rodmeter. The handwheel is turned to expose the rodmeter to the water when measurements are to be made. After the measurements have been completed, the valve is closed to seal off the hull opening. The rodmeter (fig. 12-11) houses the sensing unit (fig. 12-12).

## SENSING UNIT

The sensing unit produces a voltage whose magnitude is proportional to speed. The principles of operation are based on the basic rules for magnetic circuits. We will review some of these principles to show how they relate to the operation of the underwater log.

Experiments have shown that when a conductor moves in a magnetic field at right angles to the direction of the magnetic field so as to cut the lines of flux (fig. 12-13), an electromotive force is induced in the conductor. The voltage generated is equal to the product

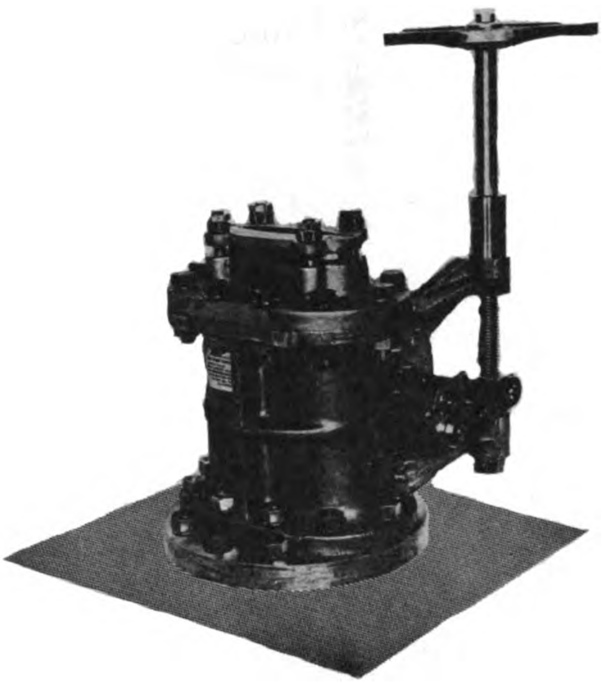


Figure 12-10.—Sea valve.

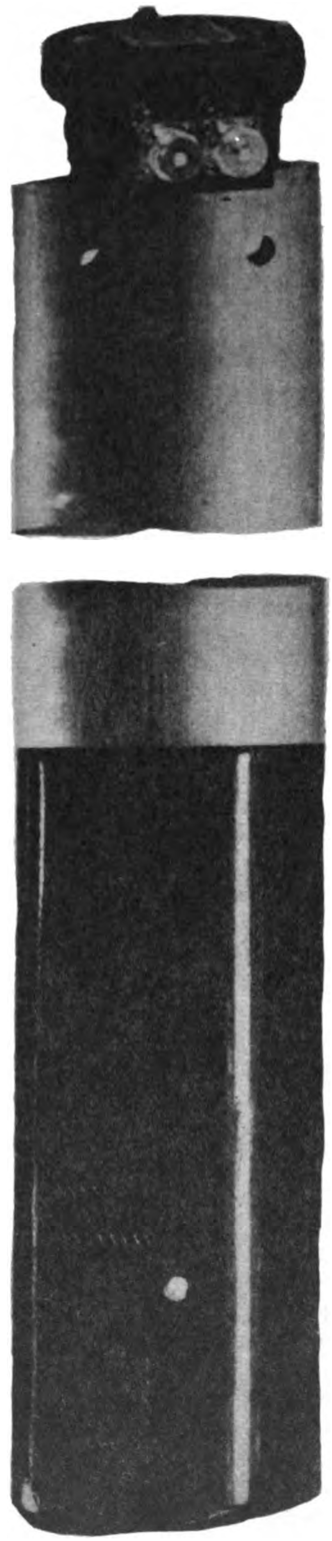


Figure 12-11.—Rodmeter.

of the flux density in which the conductor is moving, the length of the conductor cutting the flux, and the velocity of the conductor in a direction at right angles to the field.

The relationship between voltage, field (flux), and motion is given by Fleming's right-hand rule: If the thumb and two fingers are held mutually at right angles to each other (the thumb in the direction of motion and the forefinger in the direction of the field) the second finger then points in the direction of the induced voltage.

There are two methods that may be used to detect the magnitude of the voltage induced in the conductor due to its velocity through the magnetic field. Measure the voltage (first method) at the ends of the conductor, points A and B in figure 12-13.

Using the second method, close the conductor upon itself outside the magnetic field, as shown by the dotted lines in figure 12-14. Then cut the conductor by a nonconducting plane parallel to the direction of motion and to the lines of flux, and by means of suitable contacts on each side of the plane measure the voltage across the plane. The conductor, as it moves through the magnetic field, cuts lines of flux on both sides of the plane, and a voltage proportional to the velocity of the conductor is

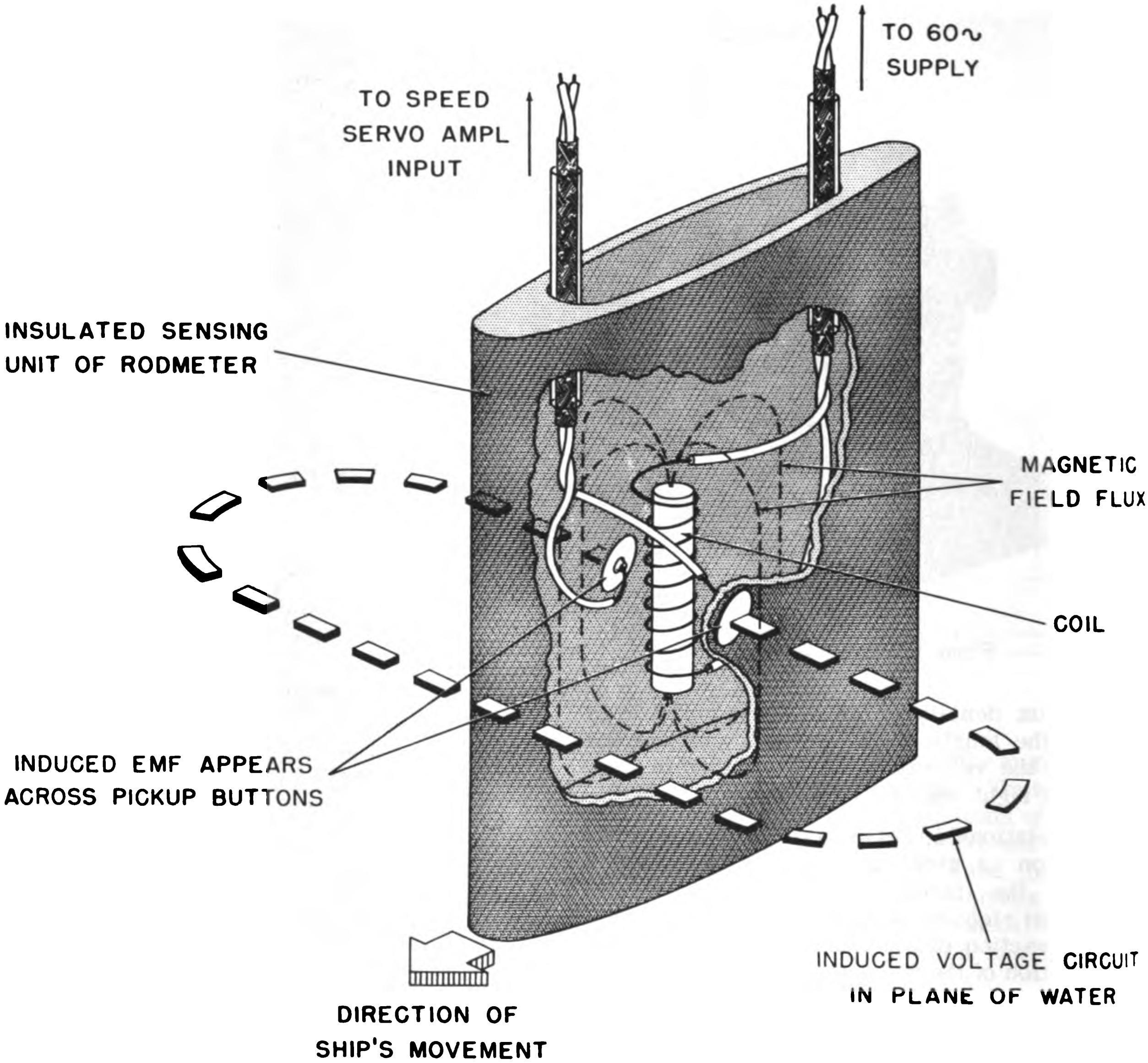



Figure 12-12.—Sensing unit.

generated in the conductor on both sides of the plane.

If the conductor shown in figures 12-13 and 12-14 is replaced by a sheet of conductive material, as shown in figure 12-15, a voltage will be induced in the conductive sheet in a manner similar to that shown in figure 12-13. If a plane could be passed through the conductive sheet (fig. 12-15) the magnitude of the voltage induced in the sheet could be measured, as shown in figure 12-14. The portion of the sheet that lies outside of the magnetic field acts as a closed loop around the insulating plane. Therefore, the total voltage induced in the conductive sheet could be measured across the plane.

The operation of the rodmeter is based on the principles just described. An a-c voltage excites the coil located in the plastic shell on the outboard end of the rodmeter, thus creating a magnetic field uniformly distributed around the rodmeter. The magnetic field is in time phase with alternating current flowing in the coil. That is, the flux density varies each half cycle with the coil current, and the direction of the magnetic field reverses as the direction of the

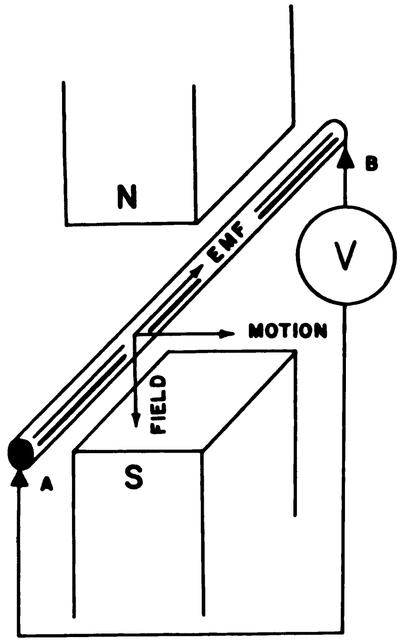



Figure 12-13.—Voltage induced in a conductor.

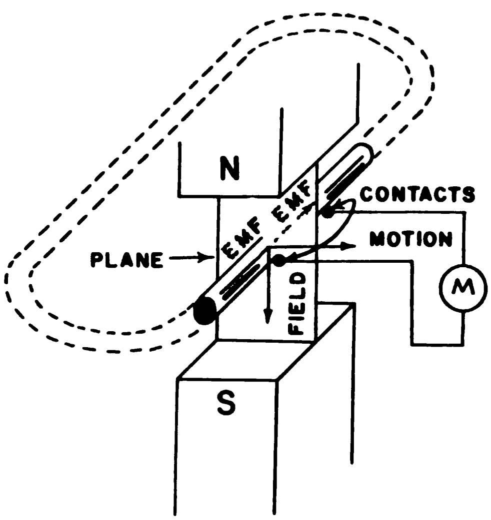



Figure 12-14.—Measurement of induced voltage.

coil current reverses each half cycle. Therefore, the magnitude of the voltage generated in the conductor is proportional to both the flux density and the velocity, as previously stated.

The water, which is a conductor, creates a closed path in its natural flow about the rodmeter. The water is cut by the nonconducting plane, which is the plastic shell of the rodmeter. As the magnetic field moves through water, the

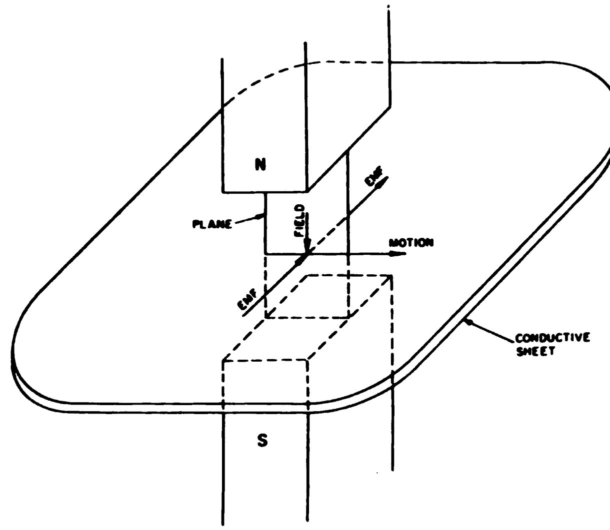



Figure 12-15.—Measurement of voltage in a conductive sheet.

water on both sides of the rodmeter is being cut by lines of flux, and a voltage proportional to the velocity of the water is generated on both sides of the rodmeter. The pickup buttons (fig. 12-12) located on each side of the rodmeter make contact with the water and pick up the voltage being generated in the water. The current producing this voltage is indicated in a similar manner, as shown by M in figure 12-14.

## COMPLETE SYSTEM

Figure 12-16 is a block diagram of the electromagnetic log equipment. The output voltage of the sensing unit is fed to a speed servo amplifier. The amplifier output is fed to a speed dial; a synchro transmitter, which sends speed signals to the ship's wiring; and to an integrator. The signal from the servo amplifier and the signal from a time motor are mechanically integrated and fed to the distance servo. The output of the distance servo is fed to a digital type miles counter, and to a synchro transmitter that sends distance signals to the ship's wiring.

This system of measuring ship's movement is remarkably accurate. It has been noted, in actual operation, that the dial pointer will oscillate as much as 1 knot (on either side of the right value) or so in phase with the ship's roll cycle. This does not indicate a fault in the system. It is due to the system following the water flow pattern under the hull. Should the oscillation become objectionable, it can be reduced by applying a field modification.

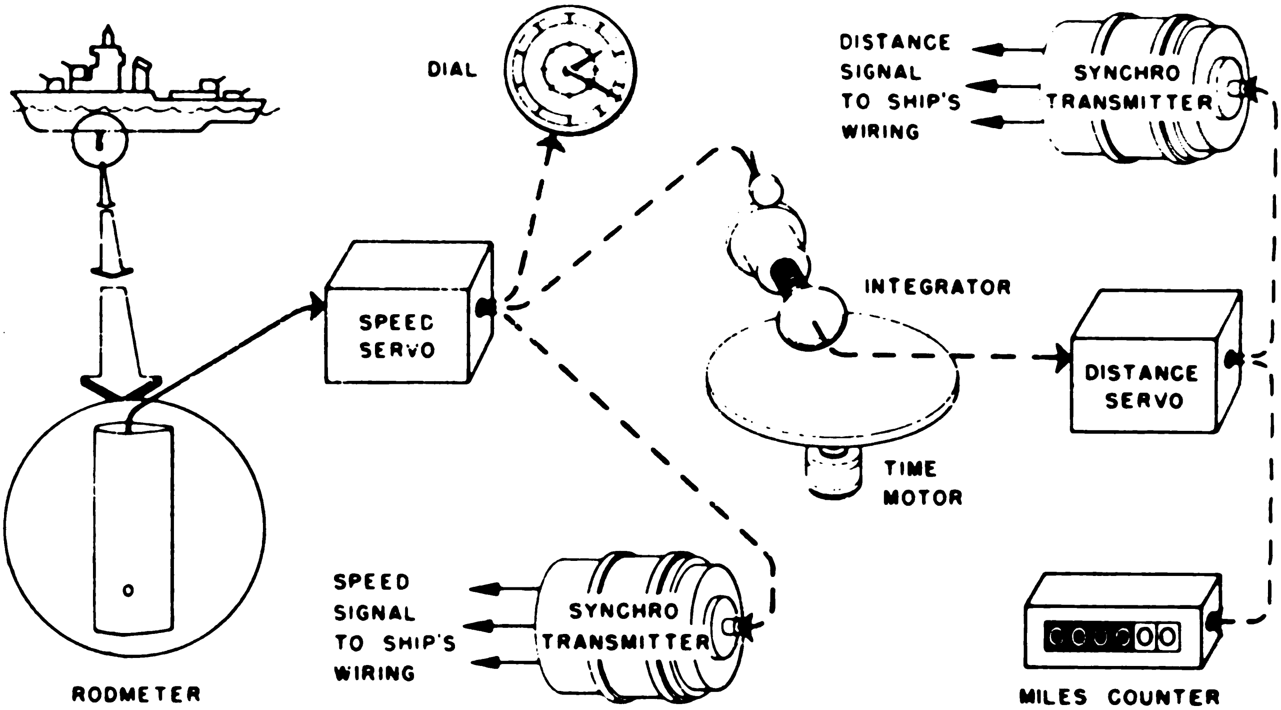



Figure 12-16.—Magnetic underwater log system.

## QUIZ

1. What name is given to a system in which a TV camera is directly connected to one or more TV receivers?
2. What name is given to the picture pickup tube?
3. What is the name of the light sensitive surface of the vidicon tube?
4. How many parallel horizontal lines make up a scene?
5. What causes streaking of moving objects?
6. How does V203B operate?
7. What is the purpose of V205?
8. What is the frequency range of the r-f oscillator?
9. What frequency signal is generated by V401B?
10. What is the plate load for V303?
11. How is the signal from the cathode of V304A used?
12. What is the output frequency of V402A?
13. How many lens assemblies are used in the optical landing system?
14. How are changes in focal length eliminated in the Fresnel lens?
15. What is the purpose of the background screen?
16. How are the wave-off and cut lights operated?
17. Where is the remote control panel selection made?
18. Why must isolation-type, step-down transformers be used with the reference lamps?
19. For what purpose is the underwater log used?
20. Name three components of the underwater log system.

# APPENDIX I

# ANSWERS TO QUIZZES

## Chapter 1

## ORGANIZATION

1. Service schools and self-study courses, textbooks, and training aids.
2. Military and professional.
3. The Manual of Qualifications for Advancement in Rating (Revised), NavPers 18068.
4. Record of Practical Factors, NavPers 760 (IC).
5. Training Publications for Advancement in Rating, NavPers 10052-G.
6. By application to your Information and Education Officer.
7. The success with which you stimulate others to learn.
8. Study and work should be carried out together.
9. Answering the questions at the end of each chapter.
10. (1) Man the battle stations, (2) perform basic administrative requirements, and (3) maintain continuous watches required under wartime conditions of readiness.
11. Three.
12. Maneuver and fight the ship.
13. The Watch, Quarter, and Station Bill.
14. Five.
15. Four hours.
16. At the control distribution switchboard.
17. The revised individual allowance list (RIAL).
18. The Material History Card—Electrical (NavShips 527A).
19. The Resistance Test Record (NavShips 531).
20. The Current Ship's Maintenance Project (CSMP).
21. A-C or D-C Electric Propulsion Operating Record (NavShips 3647), and Electrical Log—Ship's Service Electric Plant (NavShips 3649).
22. Official NavShips Forms prepared by the Bureau of Ships and ship's forms prepared by the engineering department of the individual ship.
23. Daily Ground Test Sheet.
24. The Ship's Memorandum Work Request.
25. The Equippage Custody Record (NavSandA 306A).
26. Log room, which is the office of the engineering department.
27. Custody receipts.
28. The Bureau of Ships Technical Manual.

## Chapter 2

## INSTRUMENTS AND METERS

1. Carelessness.
2. Properly fitted goggles or a face mask should be worn.
3. Rings, ID bracelets, and wrist watches.
4. Tachometer.
5. Usually one minute.

6. Revolutions per minute.
7. Slowing down or stopping of motion.
8. 600 to 14,400 rpm.
9. Flickering or a dull red glow and no flash.
10. It determines the amount of loading when the meter is connected in a circuit.
11. The internal resistance of the meter.
12. Series type and shunt type.
13. To provide various current ranges.
14. By using separate jacks for lead connections.
15. Approximately 1000 to 1.
16. During low resistance measurements.
17. No.
18. By measuring the voltage drop across the calibrated resistor.
19. It is an isolating resistor.
20. By reversing the meter connections with S2.
21. It serves to block any d-c voltage at the point of measurement.
22. To balance out contact potential at the plate of V3.
23. It is a full scale adjustment control for current measurements.
24. It is used to measure insulation resistance.
25. 500 volts.
26. Mutual conduction test and emission test.
27. Emission test.
28. Check the plug connections for correct wiring.
29. Well in excess of 1 megohm.
30. Military requirements or the safety of the ship.

# Chapter 3

# BASIC MECHANISMS

1. (1) Direction in degrees, (2) distance in yards, and (3) speed in knots.
2. Shaft rotation in one direction increases the value; whereas, rotation in the opposite direction decreases the value.
3. 36°.
4. 4.
5. 22.5°.
6. Pinion.
7. Rotary motion.
8. Linear.
9. Spur gears.
10. In a straight spur gear, the teeth are cut parallel to the axis of rotation; whereas, in a helical spur gear the teeth are cut with a lead angle (some angle other than parallel to the axis of rotation).
11. In the helical gears, the meshing action is much smoother, resulting in quieter operation than in spur gears because more than one tooth is in mesh at a time.
12. Bevel gears.
13. In a straight bevel gear the teeth are cut straight across the face of the gear; whereas, in a spiral bevel gear the teeth are cut with a lead angle across the face of the gear blank.
14. Two bevel gears of the same size, the shafts of which are at right angles.
15. On the inside circumference of a ring and parallel to the axis of rotation.
16. The axis of the external gear is parallel to, but offset from, the axis of the internal gear.
17. A helical screw.
18. 1:16.
19. (a) 1:8. (b) 1:16.
20. Large.
21. 2:7.
22. Opposite directions.
23. Between the driver and driven gears to turn the driven gear in the same direction as the driving gear.
24. It does not affect the gear ratio.
25. $\text{Gear ratio} = \dfrac{\text{number of threads on worm}}{\text{number of teeth on worm wheel}}.$
26. Speed ratio.
27. Inverse to each other.
28. 4:1.
29. The driving gear would be too large and cumbersome and would waste valuable space.
30. A gear mechanism that adds or subtracts the inputs of two shafts and translates the total, or difference, through a third shaft.
31. (1) Bevel-gear differential, (2) jewel-gear differential, and (3) internal-gear differential.
32. Because the spider only makes half as many revolutions as the sum of, or difference, between the revolutions of the end gears.
33. Spur gears.
34. (a) Small, (b) light, and (c) exact.
35. (1) Single-phase capacitor motor and (2) single-phase shaded-pole motor.
36. The servomotor must (a) start and stop quickly and (b) be electrically reversible.

37. The heart cam and the indented cam.
38. Ball bearing mounted so that it is free to turn.
39. It keeps the follower roller firmly seated in the valley of the heart cam.
40. The heart cam is rotated so that either CW or CCW comes into contact with C.
41. Opposite.
42. The signal that is used to control the output power is equal to the difference between the input signal and the feedback signal.
43. To measure the difference, or error, in position between the output and the input.
44. The spider remains stationary and holds the contacts closed, thereby allowing the servomotor to operate continuously in a direction to open the contacts.
45. (1) Bearing-mounted synchro receiver, (2) synchro transmitter, and (3) contact assembly.
46. Directly.
47. Indirectly by means of a ratchet.
48. To convert a variable rate of rotation to a proportional angular displacement that can be transmitted to indicators.

# Chapter 4

## SWITCHES, PROTECTIVE DEVICES, AND CABLES

1. Switches, fuses, and circuit breakers.
2. Rotary.
3. Momentary contact or continuous contact.
4. (a) 500 amp and (b) 10 amp.
5. 30 amperes.
6. 450 v a-c, 250 v d-c, and 120 volts a-c.
7. The two stationary contacts will be momentarily bridged by the arc and movable blade possibly causing a short circuit.
8. The formation of a high-resistance carbon film and switch failure.
9. It fills the "valleys" and distributes the pressure thereby eliminating excessive wear.
10. 120 volts, 60 cycles, 10 amperes.
11. Nonshorting.
12. Because of the possibility of severely burned contacts when operated slowly.
13. The switch may hang on the dead center position between each pair of active throws.
14. Circuit selection in sound-powered telephones.
15. By using silver contacts.
16. 2, 6, and 10 sections.
17. JA6C (16).
18. The JF switch utilizes silver contacts and a strong wiping action.
19. One ampere.
20. Nylon.
21. To prevent too much heat from being passed back to the switch deck and destroying the deck or damaging the insulation between contacts.
22. A type JA switch unit.
23. The main contacts of a contactor are designed to carry a heavier current than those of the relay.
24. Two armatures, connected by levers so arranged that the armatures move simultaneously in opposite directions.
25. (a) Two, (b) differential and operating, and (c) differential.
26. To reduce "chatter" during operation.
27. Increasing the spring tension and increasing the armature gap.
28. 3-30 amperes and not more than 250 volts.
29. 10 amperes.
30. Type TL.
31. 10 percent.
32. Two and one half times the rated capacity of the smallest cable in the circuit.
33. By a neon lamp and series resistor connected in parallel with each fuse.
34. Type MI, mechanical indicating.
35. To clear faults (with high speed) such as short circuits and overloads.
36. Heavy springs.
37. To prevent momentary current surges and short-time overloads from causing the breaker to open.
38. Switchboards and load center.
39. Silicone and glass fiber.
40. Vital, semivital, and nonvital circuits.
41. (a) M and (b) MM.

# Chapter 5

# I.C. AND A.C.O. SWITCHBOARDS

1. To energize all I.C. and F.C. circuits, including F.C. electronic systems in large ships and to supply power to other electronic equipment in small ships.
2. Behind the armor belt and below the waterline.
3. Normal, alternate, and emergency power supplies.
4. Live-front, semidead-front, dead-front and dead-front front-service switchboards.
5. Installation, operation, and maintenance can be accomplished from the front of the switchboard.
6. To isolate various I.C. systems and to transfer control of certain systems from one station to another.
7. In the I.C. room.
8. The most important circuits, the loss of which might endanger the ship.
9. By grouping two synchro indicators on each multipole rotary switch.
10. To energize local I. C. circuits.
11. The preferred, alternate, or emergency power supply.
12. A fault in the associated circuit.
13. Yearly, or during each shipyard overhaul.

# Chapter 6

# POWER DISTRIBUTION SWITCHBOARDS

1. One or more.
2. Centralized control of generator and major switching operations.
3. A mimic bus.
4. Because it is provided with instruments and governor control for the after generator.
5. Reverse power relay.
6. The ground on phase A and switch S shunt the primary of the transformer to remove voltage from the primary.
7. The automatic bus-transfer controller.
8. Both contactors may be open, but only one may be closed at a given time.
9. (a) Dropout, (b) open, (c) open, (d) closes, (e) completes, (f) energizes, and (g) closes.
10. (a) Closes, (b) completed, (c) opened, (d) closed, (e) closed, (f) opens, and (g) opens.
11. Selective tripping.
12. The breaker closest to the fault trips first, and the one closest to the generator, last.
13. Parallel (cross plant), or separately (split plant).
14. (a) Closed, (b) open.
15. Maximum assurance against loss of all ship's service power.
16. Close the bus tie after the damage has been isolated.
17. To prevent the emergency generator from starting due to the momentary loss of power.
18. They must not be paralleled.
19. To prevent working the energized cables.
20. Deenergize the circuit and reverse (or change) any two of the three leads.
21. Because protective devices do not prevent careless operation but afford protection against equipment failure.
22. (a) Normal, alternate, and emergency and (b) forward main power distribution switchboard, after main power distribution switchboard, and forward emergency switchboard, respectively.
23. (a) Delta-delta. (b) To provide reduced power with an open-delta connection when one transformer fails.
24. Vital ship control, and fire control circuits.
25. All switches or circuit breakers that might inadvertently energize the circuit.
26. A tag for each party is placed on the switches.
27. By a thorough inspection, and tightening where necessary.
28. Phosgene gas.
29. Rust on the sealing surface of the circuit breaker's magnet.

## Chapter 7

# MAINTENANCE OF MOTORS AND GENERATORS

1. To keep the equipment clean and free of oil, water, dirt, and other foreign particles.
2. To convert ship's supply a-c into d-c suitable for use in a dial telephone system.
3. Current at a constant voltage.
4. A magnetic bridge.
5. (a) It increases. (b) No, diverted.
6. "V".
7. Exchange battery.
8. (1) Wiping, (2) use of suction, (3) use of compressed air, and (4) use of a solvent.
9. Because it lessens the possibility of damage to insulation.
10. Do not allow drops of solder to get into the windings. Excess solder that may later break off should be removed from the soldered joints.
11. To prevent electrolytic action between the brushes and rings or segments.
12. They should be inspected at frequent intervals to make sure they are tight.
13. Abrasive materials.
14. A uniform, glazed dark brown color on the places where the brushes ride.
15. Emery cloth, emery paper, or emery stone.
16. Pitting due to electrolytic action on the surface of the rings.
17. When they are worn down to half their original length or if the corners or edges are chipped.
18. The no-load neutral.
19. Equidistant.
20. (a) They should be separated by a spreader. (b) To prevent the slings from coming into contact with the a-c rotor or d-c armature coils.
21. By placing one end of a screw driver or steel rod against the bearing housing and the other end against the ear. (b) A loud, irregular grinding, clicking, or scraping noise is heard.
22. (a) A bearing housing too full of lubricant. (b) The grease becomes sticky and seals the bearing against fresh lubricant.
23. To prevent the flow of shaft currents through the bearing.
24. An open armature coil.
25. Practically zero.
26. The real grounds remain in the same bars while the phantom grounds will shift.
27. (a) Maximum and (b) minimum.
28. (1) Disconnecting both ends of the coil and (2) installing a jumper across the risers from which the coil was disconnected.
29. (1) Cage and (2) wound.
30. An open circuit in the wound rotor.
31. An open in the shunt field winding.
32. The greatest difference in potential.
33. A small magnetic compass and battery.
34. To determine whether or not proper maintenance procedures are being carried out.
35. Daily.
36. Weekly.
37. Monthly.
38. Quarterly.
39. Semiannually.

## Chapter 8

# ALARM AND WARNING SYSTEMS

1. To prevent casualties to machinery and personnel.
2. Flight deck warning signal system.
3. At the screw marked, higher.
4. A sealed-in liquid that expands.
5. 100° to 225°F.
6. Adjusting the angular positions of the cams.
7. Mechanical switches.
8. Limits.
9. Causes its contacts to open or close.
10. The armature.
11. Indicating lights, annunciator drops, and audible signals.
12. Closes and opens the contacts at a prearranged rate.
13. Nonwatertight, watertight, and pressureproof.

14. Heat or temperature rise, smoke or combustible gases, and flame.
15. (1) Temperature rise and (2) combustible gas and smoke.
16. Completes the circuit between connections.
17. Inner and outer chambers and gas discharge (cold cathode) tube.
18. A change in the gas.
19. Causes a sharp drop in current flow.
20. 5 amperes; 3 amperes; 105 volts.
21. 110 volts.
22. Solenoid and spring.
23. Converts electrical power into mechanical power to ring the bell.
24. Lamp-type indicators and annunciators.
25. Provide protection against loss of illumination in case one lamp burns out.
26. To identify the alarm being sounded.
27. Current or amperes.
28. Current limiting device.
29. 0.0124 + amp or 12.4 + milliamps.
30. The rectifier and transformer.
31. To operate up to four fire alarm bells at other stations on the ship.
32. One.

## Chapter 9

## SOUND-POWERED TELEPHONES

1. (1) Cantilever, (2) balanced-armature, and (3) bipolar.
2. (1) Two permanent magnets, (2) two pole pieces, (3) an armature, (4) a driving rod, (5) a diaphragm, and (6) a coil.
3. Yes.
4. (1) To prevent picking up external noise when the phone is not in use, and (2) to reduce the number of units on any line to those actually in use.
5. The transmitter circuit.
6. Displacement of the armature from the exact center of the air gap.
7. The armature and diaphragm are not free to move.
8. Yes.
9. (a) The selector switch is used to connect one telephone to any one of a group of circuits. (b) The transfer switch is used to connect one group of circuits to one of several other groups of circuits.
10. Circuit E.
11. For calling officers' pantry attendants and orderlies and for calling the attendants desk from berths in the sick bay.
12. To identify the calling station by circuit or location.

## Chapter 10

## PRINCIPLES OF THE GYROCOMPASS

1. (1) Rigidity of plane; and (2) precession.
2. (1) Increasing the weight of the rotor; (2) increasing the speed of the rotor; and (3) concentrating the rotor weight near the circumference of the rotor.
3. The rotation of a gyroscope about an axis that is perpendicular to the axis about which a torque is exerted.
4. A force acting through the center of gravity of the gyroscope.
5. The rotation of the earth (the rigidity of plane).
6. The mercury ballistic.
7. Counterclockwise.
8. (a) 21-1/4 minutes; (b) 21-1/4 minutes.
9. (a) About 4 hours; (b) about 4 hours.
10. Yes.
11. 15°.
12. The oil ballistic.

# Chapter 11

# MAGNETIC AMPLIFIERS

1. Flux.
2. (1) High efficiency, (2) reliability, (3) ruggedness, (4) space and weight economy, and (5) no warm-up time.
3. (1) It cannot handle low-level signals, (2) it is not useful at high frequencies, (3) it has a time delay associated with magnetic effects, and (4) the output waveform is not an exact reproduction of the input waveform.
4. The induced voltage.
5. (a) Increase, (b) increase, (c) decrease, and (d) decrease.
6. (a) Large, (b) high, (c) low amplitude, and (d) low.
7. (a) Small, (b) small, (c) large, and (d) high.
8. High permeability alloys and grain-oriented alloys.
9. Rectangular shaped.
10. In series.
11. In series.
12. Electron flow.
13. (1) The magnitude of the applied voltage across the control winding and (2) the time interval during which this voltage is applied.
14. (a) From negative saturation $\Phi_1$ to positive saturation $\Phi_2$, (b) from the $\Phi_2$ level to the $\Phi_1$ level, (c) maximum.
15. (a) Zero, (b) zero, (c) full value.
16. (a) Because the rectifier opposes it, (b) from negative saturation $\Phi_1$ to some value $\Phi_3$ below saturation. (c) Because the core flux saturates and the impedance drops. (d) They are proportional.
17. Unity.
18. (a) No change in flux will occur and (b) no voltage will be induced.

# Chapter 12

# NEW INSTALLATION EQUIPMENTS

1. Closed circuit television.
2. Vidicon tube.
3. Mosaic.
4. 525.
5. Excessive target voltage.
6. As a d-c restorer.
7. It clips the negative blanking peaks and the negative sync peaks.
8. 54 to 88 mcs.
9. 31.5 kc.
10. The horizontal output transformer, T302.
11. To provide a blanking signal of the correct amplitude and duration.
12. 10,500 cps.
13. 3.
14. By operating the lens at a constant temperature.
15. It blocks out objects behind the assembly that might confuse the pilot.
16. By buttons on the hand-held switch.
17. At the power panel.
18. Because full-line voltage would destroy the lamps.
19. To measure, indicate, and transmit speed and distance data.
20. Rodmeter, indicator-transmitter, and sea valve.

# APPENDIX II

# QUALIFICATIONS FOR ADVANCEMENT IN RATING

## INTERIOR COMMUNICATIONS ELECTRICIAN (IC)

**Quals Current Through Change 14**

### General Rating

#### Scope

Interior Communications Electricians: Maintain and repair interior communications (IC) systems, gyrocompass systems, amplified and unamplified voice systems, alarm and warning systems, and related equipment; stand IC and gyrocompass watches.

#### Service Ratings

None.

#### Path of Advancement to Limited Duty Officer

Interior Communications Electricians advance to Limited Duty Officers, Electrician.

#### Navy Enlisted Classification Codes

See Manual of Navy Enlisted Classifications, NavPers 15105-B.

#### Qualifications for Advancement in Rating

1. Qualifications for advancement to a higher rate include the qualifications of the lower rate or rates in addition to those stated for the higher rate.
2. Practical factors will be completed before recommendation for participation in the advancement examination. (Bureau of Naval Personnel Manual, NavPers 15791-A, Articles B-2326 and C-7201.)
3. Knowledge factors and knowledge aspects of practical factors will form the basis for questions in the written advancement examination.

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **A. THEORY OF ELECTRICITY, ELECTRONICS** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Interpret RETMA color coding of: capacitors, resistors, internal connections of power and audio transformers, and chassis wiring | 3 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Meaning and/or significance of terms such as: | |
| a. Volt | 3 |
| b. Ohm | 3 |
| c. Ampere | 3 |
| d. Watt | 3 |
| e. Volt-ampere | 3 |
| f. Henry | 3 |
| g. Farad | 3 |
| h. Cycle | 3 |
| i. Ampere-turn | 3 |
| j. Conductor and insulator | 3 |
| k. Flux density | 3 |
| l. Permeability | 3 |
| m. Electromagnetic induction | 3 |
| n. Power factor | 3 |
| o. Frequency | 3 |
| p. Phase | 3 |
| q. Amplifier | 3 |
| r. Hysteresis and eddy current | 3 |
| s. Reactance | 3 |
| t. Impedance | 3 |
| u. Capacitance | 3 |
| v. Inductance | 3 |
| w. Magnetic lines of force | 3 |
| x. Coulomb | 3 |
| y. Circular mil | 3 |
| z. Horsepower | 3 |
| aa. Torque | 3 |
| bb. Ambient temperature | 3 |
| cc. Gain | 2 |
| dd. Feedback | 2 |
| ee. Bias | 2 |
| ff. Cutoff | 2 |
| gg. Plate current | 2 |
| hh. Grid current | 2 |
| ii. Electron-tube characteristics | 2 |
| jj. Phase distortion | 2 |
| kk. Amplitude | 2 |
| ll. Transistor characteristics | 2 |
| 2. Relationship of current, voltage, and resistance in d.c. circuits | 3 |
| 3. Relationship of current, voltage, and impedance in a.c. circuits | 3 |
| 4. Relationship of reluctance, flux, and magnetomotive force (m.m.f.) in a.c. and d.c. magnetic circuits | 3 |
| 5. Relationship of resistance, temperature, and current in an electrical conductor | 3 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **A. THEORY OF ELECTRICITY, ELECTRONICS–Continued** | |
| 2.0 KNOWLEDGE FACTORS–Continued | |
| 6. Relationship of length and cross-sectional area to resistance of a conductor | 3 |
| 7. Function and operating principles of: | |
| a. Electron (diode and triode) tubes used in IC equipment. | 3 |
| b. Electron, gas-filled, and cathode-ray tubes | 2 |
| c. Transistors and diodes. | 2 |
| 8. Construction of electron tubes, gas-filled tubes, transistors, and diodes, and cathode-ray tubes used in IC equipment. | 2 |
| 9. Methods of coupling amplifier stages: transformer impedance, capacitive, resistive, and direct | 2 |
| 10. Characteristics and use of synchros; methods of setting to electrical zero; purpose of gain, phase, and balance adjustments | 2 |
| **B. EQUIPMENT DEVICES AND SYSTEMS** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Energize and start, test for proper operation, operate and secure, ship's metering and indicating systems, ship's control systems, alarm and warning systems, signal systems, gyrocompass and associated equipment, and amplified voice and projection equipment | 3 |
| 2. Cross-connect IC systems to operate under battle, emergency, and casualty conditions | 2 |
| 3. Effect authorized field changes to IC equipment in accordance with instructions and diagrams | 1 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Construction and operating principles of power units such as motor-generator sets, control panels, transformers, and rectifiers of IC equipment | 3 |
| 2. Construction and principles of operation of IC systems: | |
| a. Underwater log | 3 |
| b. Wind indicators | 3 |
| c. Central-amplifier announcing systems | 2 |
| d. Gyrocompasses | 2 |
| e. Optical landing system | 2 |
| f. Magnesyn compass system | 2 |
| g. Automatic telephones | 1 |
| h. Closed-circuit television | 1 |
| i. Communication console | 1 |
| **C. MAINTENANCE** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Make tests for, locate, and clear short and open circuits and grounds in cables, wiring, fittings, buzzers, call bells, and other simple circuits | 3 |
| 2. Inspect, clean, and lubricate IC equipment in accordance with technical maintenance publications | 3 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **C. MAINTENANCE—Continued** | |
| **1.0 PRACTICAL FACTORS—Continued** | |
| 3. Make complete casualty analysis and repair of sound-powered telephone hand and head sets | 3 |
| 4. Use and perform preventive maintenance on the following test equipment: | |
| a. Nonelectronic volt-ohm-ammeter | 3 |
| b. Electronic volt-ohm-ammeter | 3 |
| c. Tube tester | 3 |
| d. Megger | 3 |
| e. Tachometer | 3 |
| f. Circuit analyzer | 2 |
| g. Oscilloscope | 2 |
| h. Signal generator | 2 |
| 5. Test, repair, and/or replace parts such as relays, plugs, lamps, fuses, switches, tubes, jacks, cables, wiring, fixed capacitors, variacs, transformers, fixed resistors, and potentiometers within a component, assembly, or subassembly | 2 |
| 6. Localize casualties and perform corrective maintenance on the following: | |
| a. Alarm and warning systems including toxic vapor and contaminated air systems | 3 |
| b. Voice recorders and record players | 2 |
| c. Sound motion picture projectors (16 mm.) | 2 |
| d. Intercoms and portable announcing systems | 2 |
| e. Ship-control order and indicating system | 2 |
| f. Ship order and indicating units (synchro) | 2 |
| g. Motor-generator sets and control panels as applied to IC equipment | 2 |
| h. Central amplifier system | 2 |
| i. Underwater logs | 2 |
| j. Wind indicators | 2 |
| k. Magnetic amplifiers | 2 |
| l. Sound-powered telephone circuits | 2 |
| m. Optical landing system | 2 |
| n. Magnesyn compass | 2 |
| o. Constant frequency control | 2 |
| p. Automatic telephones | 2 |
| q. Gyrocompass and associated navigation equipment such as dead-reckoning analyzer (DRA), dead-reckoning tracer (DRT), gyrorepeaters, and synchro-amplifiers | 1 |
| r. Self-synchronous alidades | 1 |
| s. Closed-circuit television | 1 |
| t. Communication console | 1 |
| u. Synchro-amplifier | 1 |
| 7. Make tests, adjustments, and repairs necessary for proper operation of synchro-control circuits including servoloops | 1 |
| 8. Test, remove, and install meters and instrument transformers | 1 |
| 9. Make periodic inspections and internal adjustments of IC units | 1 |
| 10. Localize casualties to parts or subassemblies of IC equipment; repair by replacement of subassemblies or parts | 1 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **C. MAINTENANCE–Continued** | |
| 1.0 PRACTICAL FACTORS–Continued | |
| 11. Test and evaluate new or overhauled components, assemblies, or subassemblies of IC equipment for proper and secure installation and optimum performance . . . . . . | C |
| 12. Analyze and evaluate electrical and electronic tests; make adjustments, calibrations, and repairs for optimum performance of IC equipment . . . . . . . . . . . . . . . . . . . . . . | C |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Procedures for replacing electron tubes, transistors, and diodes . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| 2. Casualty analysis and corrective maintenance for the following IC equipment: | |
| a. Cables, wiring, and fittings . . . . . . . . . . . . . . . . . . . . | 3 |
| b. Sound-powered telephone handsets and headsets . . . . . . | 3 |
| 3. Lubricants, cleaning materials, and solutions used, and safety precautions to be observed in their use, in the maintenance of IC equipment . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| 4. Methods and equipment used in electrical tests for continuity, grounds, and short circuits . . . . . . . . . . . . . . . . . . . . . | 3 |
| 5. Preventive maintenance for, function of, and operating procedures using the following: | |
| a. Nonelectronic volt-ohm-ammeter. . . . . . . . . . . . . . . . . | 3 |
| b. Electronic volt-ohm-ammeter . . . . . . . . . . . . . . . . . . | 3 |
| c. Tube tester . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| d. Megger . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| e. Tachometer . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| f. Circuit analyzer . . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| g. Oscilloscope. . . . . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| h. Signal generator . . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| 6. Theory of operations of magnetic amplifiers . . . . . . . . . . | 2 |
| **D. MOTORS, GENERATORS, AND RELATED EQUIPMENT** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Inspect and clean commutators and slipring assemblies and observe safety precautions . . . . . . . . . . . . . . . . . . . . . . | 3 |
| 2. Replace and adjust brushes on commutators and slipring assemblies. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Construction of motors, generators, and alternators; application of laws of magnetism to electric rotating machinery | 2 |
| 2. Methods and procedures for adjusting voltage regulators . . | 1 |
| **E. CABLES AND CONNECTIONS** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Renew section of cable between: | |
| a. Junction boxes . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| b. Junction boxes and equipment . . . . . . . . . . . . . . . . . | 3 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **E. CABLES AND CONNECTIONS—Continued** | |
| 1.0 PRACTICAL FACTORS—Continued | |
| 2. Connect casualty powerlines | 3 |
| 3. Make electric connections and splices including soldered joints and pressure-type terminals (solderless type) | 3 |
| 4. Identify by marking systems electric cables, wiring, and fittings | 3 |
| 5. Install necessary leads for connecting a synchrogenerator to independent synchromotors through a rotary switch | 2 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Construction, types, and uses of shipboard electric cable | 3 |
| 2. Normal, alternate, and emergency-power distribution sources for shipboard lighting and IC power | 3 |
| **F. SWITCHBOARDS** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Operate IC switchboards: | |
| a. Transfer circuits for normal, battle, emergency, and casualty conditions | 3 |
| b. Set up control circuits for anchor and underway conditions | 3 |
| 2. Tighten connections on switchboards and control panels | 3 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Procedures for energizing, testing, proper operation of, transferring control of, and securing IC circuits and equipment on IC switchboards for normal, battle, emergency, and casualty conditions | 3 |
| 2. Methods and procedures for overhaul of IC switchboards | 1 |
| **G. CIRCUITS AND DIAGRAMS** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Read schematic and wiring diagrams, IC technical-maintenance publications, and installation blueprints; identify and interpret electric, electronic, and mechanical symbols shown in schematic and wiring diagrams, IC technical-maintenance publications, and installation blueprints | 3 |
| 2. Test IC circuits that are external to major units of IC equipment for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, and power, and compare with established values | 3 |
| 3. Test internal circuits of major units of IC equipment for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, and power, and compare with established values; use an oscilloscope to view circuit waveforms and compare with established optimum-performance waveforms required in IC equipment | 2 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **G. CIRCUITS AND DIAGRAMS–Continued** | |
| **1.0 PRACTICAL FACTORS–Continued** | |
| 4. Prepare diagrams and sketches of IC devices and equipment, using standard designations for cables, wiring, terminal markings, and circuit components . . . . . . . . . . . . . . | C |
| **2.0 KNOWLEDGE FACTORS** | |
| 1. Types of information shown and meaning of electric, electronic, and mechanical symbols used in equipment schematic diagrams and wiring diagrams, block diagrams, IC technical maintenance publications, and installation blueprints . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| 2. Calculate current, voltage, and resistance in d.c. series and parallel circuits of not more than four elements . . . . . . | 3 |
| 3. Function of component parts in IC electric and electronic circuits such as: | |
| a. Resistors. . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| b. Rheostats. . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| c. Potentiometers . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| d. Solenoids . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| e. Inductors . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| f. Capacitors . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| g. Fuses . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| h. Switches . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| i. Transformers. . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| j. Relays. . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| k. Saturable reactors. . . . . . . . . . . . . . . . . . . . . | 2 |
| l. Transistors . . . . . . . . . . . . . . . . . . . . . . . . . . | 1 |
| 4. Methods of obtaining three general types of bias: fixed, cathode, and grid leak . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| 5. Principles of IC polyphase circuits. . . . . . . . . . . . . . . . | 2 |
| 6. Function and operating principles of the following circuits: | |
| a. Audioamplifier . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| b. Rectifier . . . . . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| c. Transistor . . . . . . . . . . . . . . . . . . . . . . . . . . | 1 |
| 7. Daily, weekly, monthly, quarterly, semiannual, and annual tests required on IC circuits and equipment. . . . . . . . . . . | 1 |
| **H. MATERIALS AND EQUIPMENT** | |
| **1.0 PRACTICAL FACTORS** | |
| 1. Select, use, and maintain electrician's common hand and small bench tools including soldering irons and electric-powered tools such as drills and grinders provided for maintenance and repair of IC equipment . . . . . . . . . . . . . | 3 |
| 2. Inspect, maintain, test, and install storage and dry-cell batteries . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| **2.0 KNOWLEDGE FACTORS** | |
| 1. Care and storage of IC materials. . . . . . . . . . . . . . . . . | 3 |
| 2. Types and purposes of handtools and small portable power tools provided for maintenance and repair of IC equipment. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **H. MATERIALS AND EQUIPMENT—Continued** | |
| 2.0 KNOWLEDGE FACTORS—Continued | |
| 3. Types and identification of insulating materials and varnishes . . . . . . . . . . . . | 3 |
| 4. Soldering equipment and methods used in maintenance and repair of IC equipment . . . . . . . . . . . . | 3 |
| 5. Types, structure, and electrical characteristics of batteries . . . . . . . . . . . . | 3 |
| **I. SUPPLY PROCEDURES** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Obtain parts and stock numbers from technical and supply publications and prepare requisitions for tools and replacement parts . . . . . . . . . . . . | 3 |
| 2. Take, record, and report inventories of tools and portable test equipment available for maintenance and repair of IC equipment . . . . . . . . . . . . | 2 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Accounting procedures for IC equipment, maintaining control of inventories and workflow, and reporting equipment status and work accomplished . . . . . . . . . . . . | C |
| **J. REPORTS, PUBLICATIONS, AND RECORDS** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Maintain all required records at watch station . . . . . . . . . | 3 |
| 2. Use electrical publications for selecting materials and identifying equipment parts . . . . . . . . . . . . | 3 |
| 3. Locate and identify by reference to technical maintenance publications, block diagrams and installation blueprints, components, assemblies, subassemblies, and primary and casualty power circuits of IC equipment . . . . . . . . . . . . | 3 |
| 4. Prepare job orders and work requests for both tender and shipboard repairs to IC or gyrocompass equipment . . . . . | 1 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Types of entries and information recorded in IC equipment failure reports, work logs, equipment histories, checkoff lists, and current ship's maintenance project (CSMP) . . . . | 3 |
| 2. Types of information reported in periodic or recurring reports concerning performance and maintenance of IC equipment . . . . . . . . . . . . | 1 |
| **K. ADMINISTRATION, SUPERVISION, AND TRAINING** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Supervise setting up of public-address systems . . . . . . . . | 2 |
| 2. Take charge of gyrocompass and IC watches . . . . . . . . . . | 2 |

| Qualifications for Advancement in Rating | Applicable Rates IC |
|---|---|
| **K. ADMINISTRATION, SUPERVISION, AND TRAINING–Continued** | |
| 1.0 PRACTICAL FACTORS–Continued | |
| 3. Supervise the underway watch in the IC room of a large combat vessel. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 1 |
| 4. Plan, organize, and direct work of personnel operating, maintaining, and repairing IC and gyrocompass systems . . | C |
| 5. Estimate time, materials, and labor required for repair of IC systems and equipment. . . . . . . . . . . . . . . . . . . . . | C |
| 6. Supervise and train personnel in operation, maintenance, and repair of IC and gyrocompass equipment . . . . . . . . . . | C |
| 2.0 KNOWLEDGE FACTORS | |
| 1. System of assigning of "AN" letter-number combinations as designation for IC equipment. . . . . . . . . . . . . . . . . . . | 3 |
| **L. SAFETY PRECAUTIONS, FIRST AID, AND FIREFIGHTING** | |
| 1.0 PRACTICAL FACTORS | |
| 1. Rescue a person in contact with an energized circuit; resuscitate a person unconscious from electric shock; treat for electric shock and burns. (Simulated conditions.) . . . . . . . | 3 |
| 2. Demonstrate and observe while servicing equipment, safety precautions such as tagging switches, removing fuses, grounding test equipment, using shorting bar and rubber mats . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| 3. Extinguish electric fires, using $CO_2$ extinguishers. (Simulated conditions.). . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| 2.0 KNOWLEDGE FACTORS | |
| 1. Electrical and electronic safety precautions including those set forth in Chapter 18, U.S. Navy Safety Precautions (OPNAV 34P1), to be observed in servicing IC equipment. . | 3 |
| 2. Effects of electric shock, methods of resuscitation of a person unconscious from electric shock, and treatment for electric and acid burns. . . . . . . . . . . . . . . . . . . . . . . . . | 3 |

# APPENDIX III

# I.C. CIRCUITS

| Circuit Designation | System Title | Importance | Readiness Class | For Details, See Section |
|---|---|---|---|---|
| A | Officer call bell | NV | 4 | S65-5 |
| CA | Collision alarm system | SV (Surface Ships) | 1 | S65-4 |
| | | V (Submarines) | 1 | S65-4 |
| CF | Constant frequency supply system | SV | 1 | S65-5 |
| DC | Depth control system | V | 2 | S65-5 |
| DG | Remote draft indicator system | NV | 2 | S65-5 |
| DW | Wrong direction alarm system | V | 2 | S65-4 |
| E | Voice tube and sound-powered telephone call bell system | SV | 1 | S65-5 |
| EA | Fireroom emergency signal system | NV | 1 | S65-4 |
| EB | Boiler feed signal system | NV | 1 | S65-5 |
| 1EC | Lubricating oil low pressure alarm system-propulsion engines and motors | SV | 2 | S65-4 |
| 2EC | Lubricating oil low pressure alarm system; auxiliary machinery | SV | 1 | S65-4 |
| ED | Generator air high temperature alarm system | SV | 1 | S65-4 |
| EF | Generator bearing high temperature alarm system | NV | 1 | S65-4 |
| EG | Engine governor control system | SV | 2 | S65-5 |
| EH | Cruising turbine exhaust alarm system | SV | 2 | S65-4 |
| EJ | Feed pressure alarm system | NV | 2 | S65-4 |
| EK | Air pressure alarm system | NV | 2 | S65-4 |
| EQ | Desuperheater high temperature alarm system | SV | 1 | S65-4 |

| Circuit Designation | System Title | Importance | Readiness Class | For Details, See Section |
|---|---|---|---|---|
| ET | Boiler temperature alarm system | NV | 1 | S65-4 |
| EV | Explosive vapor detector system | SV | 1 | S65-4 |
| EW | Circulating water high temperature alarm system | NV | 1 | S65-4 |
| F | High temperature alarm system | SV | 1 | S65-4 |
| FC | Flight crash signal system | NV | 2 | S65-4 |
| FD | Flooding alarm system | NV | 1 | S65-4 |
| FH | Sprinkling alarm system | SV | 1 | S65-4 |
| FL | Flight deck landing observer's signal system | NV | 2 | S65-4 |
| FR | Carbon dioxide release alarm system | NV | 1 | S65-4 |
| FW | Flight deck warning system | NV | 2 | S65-4 |
| FZ | Security alarm system | NV | 1 | S65-4 |
| G | General and chemical attack alarm system | SV | 1 | S65-4 |
| GD | Diving alarm system | SV | 2 | S65-4 |
| HA | Hydraulic accumulator contents indicator system | V | 2 | S65-5 |
| HB | Anchor order system | NV | 2 | S65-5 |
| HC | Anemometer indicator system | NV | 1 | S65-5 |
| HD-HE | Wind direction and speed indicator system | NV | 1 | S65-5 |
| HG | Air flow indicator system | NV | 1 | S65-5 |
| HT | Heeling order system | NV | 2 | S65-5 |
| HY | Hydrogen detector system | SV | 1 | S65-4 |
| J | Dial telephone system | NV | 1 | S65-1 |
| JA-JZ | Primary sound-powered telephone systems | V | - | S65-1 |
| K | Propeller revolution indicator system | NV | 2 | S65-5 |
| KM | Engine revolution indicator system | NV | 2 | S65-5 |
| L | Rudder order system | V | 2 | S65-5 |
| 1LA | Course-steering order system | SV | 2 | S65-5 |
| LB | Steering emergency signal system | V | 2 | S65-4 |
| LC | Gyro compass system | V | 2 | S65-5 |

| Circuit Designation | System Title | Importance | Readiness Class | For Details, See Section |
|---|---|---|---|---|
| LM | Magnetic compass system (remote indicating) | SV | 2 | S65-5 |
| LR | Periscope sextant data recorder system | SV | 2 | S65-5 |
| LS | Submersible steering gear alarm system | SV | 2 | S65-4 |
| M | Propeller order system | NV | 2 | S65-5 |
| MB | Engine order system or motor order system | V | 2 | S65-5 |
| 3MB | Engine control order system | V | 2 | S65-5 |
| 4MB | Propulsion control order system | V | 2 | S65-5 |
| 1MC | General announcing system | SV (Surface ships) | 1 | S65-2 |
| | | V (Submarines) | 1 | S65-2 |
| 2MC | Engineers' announcing system | SV | 1 | S65-2 |
| 3MC | Aviators' announcing system | SV | 1 | S65-2 |
| 4MC | Damage control announcing system | SV | 2 | S65-2 |
| RW | Rocket and torpedo warning system | SV | 3 | S65-4 |
| SB | Salinity indicator system | SV | 1 | S65-5 |
| SE | Ship entertainment system | NV | 4 | S65-2 |
| SN | Snorkel safety system | V | 2 | S65-4 |
| SP | Shaft position alarm system | NV | 2 | S65-4 |
| SR | Electric character transmission and indicator system | NV | 1 | S65-5 |
| TB | Forced draft blower tachometer system | NV | 1 | S65-5 |
| 1TD | Water level alarm system | NV | 1 | S65-4 |
| TL | Dead reckoning system | SV | 2 | S65-5 |
| 1TM | Bearing temperature monitor system | SV | 2 | S65-5 |
| 2TM | Reactor plant remote temperature monitor system | V | 2 | S65-5 |
| 3TM | Navol temperature monitoring system | V | 1 | S65-5 |

| Circuit Designation | System Title | Importance | Readiness Class | For Details, See Section |
|---|---|---|---|---|
| TP | Main ballast tank indicator system | NV | 1 | S65-5 |
| TR | Hull opening indicator system | V (Submarines) | 1 | S65-5 |
| | | NV (Landing craft) | 1 | S65-5 |
| TS | Turret sprinkling control system | NV | 1 | S65-5 |
| TW | Train warning signal system | NV | 1 | S65-4 |
| VP | Controllable pitch propeller control system | V | 2 | S65-5 |
| VR | Sound recorder reproducer system | SV | 2 | S65-2 |
| VS | Value position indicator system | NV | 1 | S65-5 |
| W | Whistle operating system | NV | 2 | S65-4 |
| XJ | Supplementary sound-powered telephone systems | SV | - | S65-1 |
| XJA-XJZ | Auxiliary sound-powered telephone systems | SV | - | S65-1 |
| XLC | Auxiliary gyrocompass system | V | 2 | S65-5 |
| XN | Auxiliary rudder angle indicator system | NV | 2 | S65-5 |
| XNB | Auxiliary bow plane angle indicator system | NV | 2 | S65-5 |
| XNS | Auxiliary stern plane angle indicator system | NV | 2 | S65-5 |
| Y | Underwater log system | V | 2 | S65-5 |
| 4Y | Dummy log system | NV | 3 | S65-5 |

# INDEX