This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

Digitized by Google

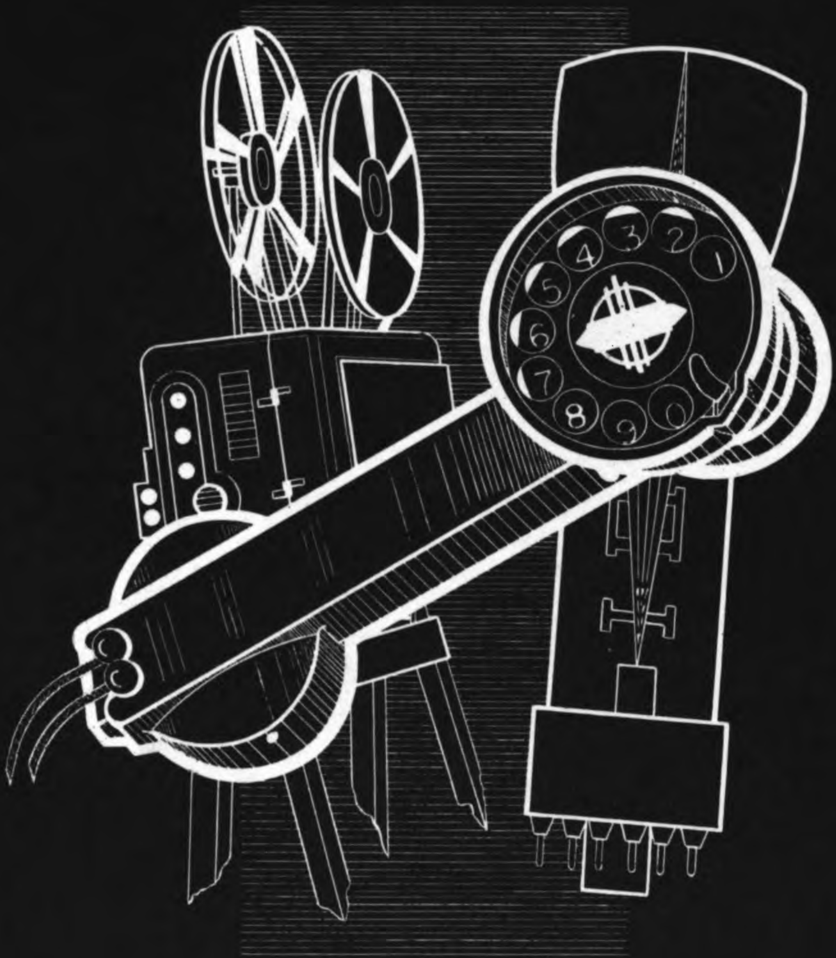
Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google



U.S.S.D.

IC ELECTRICIAN 3 & 2

DOCUMENTS DEPARTMENT
LIBRARY
UNIVERSITY OF CALIFORNIA

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10558

Digitized by Google

Digitized by Google

PREFACE

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

The qualifications for advancement are listed in the Manual of Qualifications for Advancement in Rating, NavPers 18068-B. Because examinations for advancement in rating are based on these qualifications, you should refer to them for guidance.

This training course was prepared by the Training Publications Division, Naval Personnel Program Support Activity, Washington, D. C., for the Bureau of Naval Personnel. Technical assistance was provided by the IC Electrician School, Naval Training Center, Great Lakes, Illinois; the Bureau of Ships; and other activities cognizant of IC equipments and the duties of IC Electricians.

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1966

Digitized by Google

CREDITS

The illustrations indicated below are included in this edition of IC Electrician 3 & 2 through the courtesy of the designated companies. Permission to use these illustrations is gratefully acknowledged.

SOURCE	FIGURES
Lanier Electronic Laboratory, Inc.	8-32
U. S. Instrument Corporation	6-6, 6-7, and 6-9

L.S.
DOC.
COLL
DOC.
COLL

Digitized by Google

VM 473
A 322

CONTENTS

531

Digitized by Google

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.

Digitized by Google

READING LIST

NAVY TRAINING COURSES

Basic Electricity, NavPers 10086-A

Basic Handtools, NavPers 10085-A

Blueprint Reading and Sketching (chapters 5 & 6), NavPers 10077-B

Introduction to Electronics (chapters 1 thru 6), NavPers 10084

Standard First Aid, NavPers 10081-B

Mathematics Vol 1, NavPers 10069-B

Mathematics Vol 2, NavPers 10071-A

OTHER PUBLICATIONS

Projectionist's Manual, NavPers 91983-A

Bureau of Ships Technical Manual, chapters 9003; 9004; 9650; 9850; 9450 (sections 1, 2, and 3); and 9880 (section 3 part 2)

USAFI TEXTS

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

D290	Physics I
C781	Fundamentals of Electricity
C858	The Slide Rule
D435	Plane Trigonometry

---

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

Digitized by Google

CHAPTER 1

ADVANCEMENT

This training course is designed to aid you in preparing for advancement to IC3 and IC2. There are many requirements for advancement, and they are discussed in this chapter. The professional (technical) requirements for advancement to IC3 and IC2 used as a guide in the preparation of this training course are listed in Group VII of the Manual of Qualifications for Advancement in Rating, NavPers 18068-B.

Chapters 2 through 16 of this training course discuss various shipboard equipments and systems that are maintained by IC Electricians. The principles of operation are presented along with operating procedures, safety precautions, and maintenance information. Chapter 17 presents additional maintenance information concerning IC equipments, and includes special repair techniques for transistorized and printed circuits.

The remainder of this first chapter contains information that will help you in preparing for advancement. Study this chapter carefully before beginning intensive study of the remainder of this training course.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure, are general ratings and service ratings.

General ratings identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Service ratings identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

THE IC RATING

The IC rating, a general rating only, was established in 1948. Interior Communications Electricians maintain and repair IC systems, gyrocompass systems, navigation systems, amplified and unamplified voice systems, alarm and warning systems, and related equipment. Interior Communications rates are included in the personnel allowance for practically all types of Navy ships including submarines.

Classification codes for the IC rating are listed in Group VII of the Manual of Navy Enlisted Classifications, NavPers 15105 (revised). Included are IC classification codes for jobs that require special training such as automatic telephone repairman, closed circuit TV technician, gyrocompass repairman, optical landing system technician, and submarine steering and diving control technician.

The IC Electrician must have a good working knowledge of the basic principles of electricity and electronics. The courses listed in the front of this training course will be helpful to you in acquiring this knowledge.

Also upon advancement to IC3, you will be graded on your leadership and supervisory ability as well as your ability to perform your technical duties. Leadership principles and their application are discussed in Military Requirements for Petty Officer 3 & 2, NavPers 10056 (revised).

ADVANCEMENT IN RATING

Some of the rewards of advancement in rating are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

Digitized by Google

But the advantages of advancing in rating are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement in rating? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required military and professional training courses.
3. Demonstrate your ability to perform all the practical requirements for advancement by completing the Record of Practical Factors, NavPers 760.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Demonstrate your knowledge by passing a written examination on (a) military requirements and (b) professional qualifications.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the requirements for advancement can change. Check with your division officer or training officer to be sure that you know the most recent requirements.

Advancement in rating is not automatic. After you have met all the requirements, you are eligible for advancement. You will actually be advanced in rating only if you meet all the requirements (including making a high enough score on the written examination) and if the quotas for your rating permit your advancement.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement in rating? You must study the qualifications for advancement, work on the practical factors, study the required Navy Training Courses, and study other material that is required for advancement in your rating. To prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NavPers 760, (3) a NavPers publication called Training Publications for Advancement in Rating, NavPers 10052, and (4) applicable Navy Training Courses. Figure 1-3 illustrates these materials; the following sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

The Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068B (with changes), gives the minimum requirements for advancement to each rate within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications.

Military requirements apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into practical factors and knowledge factors. Practical factors are things you must be able to do. Knowledge factors are things you must know in order to perform the duties of your rating.

The written examination you will take for advancement in rating will contain questions relating to the practical factors and the knowledge factors of both the military requirements and the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The professional qualifications for

Digitized by Google

CHAPTER 1

ADVANCEMENT

This training course is designed to aid you in preparing for advancement to IC3 and IC2. There are many requirements for advancement, and they are discussed in this chapter. The professional (technical) requirements for advancement to IC3 and IC2 used as a guide in the preparation of this training course are listed in Group VII of the Manual of Qualifications for Advancement in Rating, NavPers 18068-B.

Chapters 2 through 16 of this training course discuss various shipboard equipments and systems that are maintained by IC Electricians. The principles of operation are presented along with operating procedures, safety precautions, and maintenance information. Chapter 17 presents additional maintenance information concerning IC equipments, and includes special repair techniques for transistorized and printed circuits.

The remainder of this first chapter contains information that will help you in preparing for advancement. Study this chapter carefully before beginning intensive study of the remainder of this training course.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure, are general ratings and service ratings.

General ratings identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Service ratings identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

THE IC RATING

The IC rating, a general rating only, was established in 1948. Interior Communications Electricians maintain and repair IC systems, gyrocompass systems, navigation systems, amplified and unamplified voice systems, alarm and warning systems, and related equipment. Interior Communications rates are included in the personnel allowance for practically all types of Navy ships including submarines.

Classification codes for the IC rating are listed in Group VII of the Manual of Navy Enlisted Classifications, NavPers 15105 (revised). Included are IC classification codes for jobs that require special training such as automatic telephone repairman, closed circuit TV technician, gyrocompass repairman, optical landing system technician, and submarine steering and diving control technician.

The IC Electrician must have a good working knowledge of the basic principles of electricity and electronics. The courses listed in the front of this training course will be helpful to you in acquiring this knowledge.

Also upon advancement to IC3, you will be graded on your leadership and supervisory ability as well as your ability to perform your technical duties. Leadership principles and their application are discussed in Military Requirements for Petty Officer 3 & 2, NavPers 10056 (revised).

ADVANCEMENT IN RATING

Some of the rewards of advancement in rating are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

Digitized by Google

But the advantages of advancing in rating are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement in rating? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required military and professional training courses.
3. Demonstrate your ability to perform all the practical requirements for advancement by completing the Record of Practical Factors, NavPers 760.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Demonstrate your knowledge by passing a written examination on (a) military requirements and (b) professional qualifications.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the requirements for advancement can change. Check with your division officer or training officer to be sure that you know the most recent requirements.

Advancement in rating is not automatic. After you have met all the requirements, you are eligible for advancement. You will actually be advanced in rating only if you meet all the requirements (including making a high enough score on the written examination) and if the quotas for your rating permit your advancement.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement in rating? You must study the qualifications for advancement, work on the practical factors, study the required Navy Training Courses, and study other material that is required for advancement in your rating. To prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NavPers 760, (3) a NavPers publication called Training Publications for Advancement in Rating, NavPers 10052, and (4) applicable Navy Training Courses. Figure 1-3 illustrates these materials; the following sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

The Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068B (with changes), gives the minimum requirements for advancement to each rate within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications.

Military requirements apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into practical factors and knowledge factors. Practical factors are things you must be able to do. Knowledge factors are things you must know in order to perform the duties of your rating.

The written examination you will take for advancement in rating will contain questions relating to the practical factors and the knowledge factors of both the military requirements and the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The professional qualifications for

Digitized by Google

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. AME 3, HM 3			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.		Navy-wide examinations required for all PO advancements.				Navy-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 attached to the air program are advanced to fill vacancies and must be approved by CNARESTRA.							

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

Figure 1-1.—Active duty advancement requirements.

Digitized by Google

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.

Figure 1-2.—Inactive duty advancement requirements.

Digitized by Google

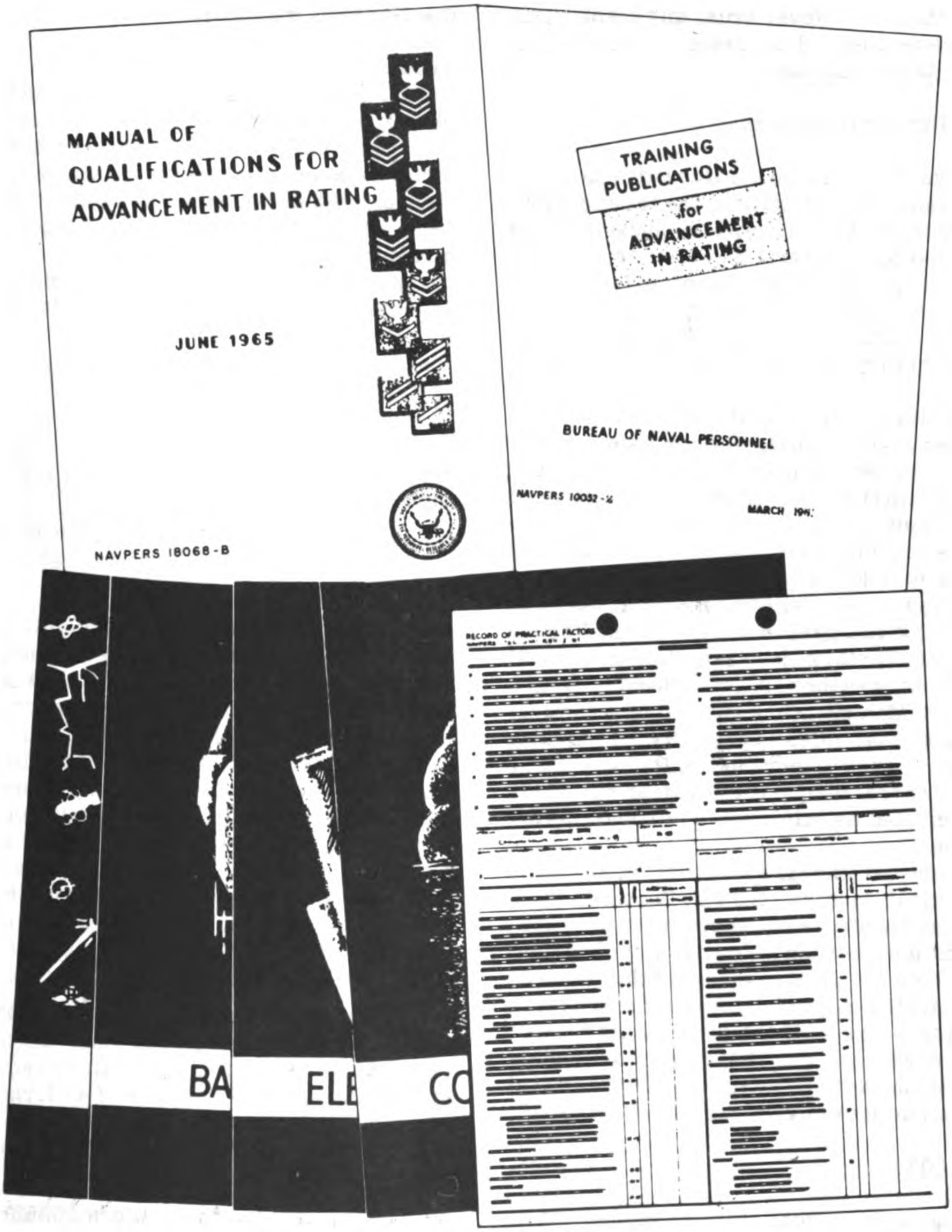


Figure 1-3.—Materials used in preparing for advancement.

Digitized by Google

your rating which are covered in this training course were current at the time the course was printed. By the time you are studying this course, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an up-to-date copy in the Quals Manual.

Record of Practical Factors

Before you can take the servicewide examination for advancement in rating, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the record of practical factors, NavPers 760, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the date and initials columns.

Changes are made periodically to the Manual of Qualifications for Advancement in Rating, and revised forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, the NavPers 760 form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NavPers 10052

Training Publications for Advancement in Rating, NavPers 10052 (revised), is a very important publication for anyone preparing for advancement in rating. This bibliography lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be sure that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NavPers 10052, a supplementary list of study material may be issued in the form of a BuPers Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a BuPers Notice has been issued to supplement NavPers 10052 for your rating.

The required and recommended references are listed by rate level in NavPers 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NavPers 10052, you will notice that some Navy Training Courses are marked with an asterisk (*). Any course marked in this way is mandatory—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement in rating. Each mandatory course may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training course; (2) passing locally prepared tests based on the information given in the training course; or (3) in some cases, successfully completing an appropriate Class A school.

Do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of ALL ratings must complete the mandatory military requirements training course for the appropriate rate level before they can be eligible to advance in rating.

The references in NavPers 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Digitized by Google

Navy Training Courses

There are two general types of Navy Training Courses. Rating courses (such as this one) are prepared for most enlisted ratings. A rating training course gives information that is directly related to the professional qualifications of one rating. Subject matter courses or basic courses give information that applies to more than one rating.

Navy Training Courses are revised from time to time to keep them up to date technically. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether any particular copy of a Navy Training Course is the latest edition by checking the NavPers number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061. (NavPers 10061 is actually a catalog that lists all current training courses and correspondence courses; you will find this catalog useful in planning your study program.)

Navy Training Courses are designed to help you prepare for advancement in rating. The following suggestions may help you to make the best use of this course and other Navy training publications when you are preparing for advancement in rating.

1. Study the military requirements and the professional qualifications for your rating before you study the training course, and refer to the quals frequently as you study. Remember, you are studying the training course primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training course intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training course in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement in rating?

5. When you have a general idea of what is in the training course and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training course to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training course, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Navy Training Courses or on other appropriate texts. As mentioned before, completion of a mandatory Navy Training Course can be accomplished by passing an Enlisted Correspondence Course based on the Navy Training Course. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training courses. Taking a correspondence course helps you to master the information given in the training course, and also helps you see how much you have learned.

Digitized by Google

your rating which are covered in this training course were current at the time the course was printed. By the time you are studying this course, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an up-to-date copy in the Quals Manual.

Record of Practical Factors

Before you can take the servicewide examination for advancement in rating, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the record of practical factors, NavPers 760, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the date and initials columns.

Changes are made periodically to the Manual of Qualifications for Advancement in Rating, and revised forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, the NavPers 760 form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NavPers 10052

Training Publications for Advancement in Rating, NavPers 10052 (revised), is a very important publication for anyone preparing for advancement in rating. This bibliography lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be sure that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NavPers 10052, a supplementary list of study material may be issued in the form of a BuPers Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a BuPers Notice has been issued to supplement NavPers 10052 for your rating.

The required and recommended references are listed by rate level in NavPers 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NavPers 10052, you will notice that some Navy Training Courses are marked with an asterisk (*). Any course marked in this way is mandatory—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement in rating. Each mandatory course may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training course; (2) passing locally prepared tests based on the information given in the training course; or (3) in some cases, successfully completing an appropriate Class A school.

Do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of ALL ratings must complete the mandatory military requirements training course for the appropriate rate level before they can be eligible to advance in rating.

The references in NavPers 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Digitized by Google

Navy Training Courses

There are two general types of Navy Training Courses. Rating courses (such as this one) are prepared for most enlisted ratings. A rating training course gives information that is directly related to the professional qualifications of one rating. Subject matter courses or basic courses give information that applies to more than one rating.

Navy Training Courses are revised from time to time to keep them up to date technically. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether any particular copy of a Navy Training Course is the latest edition by checking the NavPers number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061. (NavPers 10061 is actually a catalog that lists all current training courses and correspondence courses; you will find this catalog useful in planning your study program.)

Navy Training Courses are designed to help you prepare for advancement in rating. The following suggestions may help you to make the best use of this course and other Navy training publications when you are preparing for advancement in rating.

1. Study the military requirements and the professional qualifications for your rating before you study the training course, and refer to the quals frequently as you study. Remember, you are studying the training course primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training course intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training course in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement in rating?

5. When you have a general idea of what is in the training course and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training course to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training course, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Navy Training Courses or on other appropriate texts. As mentioned before, completion of a mandatory Navy Training Course can be accomplished by passing an Enlisted Correspondence Course based on the Navy Training Course. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training courses. Taking a correspondence course helps you to master the information given in the training course, and also helps you see how much you have learned.

Digitized by Google

10. Think of your future as you study Navy Training Courses. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance in rating; it is likely to be a waste of time, and may even be seriously misleading.

The Bureau of Ships Technical Manual, NavShips 250-000, is the basic doctrine publication of the Bureau of Ships. The Manual is kept up to date by means of quarterly changes. While you do not need to know everything that is given in this publication, you should have a general idea of where to find the information relating to electrical and IC equipment.

Beginning with the quarterly changes dated 15 July 1963, the Bureau of Ships began to renumber individual chapters in the Bureau of Ships Technical Manual according to the Navy-Marine Corps Standard Subject Classification System. Under this system, all chapters of the Manual will eventually be part of the 9000 series which identifies ship design and ship's material subject groups. When all chapters have been renumbered to conform to the 9000 numbering system, the old chapter numbers will be eliminated. In the meantime, you will have to consult the sheets in the front of the first volume of the Manual which cross-reference the new numbering system and the old.

The Bureau of Ships Journal is a monthly publication which contains useful information on all aspects of shipboard engineering. This publication is particularly useful because it presents information which supplements information contained in the Bureau of Ships Technical Manual.

The manufacturers' technical manuals that are furnished with IC equipments are valuable sources of information on operation, maintenance, and repair.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. A selected list of training films that may be useful to you is given in appendix I of this training course. Other films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

When selecting a film, note its date of issue listed in the film catalog.

As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively, if before or during its showing you carefully point out to trainees the procedures that have changed. For this reason if you are showing a film to train other personnel, take a look at it in advance if possible so that you may spot material that may have become obsolete and verify current procedures before the formal showing.

Digitized by Google

CHAPTER 2

SWITCHES, PROTECTIVE DEVICES, AND CABLES

This chapter discusses types of switches and protective devices that you will be working with as an IC Electrician. The types, construction, and uses of shipboard electric cables are discussed. Information is also presented concerning the maintenance of electric cables and the installing of new cables.

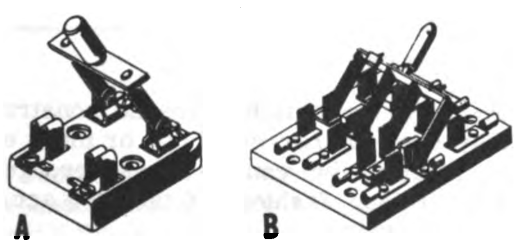
SWITCHES

A basic understanding of switches and their uses is a necessity for the IC Electrician. The Navy uses hundreds of different types of switches. They are listed in the Federal Stock Catalog in group 59, class 30. Switches associated with simple electrical circuits and IC systems are discussed below.

KNIFE

The knife switch (fig. 2-1) 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 (fig. 2-1A), has two blades with one set of clips for each blade and an insulated handle that operates both blades simultaneously. Double-throw switches (fig. 2-1B), 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.

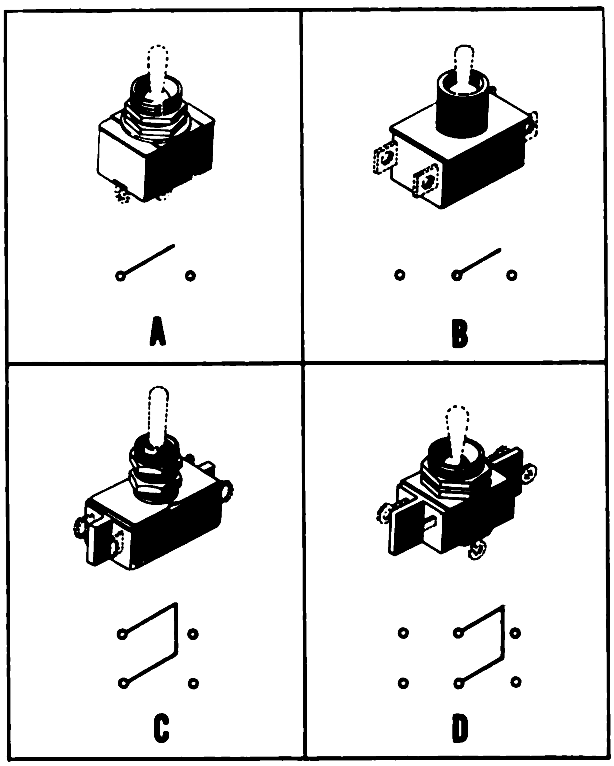


1.102

Figure 2-1.—Knife switches.

TOGGLE

Representative examples of toggle switches are shown in figure 2-2. In part A is shown a single-pole, single-throw (SPST) toggle switch,



1.98

Figure 2-2.—Toggle switches.

Digitized by Google

rated at 20 v and 20 amperes, and having 2 solder terminals. The schematic diagram is shown beneath the switch. This switch is used to open or close an electric circuit.

Part B shows a single-pole, double-throw (SPDT) switch, rated at 250 v and 1 ampere, and having 4 screw terminals. One of the uses of this switch is to turn a circuit on at one place and to turn it off at another place. It is sometimes called a 3-way switch.

A double-pole, single-throw (DPST) switch is shown in part C. It has 4 solder terminals and is rated at 250 v and 1 ampere.

A double-pole, double-throw (DPDT) switch is shown in part D. It has 6 solder terminals and is rated at 125 v and 3 amperes.

The following types of switches are also used: 3-pole, single-throw (3PST); 3-pole, double-throw (3PDT); 4-pole, single-throw (4PST); and 4-pole, double-throw (4PDT). The voltage ratings range from 20 v to 600 v, and the amperage ratings range from 1 ampere to 30 amperes.

PUSH

The contact arrangement of push switches is shown in figure 2-3A, and an example of a typical contact arrangement is shown in part B. The type and quantity of each basic form used to make up the contact assembly are determined from part A. Part B illustrates how the illustrations in part A may be used in a practical switch assembly. Thus, in part B the switch contains a total of three separate basic forms: two forms A, and one form C. The contact arrangement for this switch is therefore 2A1C. Obviously, there are many possible contact arrangements. For example, 1A, 1A1A, 1A1B, 2A, 2A1B, 1B, etc., are common.

A push switch employing a 2A contact arrangement is show in figure 2-3C. It is rated at 250 v and 3 amperes.

ROTARY SNAP

The rotary snap switch (fig. 2-4) is a device that opens or closes a circuit with a quick motion. A type SR rotary snap switch consists of one or more sections, each of which has a rotor and 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 arragements, 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 2-5.

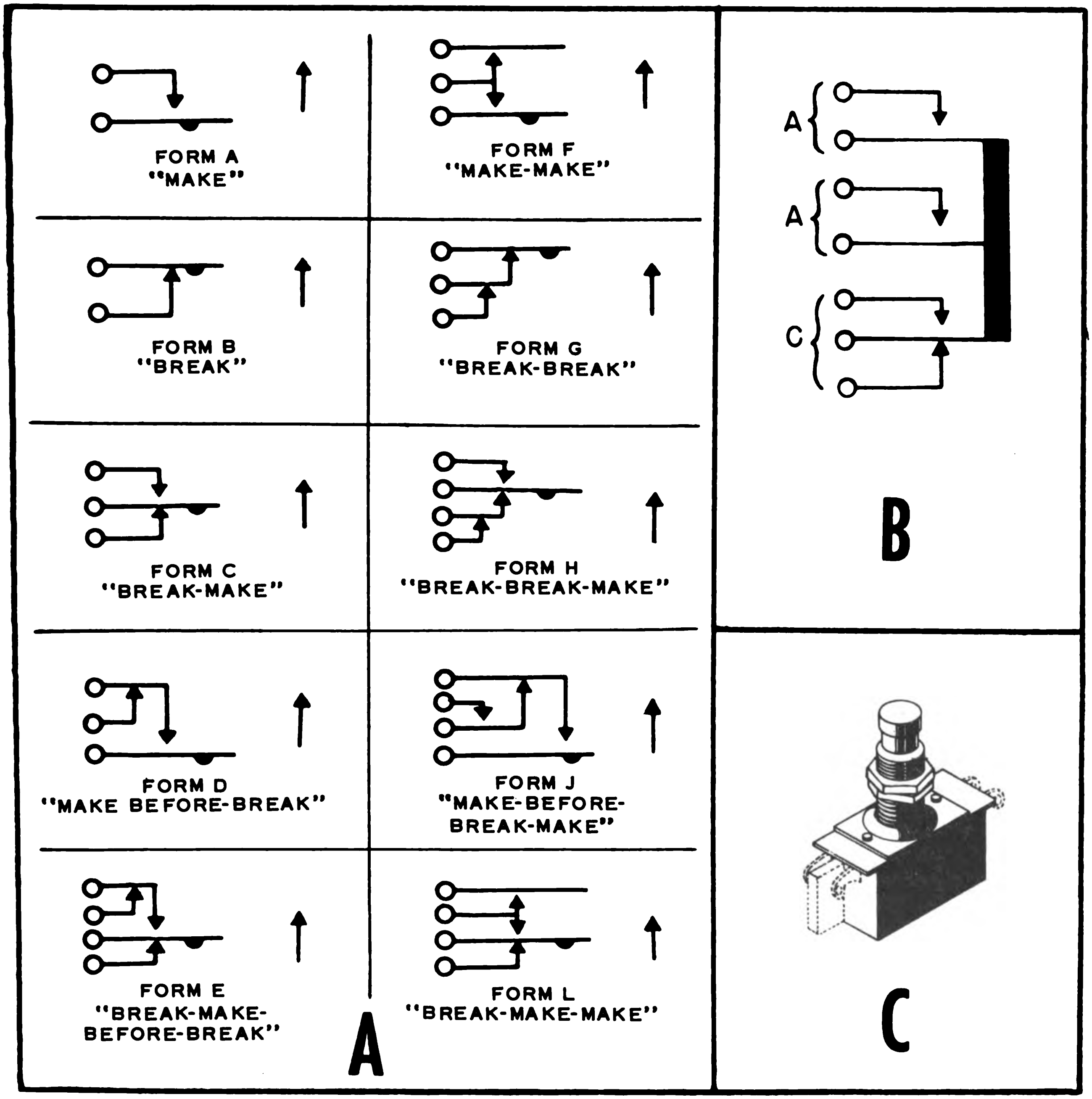
Most snap switches are suitable for 450-volt, 60-cycle, a-c and 250-volt d-c operation. Present 10-ampere switches are suitable for 120-volt operation only, although the switches are sometimes used at higher voltages where the currents are very small. Care must be exercised in the application of multithrow (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.

ROTARY PILEUP

Rotary pileup switches are so constructed that they open and/or close one or more electrical circuits; the contacts are arranged in a leaf, or pileup, fashion and they are actuated by a rotary motion.

One type of rotary pileup switch is illustrated in figure 2-6. As may be seen in the figure, there are six terminals. When the armature is

Digitized by Google



1.99

Figure 2-3.—Push switches.

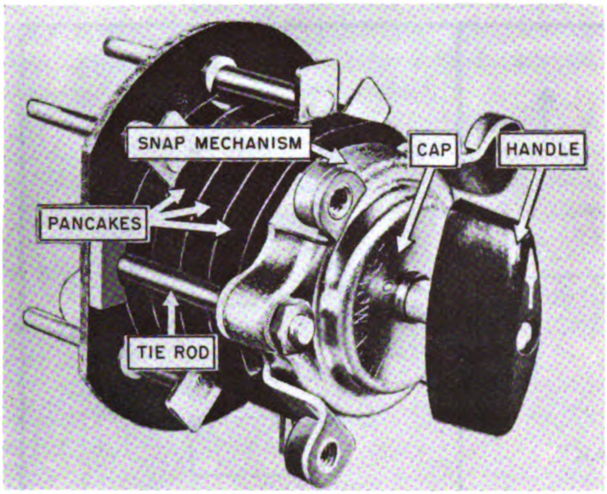
moved upward by the rotary motion of the switch knob, two circuits are opened and two other circuits are closed.

This type of switch has numerous applications in low-voltage signal circuits.

ROTARY SELECTOR

Rotary selector switches, or rotary transfer switches, have many applications.
They may be made up of any number of sections or pancakes, depending upon the

Digitized by Google



12.69
Figure 2-4.—Type SR rotary snap switch (10 ampere size, 1SR).

switching functions required. There are hundreds of possible contact arrangements.

Type J

The type J multiple rotary selector switch (fig. 2-7), 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 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.

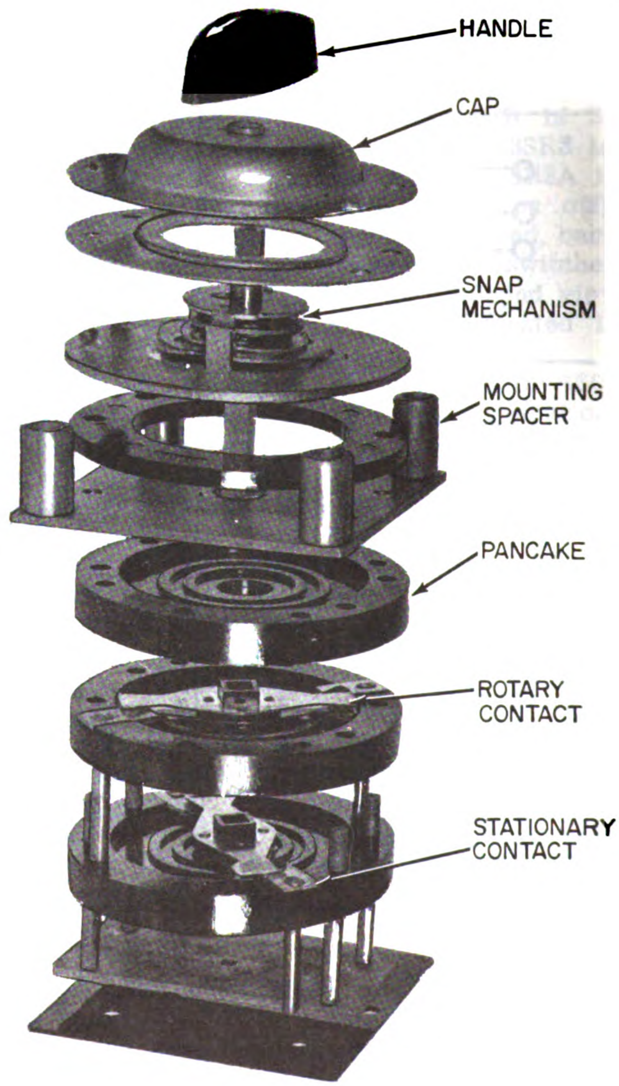
Type JR

The type JR switch (fig. 2-8) is installed on recent IC 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.

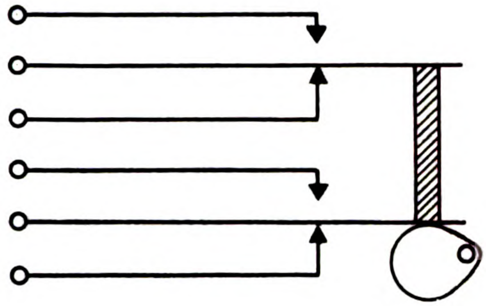
The 2JR switch has two movable contacts per section, 180° apart. Each movable contact bridges two adjacent stationary contacts.

The 3JR switch utilizes one of the stationary contacts as a common terminal. This stationary contact is connected, in turn, to each of the

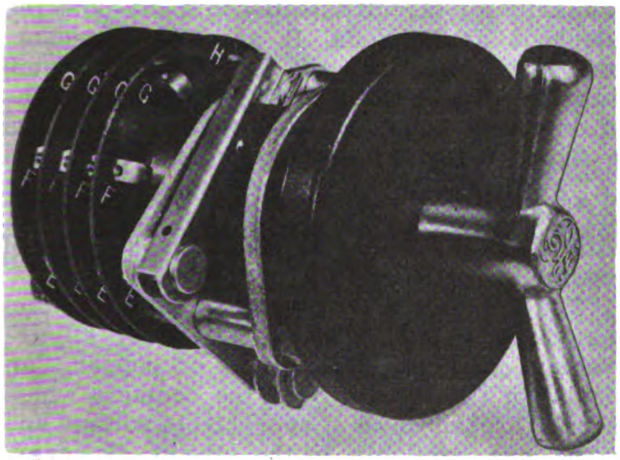


140.1
Figure 2-5.—Type SR snap switch, exploded view (60 ampere size 6SR).

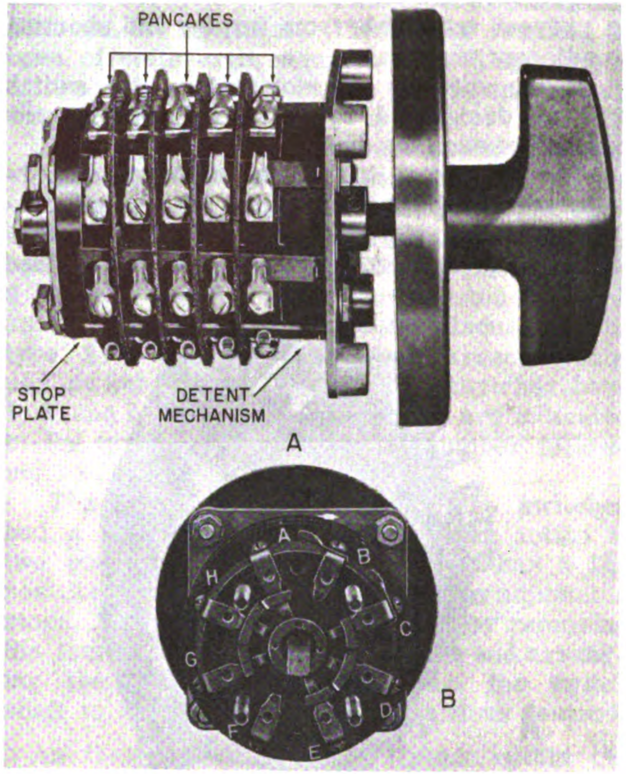
Digitized by Google



1.104
Figure 2-6.—Rotary pileup switches.



12.70
Figure 2-7.—Type J switch.



12.71
Figure 2-8.—Type 4JR switch.

other stationary contacts of the section by a single-wiper movable 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. 2-8B). This switch is used to select either or both of two indicators or synchros. The position for energizing two indicators are:

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

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 non-shorting 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.

Digitized by Google

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.

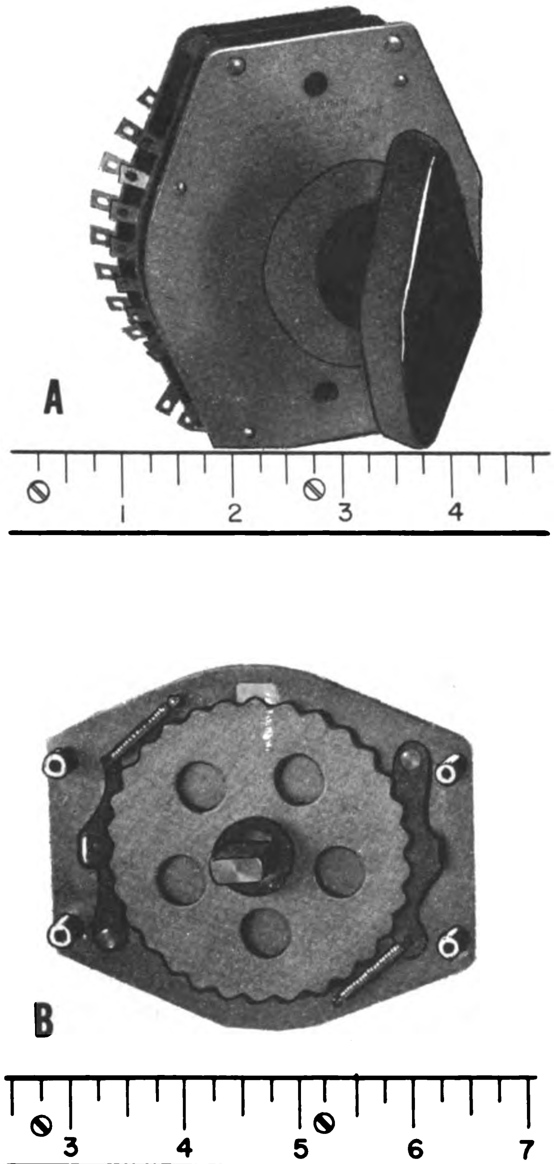
Type JL

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

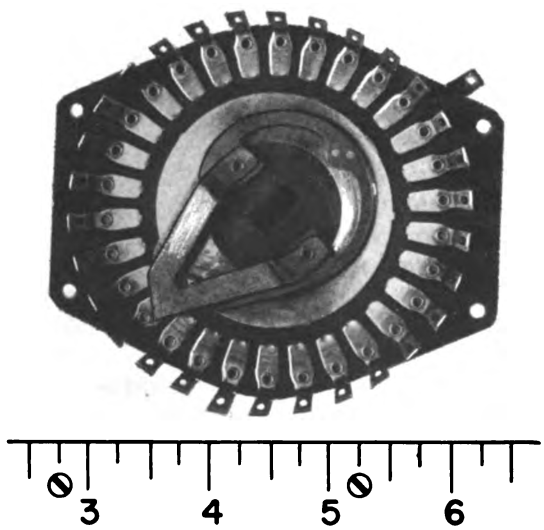
The JA switch (fig. 2-9) was developed primarily for circuit selection in sound-powered telephone applications. It provides a greater number of selections and is a smaller switch than the JR switch. The JA switch is furnished only with common rotor sections as shown in figure 2-10. Sixteen position and 30 position JA switches, which permit selection of 16 and 30 circuits respectively, 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,



140.2

Figure 2-9.—Type JA switch and detent mechanism.



65.75

Figure 2-10.—Type JA switch contacts.

Digitized by Google

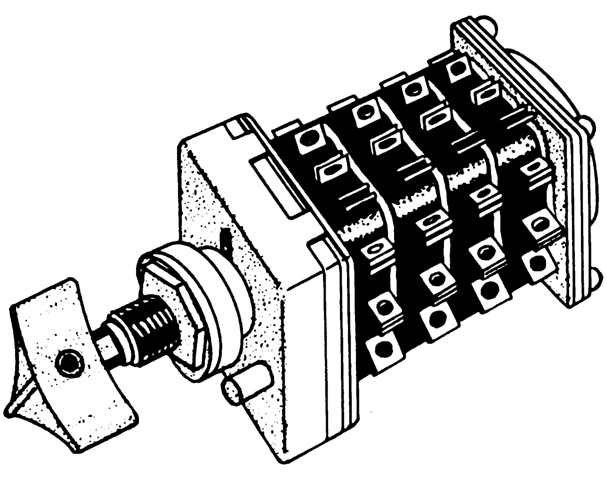
in sound-powered telephone circuits, there is insufficient power to break down the film, and relatively high resistance results. The silver-to-silver contacts of the JA switch consist of pure silver welded to beryllium copper. Silver or silver-coated contacts are now being utilized for latest type JR 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. 2-11), was developed primarily to replace toggle switches in the 10 and 20 switch boxes for sound-powered telephone applications.

Because of the problems in making toggle switches watertight, it was necessary to provide a gasketed cover for the 10 and 20 switch boxes, which contained the toggle switches. The cover had to be open when the switches were operated. Therefore, the switch box was not watertight, leading to possible malfunctioning of the switches. In addition, the lack of a strong contact wipe action in toggle switches and the low voltage and current of sound-powered



140.3

Figure 2-11.—Type JF switch.

circuits resulted in the formation of an insulating film on the contacts. This film resulted in open circuits or it required several operations of the toggle switch handle before the circuit was initially made.

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

The original production of the switches had a detent to limit the switching action to two positions. The present design has a 12-position detent 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.

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.

LEVER OPERATED

Lever 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.

Digitized by Google

Most lever operated switches utilize JR interiors (fig. 2-12). 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 arrangement of pins, lever, and locking plate, various types of switches can be obtained.

Special switches are in use where the standard switches cannot be used. For example, the diving alarm switch on the submarine bridge must be pressure proof. 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.

Lever operated switches are available in single, 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.

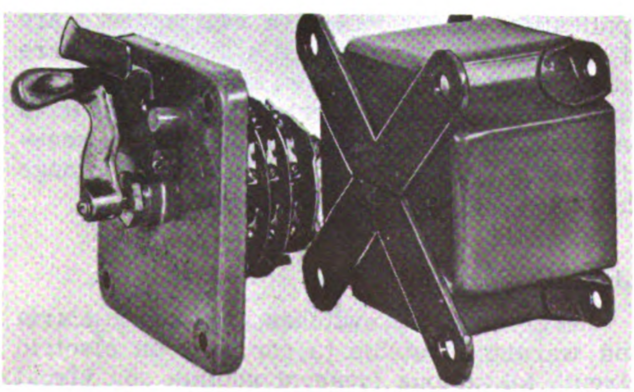
PRESSURE SWITCH

Pressure-operated switches are normally single-pole, single-throw, quick-acting switches. They contain either a bellows or a diaphragm that works against an adjustable spring. The spring causes the contacts to close automatically when the operating pressure falls below a specified value. The pressure at which the switches operate is adjustable within the ranges of 0-15, 15-50, and 50-100 psi. Make this adjustment at the screw marked, higher (fig. 2-13). These switches can be used also to indicate an increase in pressure above a predetermined point.

Pressure-operated switches are used with the lubricating oil, low-pressure alarm system; air-pressure alarm system; and booster-feed pressure alarm system.

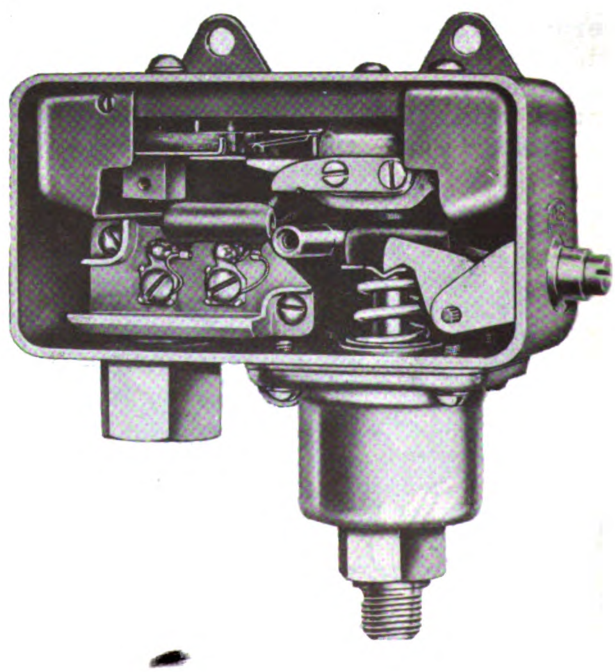
THERMOSTATIC SWITCH

Thermostatic, or temperature-operated, switches are usually single-pole, single-throw, quick-acting, normally open switches. These switches contain a bellows that works against an adjustable spring (fig. 2-14). The spring causes the contacts to close automatically when the operating temperature exceeds a specified value. The bellows motion is produced by a sealed-in liquid that expands with rising temperature. The sensitive element containing this liquid may be built into the switch or located



140.4

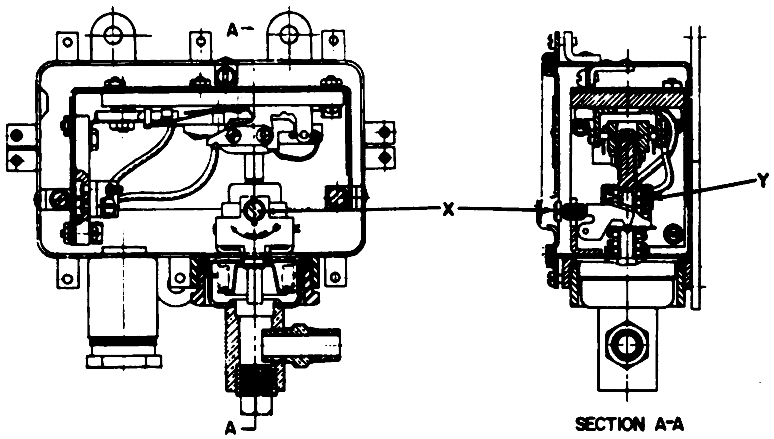
Figure 2-12.—Lever operated switch (manual contact maker).



77.119

Figure 2-13.—Pressure switch, type IC/L.

Digitized by Google



140.5

Figure 2-14.—Temperature-operated switch.

in a remote space and connected to the switch by a capillary tube. The temperature range at which the switches operate is adjustable between 100° and 225° F.

Temperature-operated switches are used with the circulating-water, high-temperature alarm system; cruising-turbine exhaust alarm system; and generator-air, high-temperature alarm system.

MECHANICAL SWITCH

The types of mechanically operated switches are the push-action (type A-S) and the cam-action (types P and P1). The push-operated switch, provided for bulkhead mounting, is a single-throw or multiple-throw, momentary action, normally open push switch. The push-action mechanism utilizes a straight-line movement of the shaft to operate the electrical contacts.

The cam-action switch consists of two single-pole, double-throw micro switches operated by two adjustable cams mounted on the rotor shaft (fig. 2-15). The cam-action mechanism utilizes a rotary motion of the shaft to move cams, which in turn operate sensitive switches. The points of operation of the sensitive switches are varied by adjusting the angular positions 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

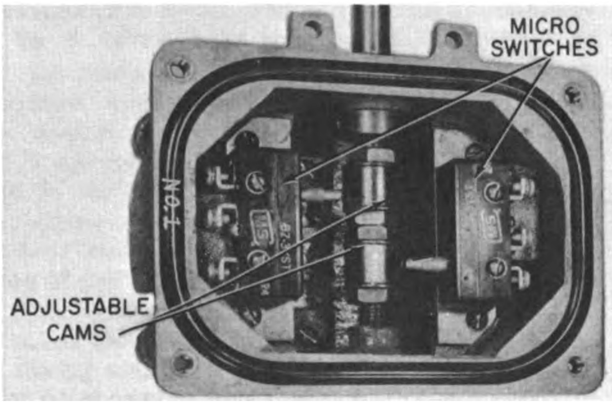
Water switches consist of a pair of terminals mounted in an insulated base within a cast fitting (fig. 2-16). There is a 7000-ohm, 5-watt resistor connected across the two terminals, which limits the current to the required value of the supervisory circuit when the switch casting is dry. The switch is 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).

RELAYS AND CONTACTORS

A relay is a magnetically operated switch. The operating coil can be connected in series

Digitized by Google



140.6

Figure 2-15.—Mechanical switch.

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 usually wound with a fairly small number of turns of large wire because the load current will be flowing through the winding. When the relay is designed for shunt connection, the coil is wound with a large number of turns of small wire, which will increase the resistance and thus lower the current through the coil.

The contacts of relays and contactors may open or close when energized. This means that relays can be used as protective devices, as control devices, or to perform both functions simultaneously. Because of this flexibility, relays and contactors are used in many shipboard applications.

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.

Shunt Type

The shunt type contactor (connected across the line) operates when line voltage is applied to its operating coil 2 (fig. 2-17). The contacts, 4, are arranged to complete or interrupt an electric circuit. In this arrangement the contacts are connected in series with the voltage supply to the controlled circuit. When voltage is applied to the coil, a magnetic pull attracts the armature, 3, which closes the main contacts, 4. When the voltage supply to the coil is interrupted, the magnetic pull on the armature is removed, and the armature spring pulls it away from the magnet. This action opens the contacts and deenergizes the controlled circuit.

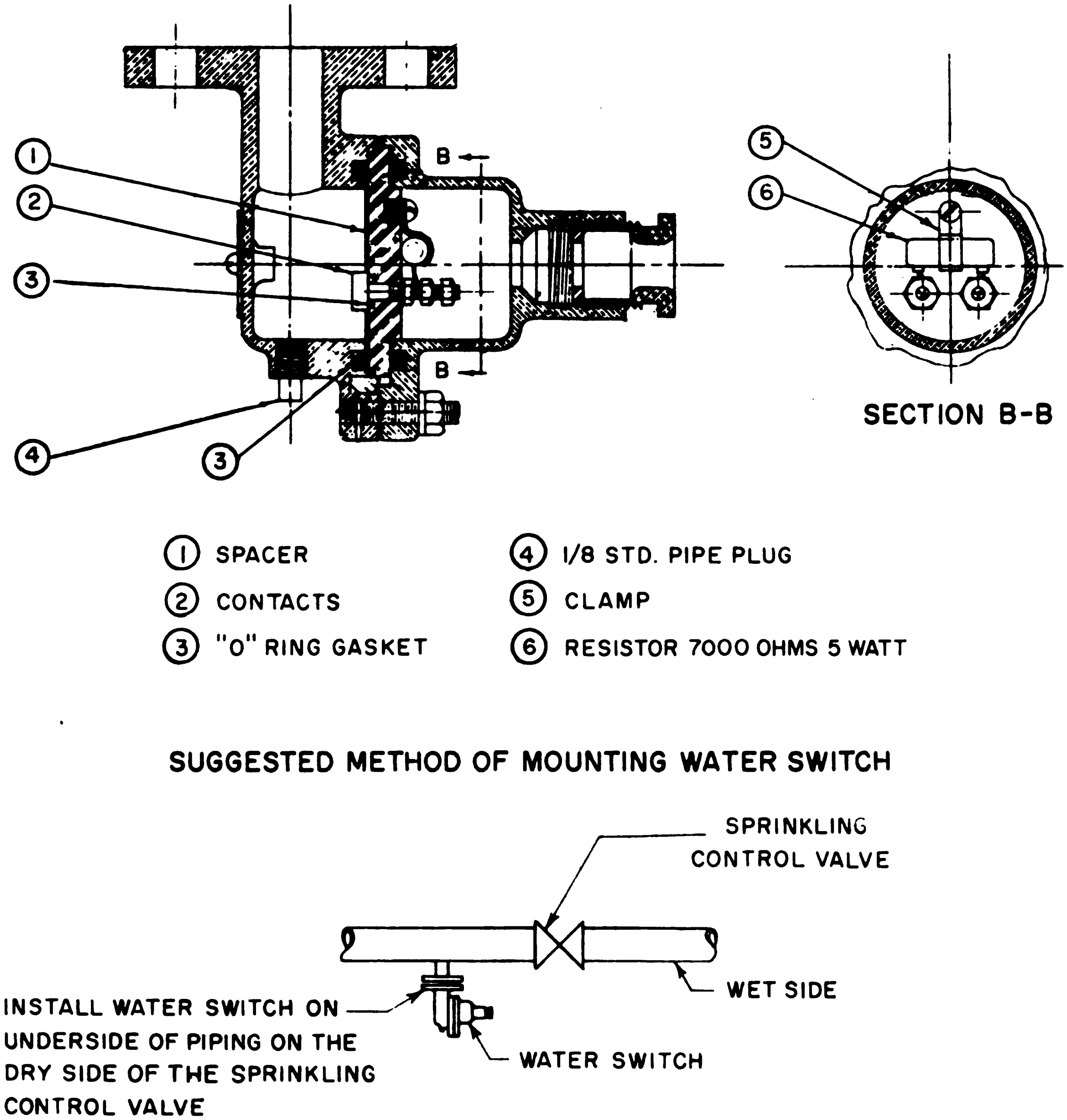
An a-c shunt relay is illustrated in figure 2-18. The basic function of the relay is to make or break an electrical control circuit when the relay coil is energized. To do this, voltage is applied to the operating coil, 2 (connected across the line), which attracts the armature, 3. When the armature is pulled down, it closes the main contacts, 4.

The pullin and dropout current values may be adjusted. In figure 2-19 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. The pullin value can be raised by increasing the spring tension or by increasing the armature gap.

Series Type

The series type relays (fig. 2-20) are operated by circuit current flowing through the coil

Digitized by Google



140.7

Figure 2-16.—Water switch.

or coils. This feature makes it possible to use the relay as a field failure relay, or for any application where the relay operation is in response to changes in circuit current flow.

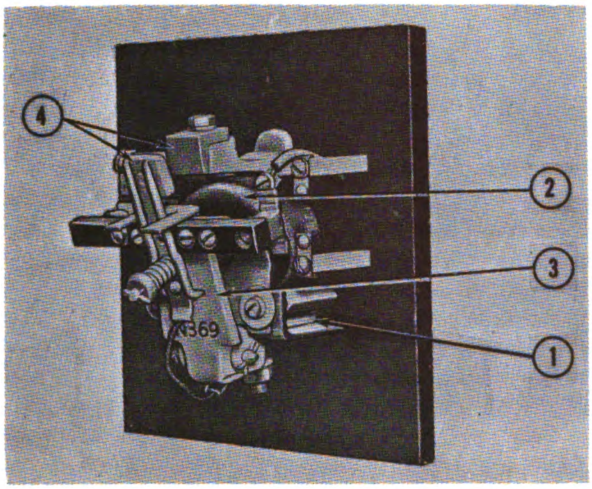
A one-coil series relay is shown in figure 2-20A, and a two-coil relay is shown in figure 2-20B.

There are two adjustments on the two-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.

MAINTENANCE

Switches should be checked periodically to ensure that all electrical connections and mechanical fastenings are tight. Avoid

Digitized by Google



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

140.8
Figure 2-17.—Shunt type d-c contactor.

overtightening the packing gland nut on watertight rotary switches as excessive pressure on the switch shaft will cause improper positioning of the switch.

Remove dirt and grease from switch and relay contacts with a cloth moistened with an approved solvent. No lubricants of any kind should be applied to the contacts. Use a burnishing tool for dressing small light contacts.

Clean burned copper contacts with fine sandpaper. Do not use emery cloth. Badly burned contacts should be replaced. Always replace contacts in pairs, rather than replacing a single contact.

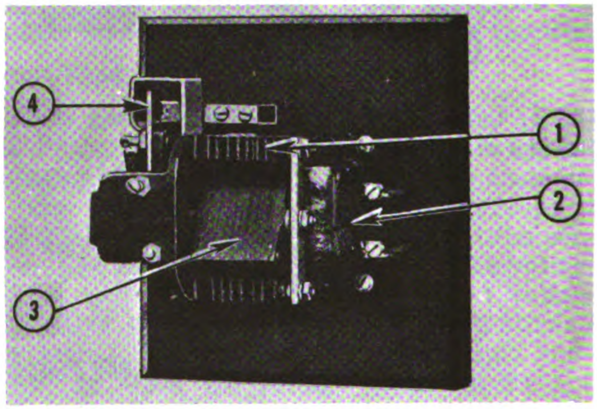
Silver contacts require very little maintenance. Removal of the tarnish that forms on silver contacts due to arcing is no longer recommended, as this blackened condition improves the operation of the contacts. Severely pitted or burned silver contacts may be dressed with a fine file or fine sandpaper.

PROTECTIVE DEVICES

Most protective devices are designed to interrupt the power to a circuit or unit when abnormal conditions such as short circuits, overloads, high or low voltage and excessive current, occur. The most common types of protective devices are fuses, circuit breakers, and overload relays.

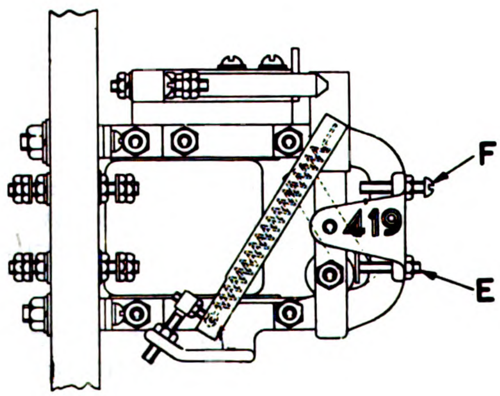
FUSES

A fuse is a protective 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,



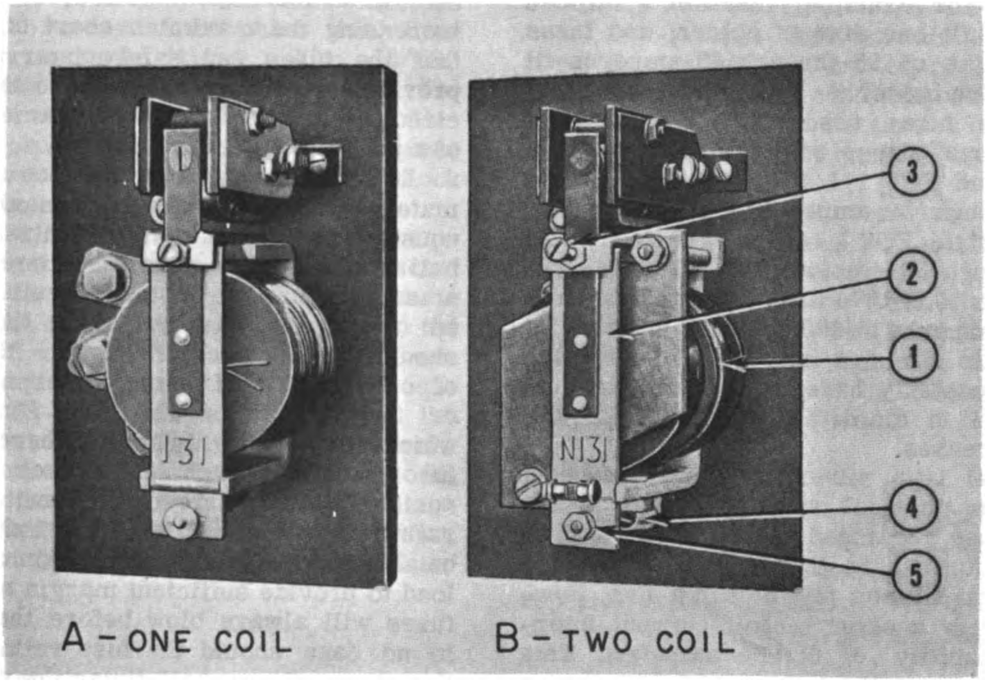
1. Magnetic frame.
2. Operating coil.
3. Armature.
4. Main contacts.

140.9
Figure 2-18.—A-c shunt relay.



140.10
Figure 2-19.—Adjustment of a-c shunt relay.

Digitized by Google



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

140.11

Figure 2-20.—Series type relays.

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

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 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 holders as fuses intended for 250-volt service. Fuses of different ampere capacity are also designed for different sizes

Digitized by Google

of holders. For example, fuses of 1 through 30 amperes fit one size of holder, and fuses with capacities of 35 through 60 amperes fit a different size holder.

Cartridge fuses used with IC 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 of greater than 10 ampere capacity are pulled, the switch for the circuit should be opened. Approved fuse pullers must be used for removing fuses. Fuses should never be short circuited or replaced with fuses of larger current capacity.

Time Delay

The time delay fuse is used for loads such as motor supply circuits in which overloads and motor-starting 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. This rating would be too high to provide necessary protection for the normal steady state current of the circuit.

The time delay 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."

Selection of Proper Fuses

Individual fuses are provided on the IC 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 small portion of the circuit is likely to be operated at any one time, the fuse rating should be 10 percent greater than the load of one associated group of signals operated, or 15 percent of the total connected load, whichever is greater. Where the circuit incorporates branch fuses, such as those associated with the fire-control switchboards, the rating of the fuses on the IC switchboard should be 20 percent above the maximum connected load to provide sufficient margin so that branch fuses will always blow before the main fuses. In no case should the fuse rating be greater than two and one-half times the rated capacity of the smallest cable in the circuit. If too large a fuse were used, a fire hazard would exist.

Fuse Holders

The type EL-1 fuse holder consists of a base and a plug, as shown in figure 2-21. 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 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.

The types, FHL10G, FHL11G, and FHL12G (fig. 2-22) 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 pushing and turning the fuse carrier in a counterclockwise direction again similar to the removal of a bayonet base lamp. The types, FHL10G and FHL11G, accomodate 1 1/4" x 1/4" diameter fuses. The type, FHL10G, will hold two fuses and can therefore be used to fuse both sides

Digitized by Google

of the line, or, in conjunction with a type FHL11G, will fuse a three phase line. Type 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.

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 FHL10G 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 fuse holders should not be used in sensitive, low-current equipment. Where an overload condition occurs and the fuse blows, the low resistance indicator circuit may pass sufficient current to damage the equipment.

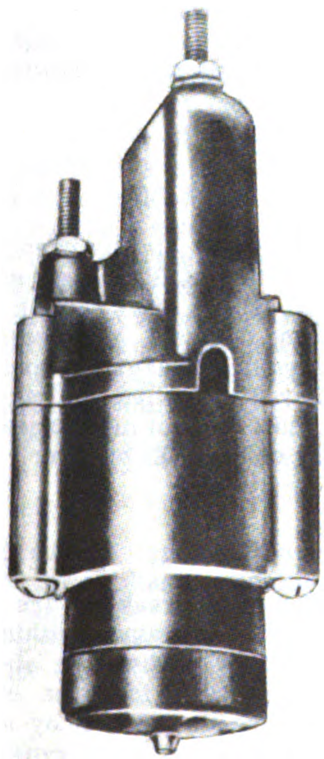
Due to the design of certain fuses and in cases where space does not permit use of indicator type fuseholders, separate indicator light circuits are mounted on a panel and connected in parallel with separately mounted fuses and fuse clips. In some cases an alarm circuit in the form of a bell or buzzer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

CIRCUIT BREAKERS

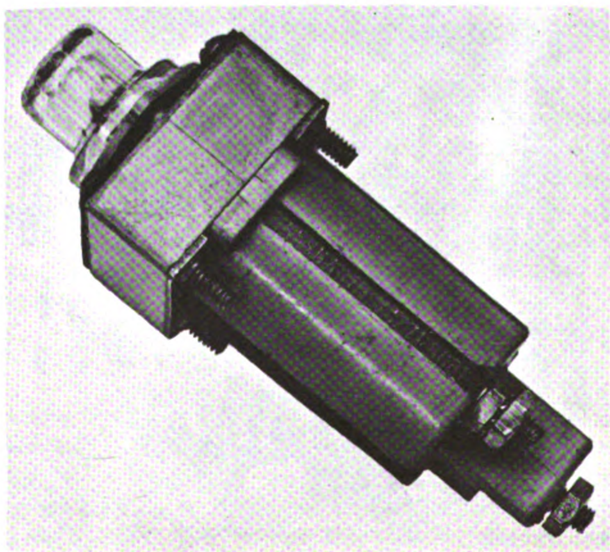
Circuit breakers are used to provide circuit protection, to perform normal switching operations, and to isolate a defective circuit while repairs are being made. The types installed on naval ships are ACB, AQB, AQB-LF, NQB, ALB, and NLB

ACB

This type of circuit breaker may be for either manual local closing or electrical remote closing. It has an open metallic frame construction mounted on a drawout mechanism and is normally applied where there may be



140.12
Figure 2-21.—Fuse holder, type EL-1.



140.13
Figure 2-22.—Fuse holder, type 12FH1.

Digitized by Google

heavy loads and high short circuit currents.

When operated electrically, the operation is usually in conjunction with a pilot device such as a relay or switch. Electrically operated circuit breakers employ an electromagnet, used as a solenoid, to trip a release mechanism that causes the breaker contacts to open. The energy to open the breaker is derived from a coiled spring. The electromagnet is controlled by the contacts in the pilot device.

Figure 2-23 shows the external appearance of a type ACB circuit breaker.

Type ACB circuit breakers are used to connect ship's service and emergency generators to the power distribution system. They are also used on all feeder circuits from the main switchboard.

AQB

The AQB circuit breaker (fig. 2-24) 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 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. The AQB breaker is used extensively in distribution switchboards and load centers.

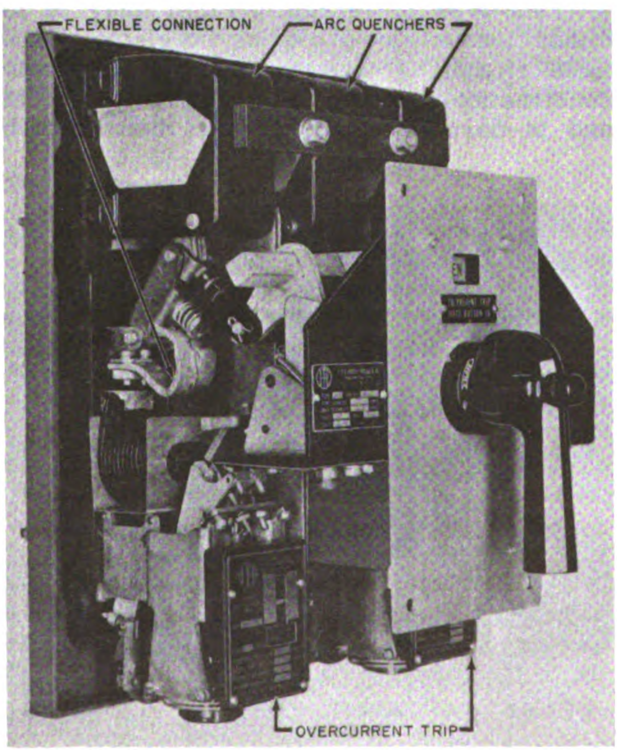
AQB-LF

Type AQB-LF are circuit breakers similar in design to the AQB. High short circuit current interrupting fuses (which also act as current limiting devices), have been incorporated in the circuit breaker in order that the breakers may be applied on circuits where the short circuit current may exceed the interrupting rating of the AQB breaker.

NQB

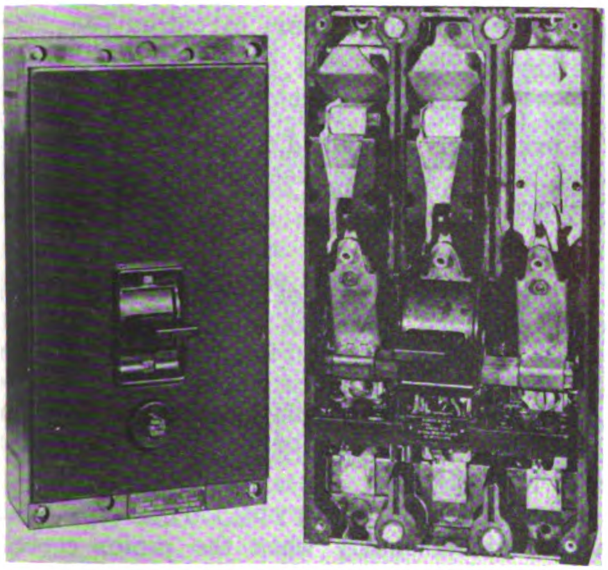
Type NQB circuit breakers are mounted on insulated supports contained within molded insulation enclosures. They are similar to the type AQB except that the type NQB has no automatic tripping devices. They are used for circuit isolation and manual transfer applications. They are not suitable for use with pilot devices.

Technically the NQB circuit breakers are used simply as ON - OFF switches.



27.73
Figure 2-23.—Type ACB circuit breaker.

Digitized by Google



27.74

Figure 2-24.—Type AQB circuit breaker.

ALB

Type ALB circuit breakers are designated low-voltage, automatic circuit breakers. The continuous duty rating ranges from 10 to 50 amperes at 125 volts a-c or d-c. The breaker is provided with a molded enclosure, draw-out type connectors, and nonremovable and non-adjustable thermal trip elements.

This circuit breaker is a quick-make, quick-break type. If the operating handle is in the tripped position, indicating a short circuit or overload, the operating handle must be turned to the off position, which automatically resets the overload unit.

NLB

Circuit breakers type NLB are small and are used on low voltage systems (24 v d-c, 120 v d-c, and 120 v a-c). They have no automatic tripping device and are used only as switches for circuit isolation.

Maintenance

Circuit breakers require careful inspection and cleaning at least once a year (more frequently if subjected to unusually severe service conditions).

A special inspection should be carefully made of each pair of contacts after a circuit breaker has opened on a heavy short circuit. Before working on a circuit breaker, deenergize all circuits including control circuits, to which it is connected.

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 contact and mechanism springs for excessive wear or corrosion and evidence of overheating.

Slowly open and close circuit breakers manually a few times to be certain that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding.

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.

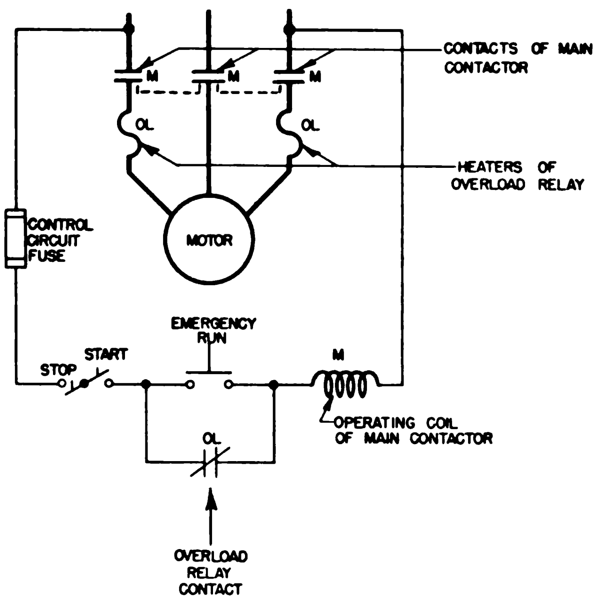
OVERLOAD RELAYS

Overload relays are provided in motor controllers to protect the motor from excessive currents. Excessive motor current causes normally closed overload relay contacts to open which break the circuit to the operating coil of the main contactor, and disconnect the motor from the line (fig. 2-25). Overload relays are of the thermal or magnetic type.

Thermal Type

The thermal type of overload relay has a heat-sensitive element and an overload heater connected in series with the motor circuit as shown in figure 2-25. When the motor current is excessive, heat from the heater causes the heat-sensitive element to open the overload relay contacts. As it takes time for the heat-sensitive element to heat up, the thermal

Digitized by Google



124.249

Figure 2-25.—Schematic diagram of motor controller with thermal type overload.

type of overload relay has an inherent time delay. Thermal overload relays may be of the solder-pot, bimetal, single metal, or induction type.

SOLDER-POT TYPE.—The heat sensitive element is a solder pot which consists of a cylinder inside a hollow tube. These are normally held together by a film of solder. In case of excessive motor current, the heater melts the solder, breaks the bond between the tube and cylinder, and releases the tripping device of the relay. After the relay trips, the solder cools and solidifies, and the relay can be reset.

BIMETAL TYPE.—The heat-sensitive element is a strip or coil of two different metals fused together along one side. When heated, one metal expands more than the other causing the strip or coil to bend or deflect, and open the overload relay contacts.

SINGLE METAL TYPE.—The heat-sensitive element is a metal tube around the heater. The tube lengthens when heated and opens the overload relay contacts.

INDUCTION TYPE.—The heat-sensitive element is usually a bimetal strip or coil. The heater consists of a coil in the motor circuit and a copper tube inside the coil. The copper tube acts as a short circuited secondary of a transformer, and is heated by the current induced in it. This type of overload relay is used only in a-c controllers, whereas the previously described types of thermal overload relays may be used in a-c or d-c controllers.

Magnetic type

The magnetic type of overload relay has a coil connected in series with the motor circuit and a tripping armature or plunger. When the motor current is excessive, the armature opens the overload relay contacts. Magnetic overload relays may be of the instantaneous or time delay type.

INSTANTANEOUS TYPE.—This type operates instantaneously when the motor current becomes excessive. The relay must be set at a tripping current higher than the motor starting current to prevent tripping when the motor is started. This type of overload relay is used mostly for motors that are started on reduced voltage then switched to full line voltage after the motor comes up to speed.

TIME DELAY TYPE.—This type is essentially the same as the instantaneous type with the addition of a time delay device. The time delay device may be an oil dashpot with a piston attached to the tripping armature of the relay. The piston has a hole through which oil passes when the tripping armature is moved due to excessive motor current. The size of the hole can be adjusted to change the speed at which the piston moves for a given pull on the armature. For a given size hole, the larger the current, the faster the operation. This allows the motor to carry a small overload current for a longer period of time than a large overload current.

CABLES

Shipboard electrical and electronic systems require a large variety of electric cables. Some circuits require only a few conductors having a high current-carrying capacity; others require many conductors having a low current-carrying capacity; still others may require cables with a special type of insulation, the conductors may have to be shielded, or in some cases

Digitized by Google

the conductors may have to be of a metal other than copper.

Shipboard electric cables are identified according to type and size. Type designations consist of letters to indicate construction and/or use. Size designations consist of a number or numbers to indicate the size of the conductor(s) in circular mil area, number of conductors, or number of pairs of conductors depending upon the type of cable.

In most cases the number of conductors in a cable, up to and including four conductors, is indicated by the first type letter as follows: S-single conductor; D-double conductor; T-three conductor; and F-four conductor. For cables with more than four conductors, the number of conductors is usually indicated by a number following the type letters. Examples of common shipboard cable designations are as follows:

DSGA-3-Double conductor, Shipboard, General use, Armored, conductor size approximately 3000 circular mils.

FHFA-4-Four conductor, Heat and Flame resistant, Armored, conductor size approximately 4000 circular mils. Type HFA cable has been replaced by type SGA.

DCOP-2-Double Conductor, Oil resistant, Portable conductor size approximately 2000 circular mils.

MSCA-30-Multiple conductor, Shipboard, Control, Armored, with 30 conductors.

MDGA-19 (6)-Multiple conductor, Degaussing, Armored, 19 conductors, conductor size approximately 6000 circular mils.

Shipboard electric cables are classified according to service as nonflexing or repeated flexing.

NONFLEXING

Nonflexing service cables are used for all cable installations where bending or twisting of the cable is not required. With a few exceptions, all armored cables are nonflexing service cables.

The SGA type cable is the most common shipboard nonflexing service cable for general use. The construction of this type of cable for sizes up to and including SGA-9, is shown in figure 2-26. For sizes above SGA-9 the silicone rubber insulation is replaced by a silicone treated glass tape insulation. In a newer type of SGA cable, the glass fiber braid is white instead of color coded, and a black nylon jacket is installed over the glass fiber braid. Conductor identification is printed on the black nylon jacket.

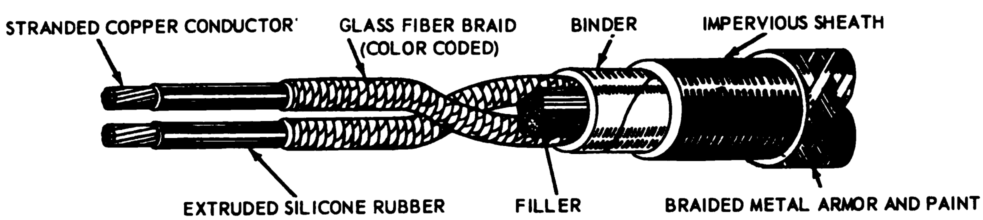
Representative nonflexing service cables for special use are shown in figure 2-27. Type MDGA (fig. 2-27A) is a multiconductor degausing cable; type SHFP (fig. 2-27B) is a single conductor heat and flame resistant propulsion cable; type PBJX (fig. 2-27C) is a pyrometer base lead cable consisting of one constantan and one iron conductor; type TTHFWA (fig. 2-27D) is a twisted pair telehone cable.

Type SHFP cable has been replaced by type SS5P, a single conductor 5000 volt propulsion cable.

REPEATED FLEXING

Repeated flexing service cables are used with portable equipment, and with permanently installed equipment where repeated bending, and/or maximum resistance to oil or water are required. Type DHOF (Double conductor, Heat and Oil resistant, Flexible) cable (fig. 2-28) is widely used on shipboard for repeated flexing service, general use.

Representative repeated flexing service cables for special use are shown in figure 2-29. Type MHFF (fig. 2-29A) is a multiconductor, heat and flame resistant, flexible,



29.226

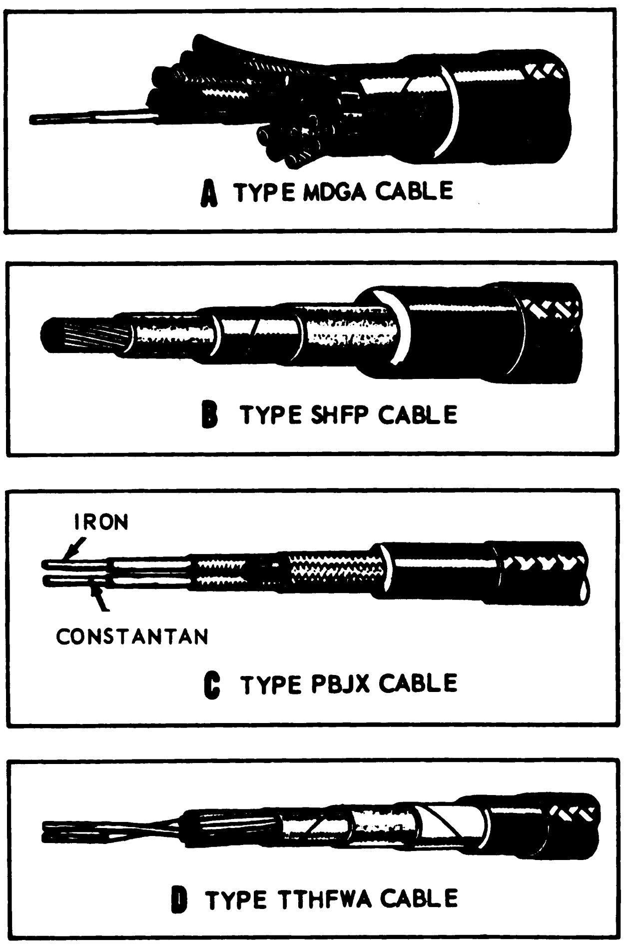
Figure 2-26.—Type DSGA shipboard nonflexing service cable.

Digitized by Google

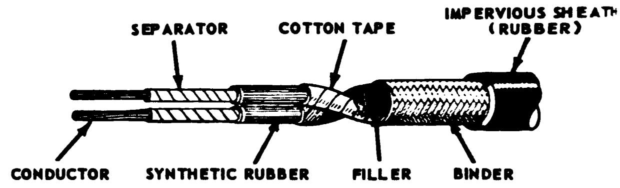
cable; type TRF (fig. 2-29B) is a tough jacket, flexible cable.

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 2-1 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 a-c and 2 wire d-c portable equipment and tools is black, white, and green. The green conductor is used to ground the equipment.



29.226
Figure 2-27.—Nonflexing service cable for special use.



29.22
Figure 2-28.—Type DHOF shipboard repeated flexing service cable.

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.

CABLE MARKING

Ready identification for maintenance and repairs of IC circuits is provided by cable designations embossed on the cable tags (fig. 2-30). 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 IC 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 IC 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 IC system). The letters, MB, denote the circuit, engine-order system, which may actually include wires of circuits IMB, 2MB, 3MB, and

Digitized by Google

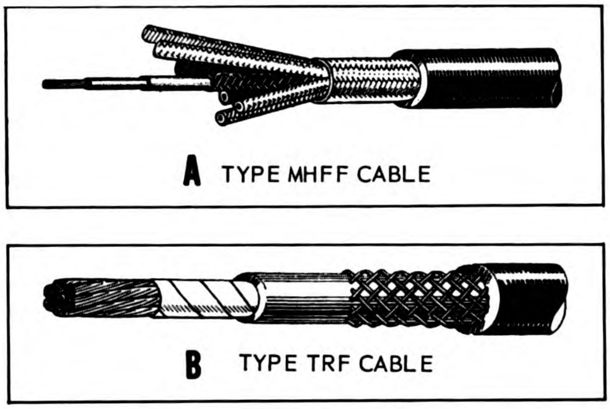
Table 2-1.—Color Coding of Multiple Conductor Cables.

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	

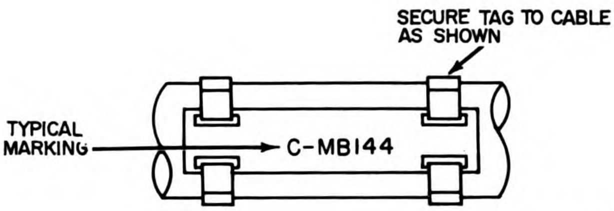
so forth. The number 144 denotes cable number 144 of circuit MB.

Permanently installed ships' cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cables located within a single compartment in such a manner that they can be readily traced are not tagged. Past practice was to use colored tags to classify vital, semivital, and nonvital cables. This

Digitized by Google



29.226
Figure 2-29.—Repeated flexing service cable for special use.



12.74
Figure 2-30.—Cable tag.

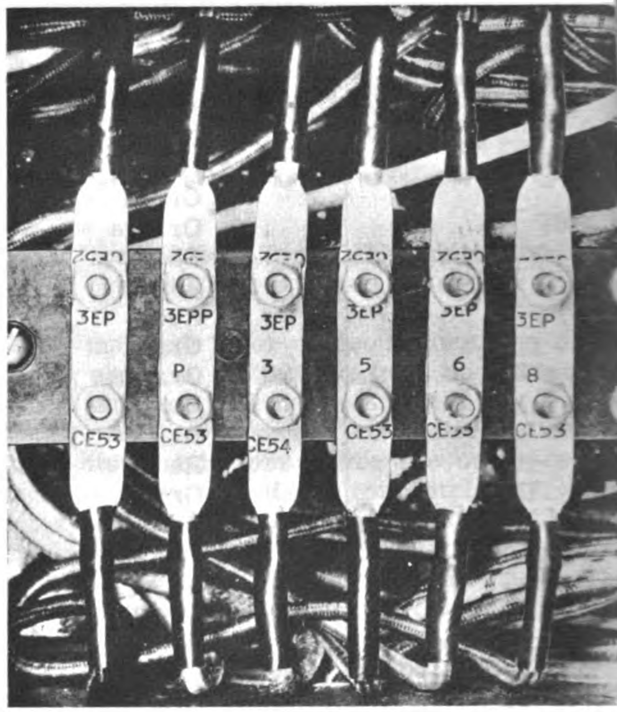
practice has been discontinued, however colored tags will still be found on some ships.

TERMINAL MARKING

In single-letter circuits and 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 IC terminals are stamped with the circuit marking and additional numbers that are necessary to identify each wire and its function in the circuit (fig. 2-31).



140.14
Figure 2-31.—Wire-terminal markings.

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

Digitized by Google

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 IC 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.

CABLE MAINTENANCE

The purpose of cable maintenance is to keep the cable insulation resistance high. Cables should be kept clean and dry, and protected from mechanical damage, oil, and salt water.

Testing Cables

Insulation resistance tests (ground tests) must be made periodically on IC cables to determine the condition of the cable. In addition to the periodic tests, tests should also be made when physical damage has been done to the cable; when cables have been disconnected for circuit or equipment changes; when there is evidence that the cable has been subjected to oil or salt water; and after shipboard overhauls.

Interior communication cables may be tested with a 500-volt megger if they are disconnected at the equipment or load end. In some cases, when it is not practical to disconnect the cable, an ohmmeter, or 50-volt tester must be used as described in BuShips Instruction 9650.37A and BuShips Technical Manual, chapter 9650.

GROUND TESTS.—To ground test a multiconductor IC cable, proceed as follows:

1. Check to see that the cable armor is grounded by measuring between the cable armor and the metal structure of the ship; normally, grounding has been accomplished by means of cable straps. If a zero reading is not obtained, ground the cable armor.
2. Select one conductor to be tested, and connect all other conductors in the cable together and ground them by means of temporary wires or jumpers.
3. Measure the resistance of the conductor being tested to ground. The test voltage should be applied until a constant reading is obtained. Hand-driven generator type meggers should be cranked for at least 30 seconds to ensure a steady reading.
4. Repeat steps 2 and 3 as necessary to test each conductor to ground.

A reading equal to, or above the accepted minimum for the cable concerned (discussed later), indicates that the conductor under test is satisfactory. A reading below the accepted minimum indicates that the insulation resistance of the conductor under test to ground, or from one or more of the grounded conductors, or both, is low. The grounded conductors must then be disconnected from ground, and each conductor tested individually to isolate the low reading conductor(s).

An alternate method of ground testing multiconductor cables is to connect all conductors together and measure the insulation resistance from all conductors to ground simultaneously. If this reading is equal to or above the accepted minimum, no other reading need to be taken. If the reading is below the accepted minimum, the conductors must be separated and tested individually to isolate the low reading conductor(s).

Factors Affecting Insulation Resistance

Factors that affect cable insulation resistance measurements are the length, type, and temperature of the cable, and the equipment connected in the circuit. Each of these factors must be evaluated to reliably determine the condition of the cable from the measurements obtained.

LENGTH OF CABLE.—The insulation resistance of a length of cable is the resultant of a number of small individual leakage paths or resistances between the conductor and the

Digitized by Google

cable sheath. These leakage paths are distributed along the cable. Hence, the longer the cable, the greater the number of leakage paths and the lower the insulation resistance. For example, if one leakage path exists in each foot of cable, there will be 10 such paths for current to flow between the conductor and the sheath in 10 feet of cable, and the total amount of current flowing in all of them would be 10 times as great as that which would flow if the cable were only 1 foot long. Therefore, to establish a common unit of comparison, cable-insulation resistance should be expressed in megohms (or ohms) per foot of length. This is determined by multiplying the measured insulation resistance of the cable by its total length in feet.

When measured insulation resistance is converted to insulation resistance per foot, the total length of cable to be used is equal to the length of the cable sheath for single conductor cable and for multiple conductor cable in which each conductor is used in one leg of a circuit. For example, in a TSGA cable with a cable sheath of 100 feet in which the three conductors are phases A, B, and C of a 3-phase power circuit, the total length of the cable is 100 feet, not 300 feet. The reason for this is that each conductor is measured separately. If this cable is connected, either in series or parallel, to a similar cable that has a sheath length of 400 feet, the total length is 500 feet. As another example, 200 feet of type MSCA-7 cable (7-conductor cable) connected to 200 feet of MSCA-24 cable (24-conductor cable) represents a total cable length of 400 feet.

TYPE OF CABLE.—Insulation resistance will vary considerably with the nature of the insulating materials employed and the construction of the cable. Therefore, it is possible to determine the condition of a cable by its insulation resistance measurements only when they are considered in relation to the typical characteristics of the particular type of cable. The minimum safe insulation resistance for types SGA, HF, DG, SCA, TTHFA, and TTHFWA cables is indicated on the reverse side of the Resistance Test Record Card, NavShips 531-1 (fig. 2-32).

TEMPERATURE OF CABLE.—With nonflexing service cables, the highest permissible operating temperature (85°C at the sheath) and the nature of the insulating material makes it essential that temperature of the cable be considered in conjunction with the insulation resistance measurements. Therefore, fairly accurate estimates or measurements of the temperature of the sheath of the cable must be made to permit proper use of the Resistance Test Record Card.

EQUIPMENT CONNECTED.—When insulation resistance measurements are made with equipment connected, always record the exact equipment included, and the type of tester used, so that accurate comparisons can be made with similar past or future measurements.

Replacement of Cable

It is seldom necessary to replace cable due to low insultation resistance readings resulting from other than actual physical damage. Cables having insulation resistance readings below the allowable limits shown on the Resistance Test Record Card, should not be replaced unless all procedures for increasing the readings as described in the BuShips Technical Manual, chapter 9600, have failed. Rusting or physical damage to the armor does not justify replacing the cable provided the impervious sheath is intact.

INSTALLING CABLE

As an IC Electrician you may be required to install electric cables to replace bad or damaged cables, or to accomplish ship alterations. Cable splices are authorized only as an emergency repair. When emergency splices are made they must be replaced at the earliest opportunity with a continuous length of cable or an approved splice accomplished by a repair activity.

Cable Fittings

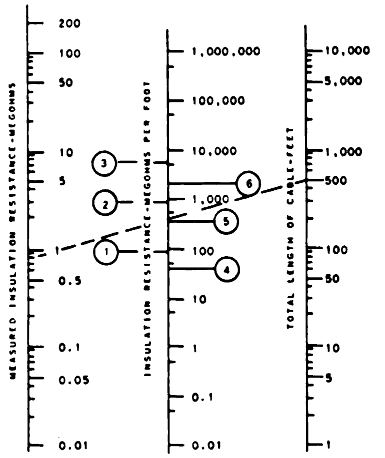
Stuffing tubes (fig. 2-33A, B, and C) are used to provide for entry of electric cables into splashproof, spraytight, submersible, and explosion-proof equipment enclosures, and watertight, airtight, and fume tight bulkheads. Cable connectors (fig. 2-33D), may be used for all other installations.

Digitized by Google

INDEX	CIRCUIT		LENGTH	CARD NO.
S65-1	1MB (MSCA-7)		200'	1

DATE (MO, DA, YR)	MEASURED RESISTANCE MEGS.	RESISTANCE PER FOOT (CABLE) MEGOHMS	AMBIENT TEMP. - ASSUMED (104°F), 70°F, OR 40°F)	REMARKS
10-27-64	A B C 20	4000	70	READINGS TAKEN WITH 500 VOLT MEGGER, TRANSMITTER AND INDICATOR CONNECTED.
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			

RESISTANCE TEST RECORD CARD NAVSHIPS 531-1 (10-63) (FRONT)



NOMOGRAPH FOR OBTAINING RESISTANCE PER. FT.

OBTAINING RESISTANCE PER FOOT - *Example*

Line is drawn on nomograph from 0.8 megohms (measured) to 500 feet (length of cable per card or plans). If points ①, ④, or ⑤ apply, cable is O.K. If points ②, ③, or ⑥ apply, cable may be in poor condition - investigate further.

MINIMUM ALLOWABLE INSULATION RESISTANCE CABLES (MEGOHMS/FT)

	TYPE OF CABLE	
	SGA, HF, DG, SCA	TTHFA, TTHFWA
JUST AFTER SHUTDOWN 104°F	95 (POINT ①)	40 (POINT ④)
↓ EQUIPMENT SECURED 4 OR MORE HOURS		
WARM CLIMATE SUMMER OR ALL IN HEATED SPACE 70°F	920 (POINT ②)	380 (POINT ⑤)
COLD CLIMATE WINTER OR AGAINST COLD HULL 40°F	5500 (POINT ③)	2200 (POINT ⑥)

RESISTANCE TEST RECORD CARD NAVSHIPS 531-1 (10-63) (REVERSE) C-33884

1.3

Figure 2-32.—Resistance Test Record Card.

Digitized by Google

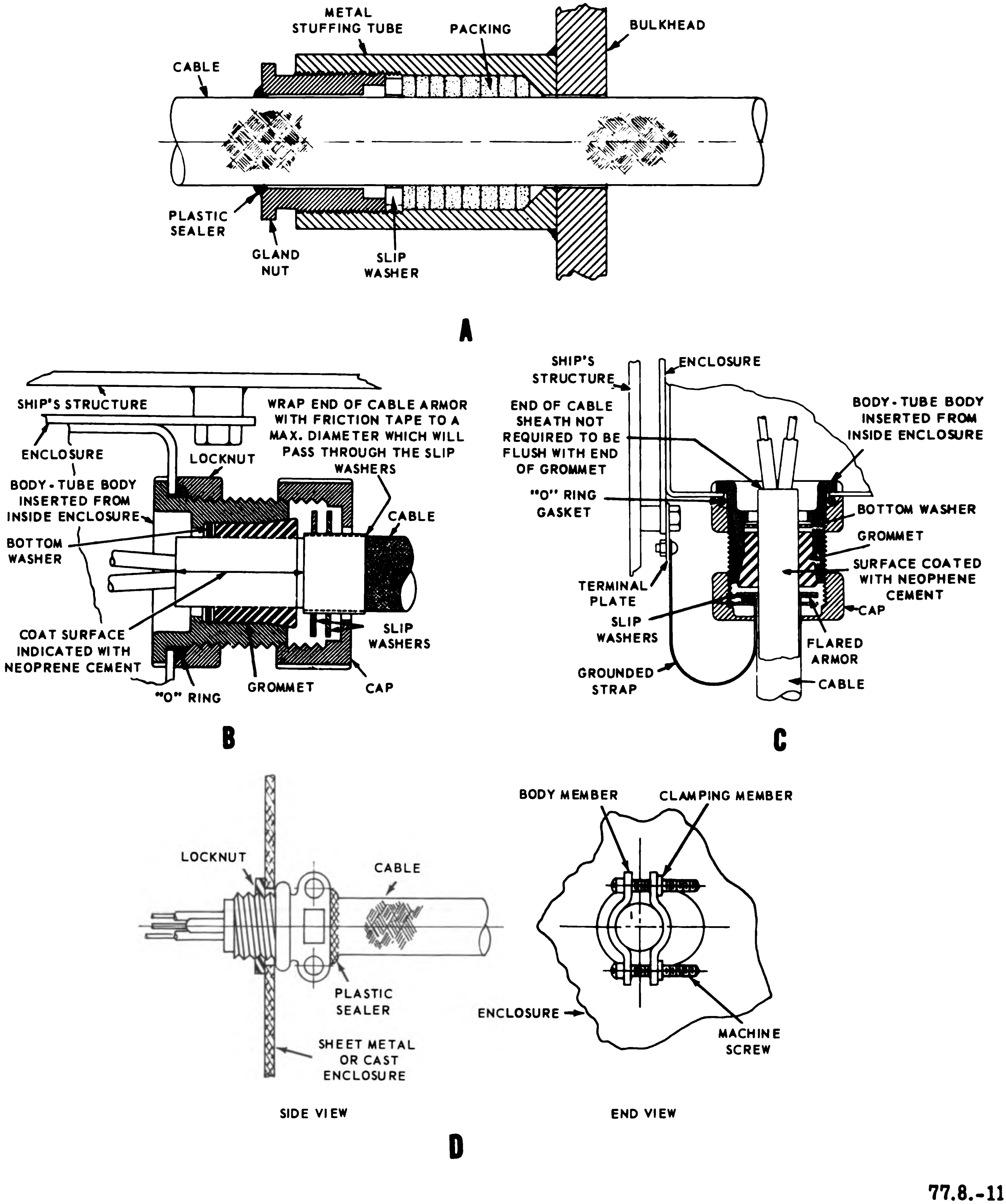


Figure 2-33.—Electric cable fittings.

Digitized by Google

Metal stuffing tubes (fig. 2-33A), are made of steel, brass, or aluminum alloys. They are available in 23 different sizes to accommodate cables up to approximately 3 1/4" in diameter.

Nylon stuffing tubes (fig. 2-33B & C) are replacing the metal tubes for cable entry into equipment enclosures, and also in bulkhead installations where the thickness of the bulkhead does not exceed 3/16".

The watertight seal between the entrance to the enclosure and nylon body of the stuffing tube is made with a neoprene "O" ring, which is compressed by a nylon locknut (fig. 2-33B). A grommet-type, neoprene packing is compressed by a nylon cap to accomplish a watertight seal between the body of the tube and the cable. Two slip washers act as compression washers on the grommet as the nylon cap of the stuffing tube is tightened. Grommets of the same external size, but with different sized holes for the cable, are available. This allows a single-size stuffing tube to be used for a variety of cables sizes, and makes it possible for nine sizes of nylon tubes to replace 23 sizes of aluminum, steel, and brass tubes.

The nylon stuffing tube is available in two parts. The body "O" ring, locknut, and cap comprise the tube; and the rubber grommet, two slip washers, and one bottom washer comprise the packing kit.

A nylon stuffing tube is applicable to both watertight and nonwatertight enclosures. Note that the tube body is inserted from inside the enclosure. The end of the cable armor is wrapped with friction tape to a maximum diameter which will pass through the slip washers.

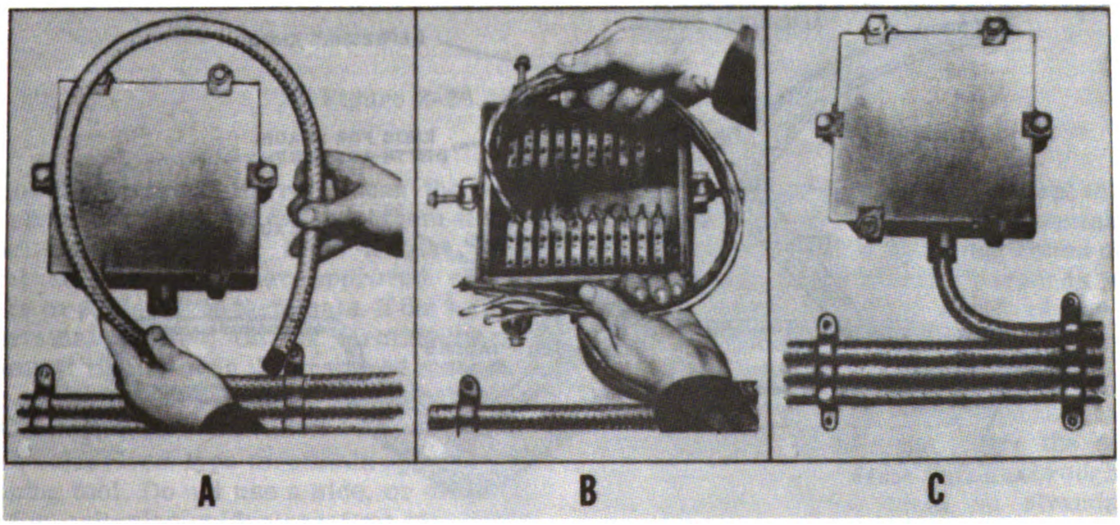
To ensure a watertight seal, one coat of neoprene cement is applied to the inner surface of the rubber grommet and to the cable sheath where it will contact the grommet. After the cement is applied, the grommet is immediately slipped onto the cable. The paint must be cleaned from the surface of the cable sheath before applying the cement.

Sealing plugs are available for sealing nylon stuffing tubes from which the cables have been removed. The solid plug is inserted in place of the grommet, but the slip washers are left in the tube.

A grounded installation that provides for cable entry into an enclosure equipped with a nylon stuffing tube is shown in figure 2-33C. This type of installation is required only when radio interference tests indicate that additional grounding is necessary within electronic spaces.

Connecting Cable

When connecting a newly installed cable to a junction box or unit of IC equipment, the length of the cable must be carefully estimated to ensure a neat installation, (fig. 2-34). Sufficient cable must be stripped for proper



140.15

Figure 2-34.—Connecting cable to a junction box.

Digitized by Google

routing and termination of the conductors. The conductors must be routed inside the enclosure with sufficient extra length allowed for re-termination at least three times, (fig. 2-34B). Excessive bends or slack in the cable must be avoided, (fig. 2-34C). The minimum radius of bend for an electric cable is equal to approximately six times the diameter of the cable.

STRIPPING CABLE.—The cable armor may be removed by using a cable stripper of the type shown in figure 2-35. Care must be taken not to cut or puncture the cable sheath where the sheath will contact the rubber grommet of the nylon stuffing tube. If either a metal stuffing tube or cable connector is used, allow the cable (with armor) to extend at least one-eighth of an inch through the tube.

Next, remove the impervious sheath, starting a distance of at least 1 1/4 inch (or as necessary to fit the requirements of the nylon stuffing tube) from where the armor terminates. The cable stripper should be used for this job. Do not take a deep cut because the conductor insulation can be easily damaged. Flexing the cable will help separate the sheath after the cut has been made. Clean the paint from the surface of the remaining impervious sheath exposed by the removal of the armor. This paint is conducting. It is applied during manufacture of the cable and passes through the armor onto the sheath. Once the sheath has been removed, the cable filler can be trimmed with a pair of diagonal cutters.

CABLE ENDS.—When a cable is terminated in an enclosed equipment through a metal stuffing tube, the cable jacket must be tapered, and the cable crotch filled with plastic sealer. The tapered section is then wrapped with synthetic resin tape, and the end of the tape served with treated glass cord.

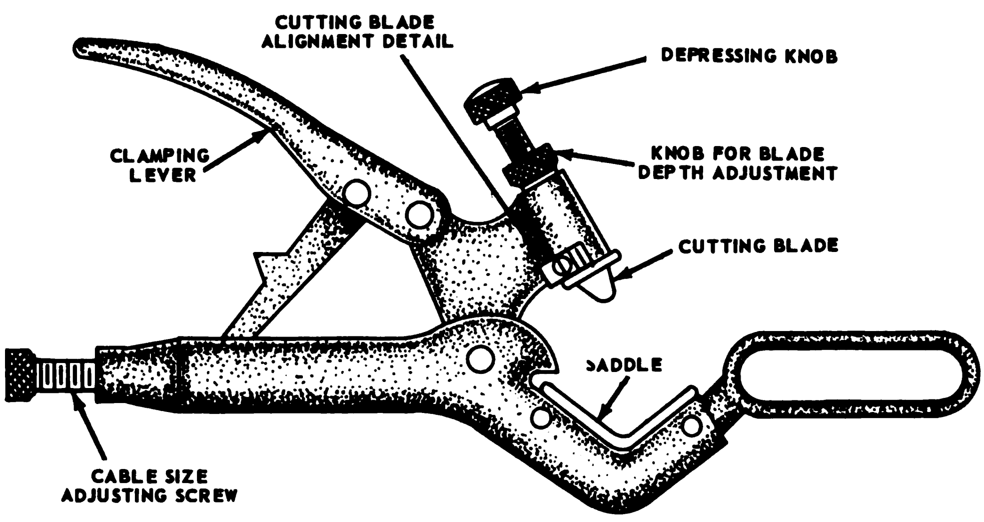
When a cable is terminated in an enclosed equipment through a nylon stuffing tube, the cable jacket is cut square and allowed to protrude through the grommet as shown in figure 2-33B and C.

When a connector is used for cable termination, the armor is cut back and taped, and the square cut jacket allowed to protrude through the connector about 1/8" as shown in figure 2-33D.

The ends of cables terminating in open equipment are tapered, taped, served with cord and varnished, as shown in figure 2-36.

CONDUCTOR ENDS.—Wire strippers (fig. 2-37) are used to strip insulation from the conductors. Care must be taken to avoid nicking the conductor while removing the insulation. Side, or diagonal, cutters should not be used for stripping insulation from conductors.

Conductor surfaces must be thoroughly cleaned before terminals are applied. After baring the conductor end for a length equal to the



77.22

Figure 2-35.—Cable strippers.

Digitized by Google

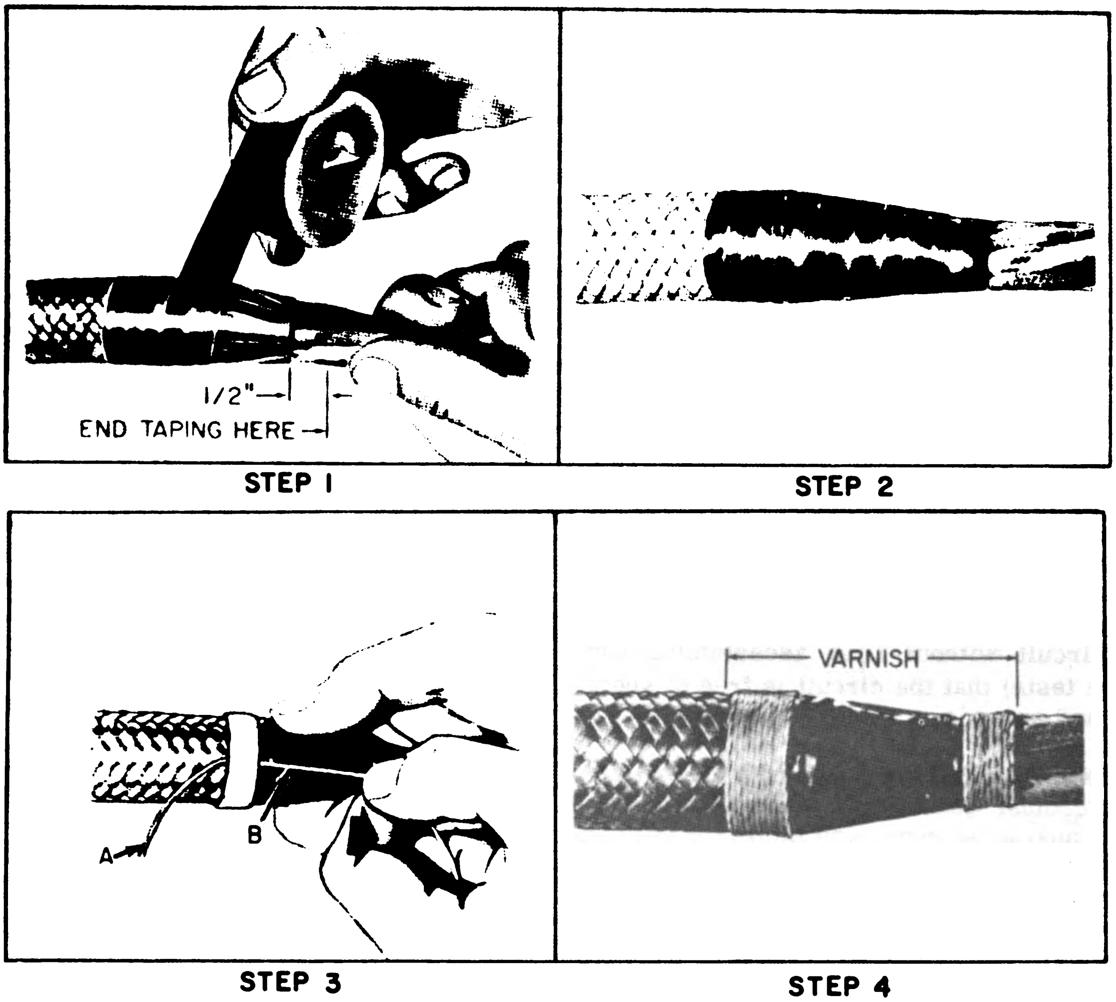


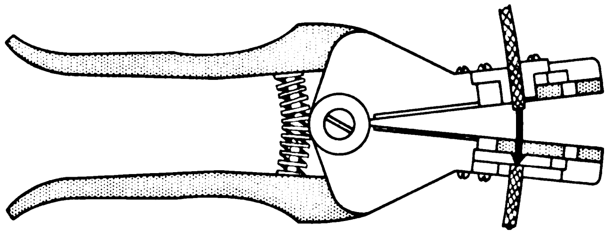
Figure 2-36.—Preparing cable ends.

length of the terminal barrel, clean the individual strands thoroughly and twist them tightly together. Solder them to form a neat, solid terminal for fitting either approved clamp-type lugs or solder-type terminals. If the solder-type terminal is used, tin the terminal barrel and clamp it tightly over the prepared conductor (before soldering) to provide a solid mechanical joint. Conductor ends need not be soldered for use with solderless-type terminals applied with a crimping tool. Do not use a side, or diagonal, cutter for crimping solderless-type terminals.

Solderless-type terminals may be used for all lighting, power, interior communications, and fire-control applications, except with equipment provided with solder-type terminals by the manufacturer, and with wiring boxes or equipment in which electrical clearances would be reduced below minimum standards by the use of the solderless-type terminal.

For connection under a screwhead where a standard terminal is not practicable, an alternate method can be used. Bare the conductor for the required distance and thoroughly clean the strands. Then twist the strands tightly together, bend them around a mandrel to form a suitable size loop (or hook where the screw is not removable), and dip the prepared end into

Digitized by Google



1.24
Figure 2-37.—Mechanical wire strippers.

solder. Remove the end, shake off the excess solder, and allow it to cool before connecting it.

After the wiring installation has been completed, the insulation resistance of the wiring circuit must be measured with a megger or similar (0-100 megohm, 500 volt d-c) insulation resistance measuring instrument. Do not energize a newly installed, repaired, or modified wiring circuit without first ascertaining (by insulation tests) that the circuit is free of short circuits and grounds.

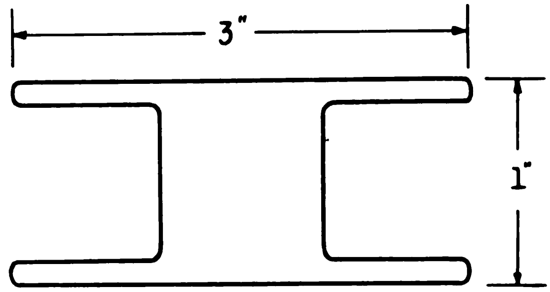
LACING CONDUCTORS.—Conductors within equipment must be kept in place in order to present a neat appearance and facilitate tracing of the conductors when alterations or repairs are required. When conductors are properly laced, they support each other and form a neat, single cable.

The most common lacing material is waxed cord. The amount of cord required to single lace a group of conductors is approximately 2 1/2 times the length of the longest conductor in the group. Twice this amount is required if the conductors are to be double laced.

Before lacing, lay the conductors out straight and parallel to each other. Do not twist them together because twisting makes conductor lacing and tracing difficult.

A shuttle on which the cord can be wound will keep the cord from fouling during the lacing operations. A shuttle similar to the one shown in figure 2-38 may easily be fashioned from aluminum, brass, fiber, or plastic scrap. Rough edges of the material used for the shuttle should be smoothed.

To fill the shuttle for single lace, measure the cord, cut it, and wind it on the shuttle. For double lace, proceed as before, except

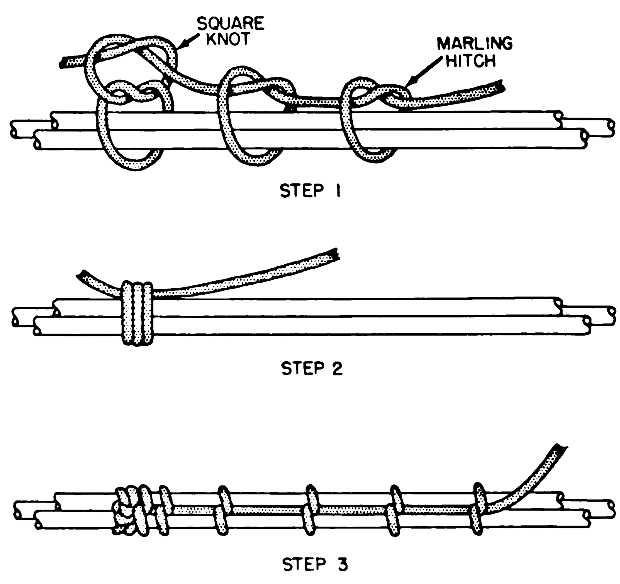


5.138
Figure 2-38.—Lacing shuttle.

double the length of the cord before winding it on the shuttle, and start the ends on the shuttle in order to leave a loop for starting the lace.

Some installations, however, require the use of twisted wires. One example is the use of "twisted pairs" for the a-c filament leads of certain electron tube amplifiers to minimize radiation of their magnetic field, thus preventing annoying hum in the amplifier output. You should duplicate the original layout, when replacing such twisted leads, and when relacing any wiring harness.

Single lace may be started with a square knot and at least two marling hitches drawn tight. Details of the square knot and the marling hitch are shown in figure 2-39. Do not confuse



12.247
Figure 2-39.—Applying single lace.

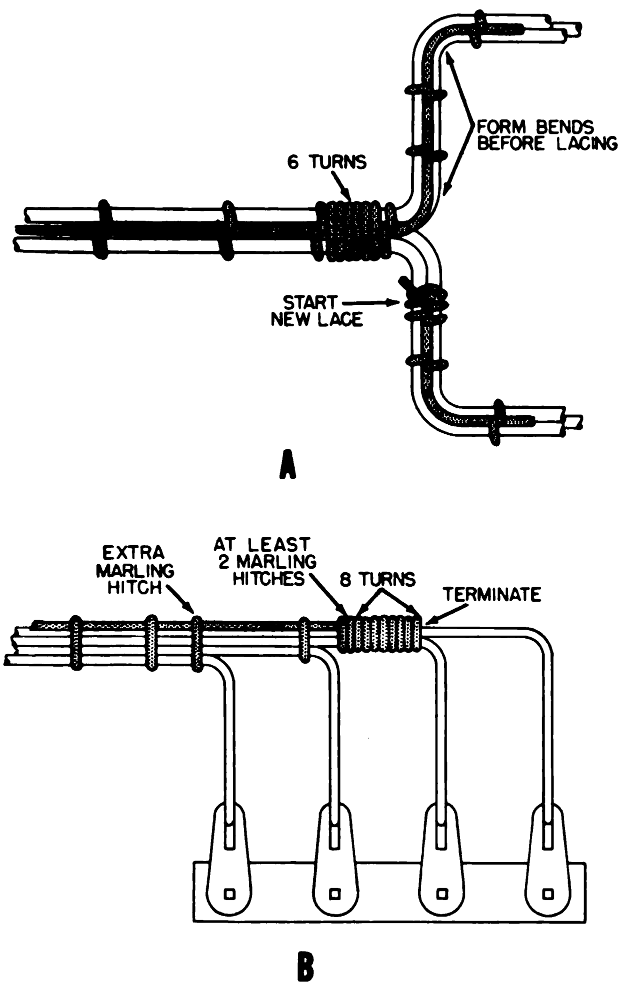
Digitized by Google

the marling hitch with a half hitch. In the marling hitch, the end is passed over and under the strand (step 1). After forming the marling hitches, draw them tight against the square knot (step 2). The lace consists of a series of marling hitches evenly spaced at one-half to one-inch intervals along the length of the group of conductors, as indicated in step 3.

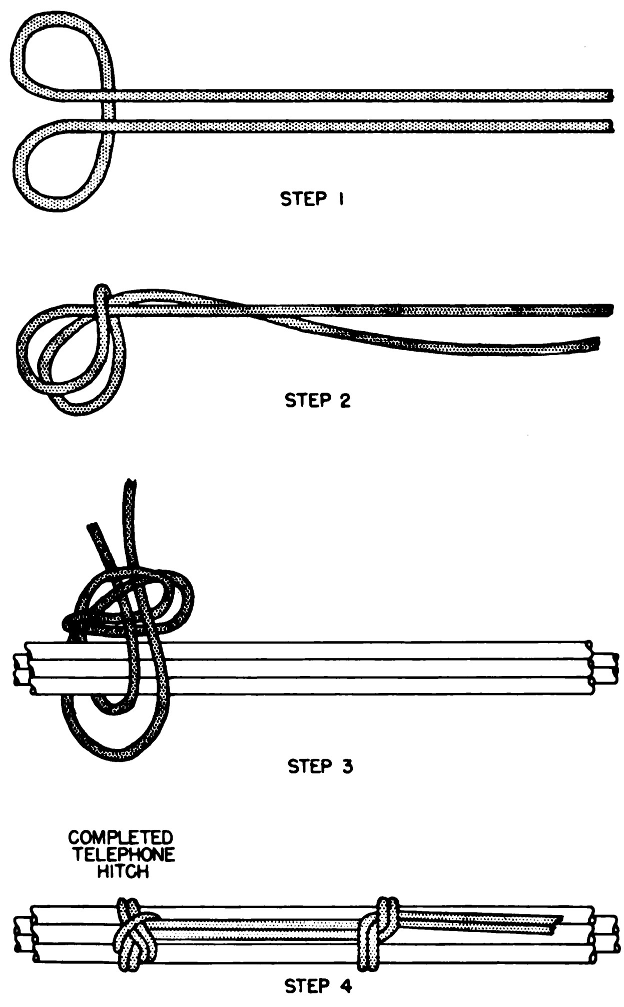
When dividing conductors to form two or more branches, follow the procedure illustrated in figure 2-40. Bind the conductors with at least six turns between two marling hitches, and continue the lacing along one of the branches (fig. 2-40A). Start a new lacing along the other branch. To keep the bends in place, form them in the conductors before lacing. Always add an extra marling hitch just prior to a breakout (fig. 2-40B).

Double lace is applied in a manner similar to single lace, except that it is started with the telephone hitch and is double throughout the length of the lacing (fig. 2-41). Double as well as single lace may be terminated by forming a loop from a separate length of cord and using it to pull the end of the lacing back underneath a serving of approximately eight turns (fig. 2-42).

Lace the spare conductors of a multiconductor cable separately, and secure them to active conductors of the cable with a few telephone

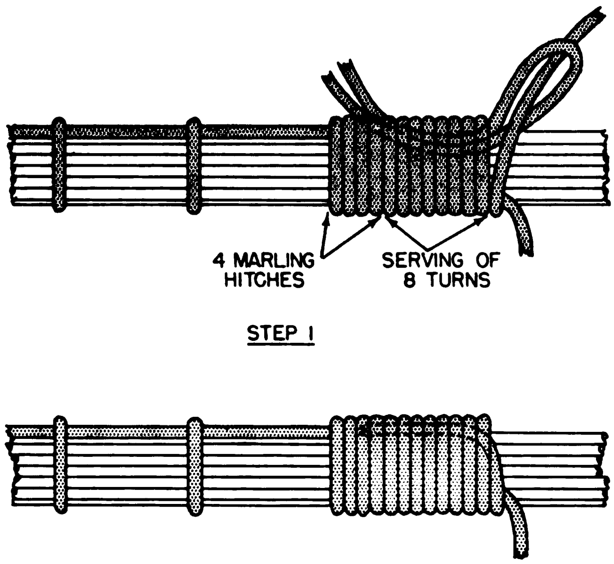


12.247
Figure 2-40.—Lacing branches and breakouts.



5.139.1
Figure 2-41.—Starting double lace with the telephone hitch.

Digitized by Google



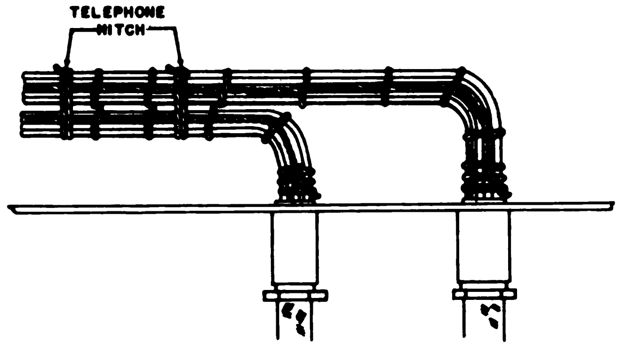
5.140.1
Figure 2-42.—The loop method of terminating the lace.

hitches. When two or more cables enter an enclosure, each cable group should be laced separately. When groups parallel each other, they should be bound together at intervals with telephone hitches (fig. 2-43).

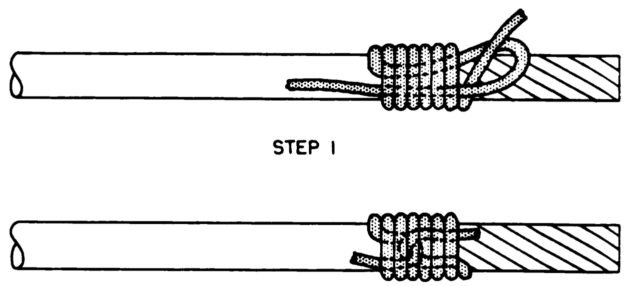
Conductor ends (3000 cm or larger) should be served with cord to prevent fraying of the insulation (fig. 2-44).

A nylon spiral wrap (fig. 2-45) is being used in some IC and electronic installations which eliminates the need for lacing multiconductor cables. The spiral wrap is easy to install, and a conductor breakout may be made at any point along the form while installing.

The Cable Comparison Guide, NavShips 250-660-23 contains the cable characteristics and installation data for all types of shipboard electric cables. Table 2-2 presents this information for type MSCA cable.



5.139
Figure 2-43.—Binding cable groups with the telephone hitch.



5.140.2
Figure 2-44.—Serving conductor ends.

Table 2-2.—Characteristics and Installation Data for Interior Communications and Fire Control Cable, Type MSCA.

Cable Size Designation	Number of Conductors	Strands Per Conductor	C.M. Area of Conductor	Diameter of Conductor	Cable Diameter (Outside)	Maximum Rating 50°C	
No.	No.	No.	C.M.	Inch	Inch	VRMS	Amps
7	7	7	1779	0.048	0.534	600	*9/6
10	10	7	1779	0.048	0.672	600	*9/6
14	14	7	1779	0.048	0.718	600	*9/6

Digitized by Google

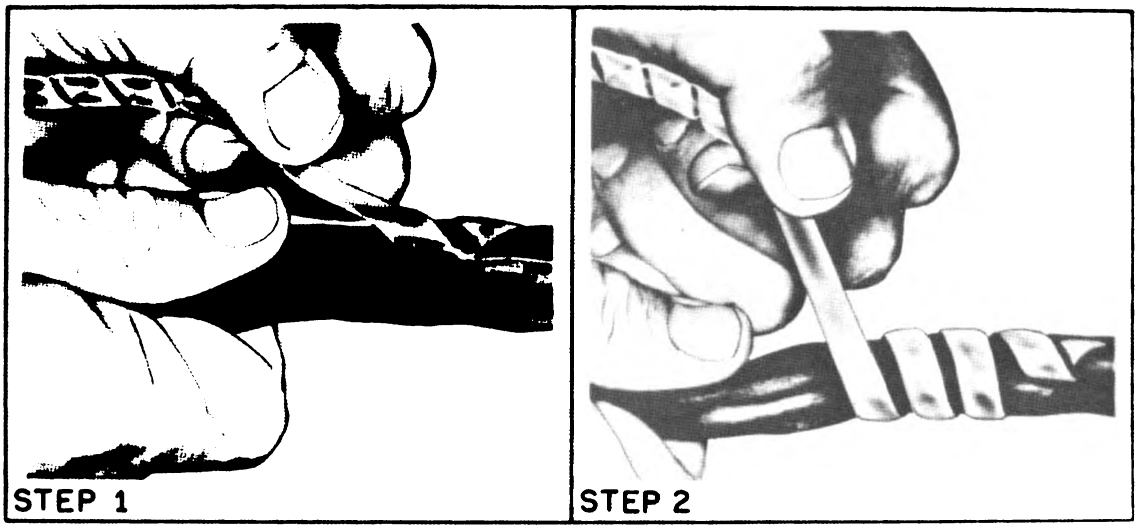
Table 2-2.—Characteristics and Installation Data for Interior Communications and Fire Control Cable, Type MSCA—Continued

Cable Size Designation	Number of Conductors	Strands Per Conductor	C.M. Area of Conductor	Diameter of Conductor	Cable Diameter (Outside)	Maximum Rating 50°C	
No.	No.	No.	C.M.	Inch	Inch	VRMS	Amps
19	19	7	1779	0.048	0.788	600	*9/6
24	24	7	1779	0.048	0.905	600	*9/5
30	30	7	1779	0.048	0.951	600	*9/5
37	37	7	1779	0.048	0.022	600	*9/5
44	44	7	1779	0.048	1.134	600	*9/4

* Denotes individual and average values

Cable Size Designation	Bend Radius (Minimum)	Metal Tube Size	Box Connector Size	Nylon Tube Size	Nylon Tube Packing Assembly	Synthetic Rubber Grommet	Kickpipe Size
No.	Inch	No.	Inch	No.	MS No.	Inch	Inch
7	3.5	C	3/8A	2	16178-5	1/2	3/4
10	4.0	D	3/4	4	16179-4	3/4	3/4
14	4.5	D	3/4	4	16179-5	3/4	3/4
19	5.0	F	3/4	4	16179-7	3/4	1
24	5.5	G	1S	5	16189-2	1	1
30	6.0	J	1	5	16189-3	1	1-1/4
37	6.0	J	1-1/4	5	16189-4	1	1-1/4
44	7.0	K	1-1/4	5	16189-7	1-1/4	1-1/4

Digitized by Google



140.16

Figure 2-45.—Installing nylon spiral wrap.

Digitized by Google

CHAPTER 3

POWER DISTRIBUTION SYSTEMS

This chapter discusses the Ship Service, Emergency, and Casualty power distribution systems aboard Navy ships. Power distribution switchboards and the operation of the electric plant are discussed briefly.

The chapter also includes a discussion of Interior Communication switchboards, and presents information concerning their operation and maintenance.

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 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.

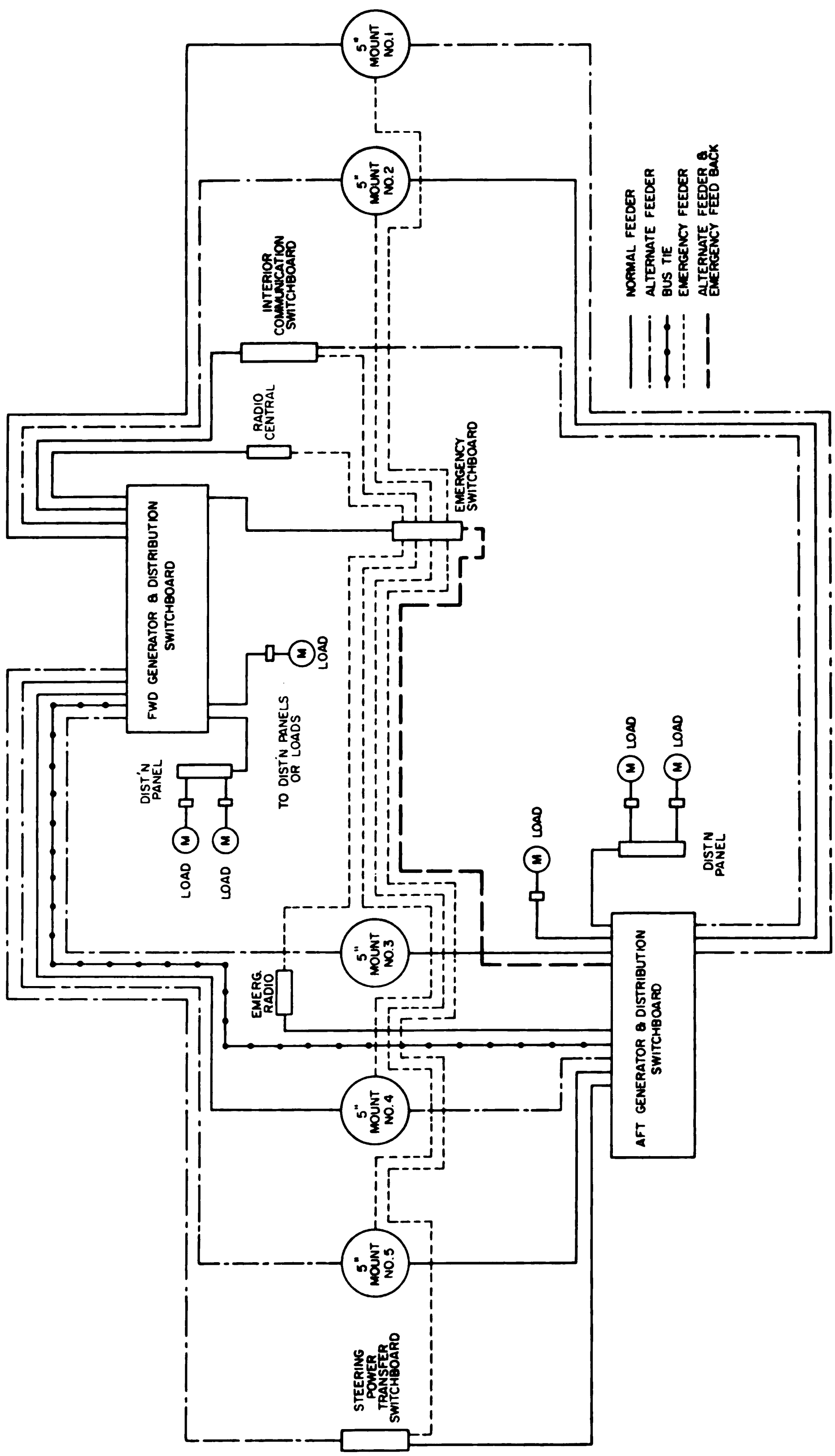
In smaller installations (fig. 3-1), the distribution panels are fed directly from the generator control and distribution switchboards. The distribution panels and load centers (if any) are located centrally with respect to the loads that they feed. This arrangement simplifies the installation and requires less weight, space, and equipment than if each load were connected to a switchboard.

POWER CIRCUITS

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; or NORMAL and ALTERNATE ship service feeder, and an EMERGENCY feeder, (fig. 3-1).

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.

Digitized by Google



65.54

Figure 3-1.—Power distribution in a destroyer.

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: AB, BC, and then CA. 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 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.

Digitized by Google

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, 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 switchboard. Each emergency switchboard is supplied by its associated emergency generator.

FEEDERS

The emergency feeders run from the emergency switchboards (fig. 3-1), 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. 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 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. 3-1), 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.

Digitized by Google

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 end 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.

RIGGING AND UNRIGGING CASUALTY POWER CABLES

There are definite procedures that must be followed and safety precautions that must be observed in rigging casualty power. Only qualified personnel should do the actual connecting: however, the portable cables may be laid out by other personnel. Safety precautions require the man making the connections to wear rubber gloves, and to stand on a rubber mat or wear rubber boots while making connections. He is further required to test each casualty power riser or bulkhead terminal with a voltage tester before making a connection. The portable cable connections for casualty power should always be made by first connecting at the load, then working back to the source of power. In making casualty power connections at a load where there are no circuit breakers or transfer switches to interrupt the incoming feeder cable, it must be disconnected or cut at the equipment. It is quite possible that this cable may be damaged by the casualty which caused the loss of power, and such a damaged cable if energized would probably trip the casualty power circuit breakers. If not disconnected, this incoming feeder cable may be reenergized and present a hazard to personnel handling the casualty power cables. Care should be exercised, in making all connections to keep the phase sequence correct in a-c systems. If the load includes motors in either a-c or d-c systems, the connections should be made so as to include the motor controller in the circuit.

Casualty power cables should be tied to the overhead and high voltage signs should be attached at each connection. Also, it is common practice to pass the word over the ship's 1MC system, informing all hands to stand clear of the casualty power cables after they are energized.

Unrigging casualty power is also hazardous if not handled correctly. The recommended procedure is for the Electrician's Mate on the switchboard at the source of the casualty power supply to open the 225 or 250 ampere AQB circuit breaker behind the switchboard that supplies the system, and to remove both ends of the first cable nearest the source. After this has been done, both ends of the last cable in the system that connects to the load are disconnected and removed. The normal feeder or feeders may now

Digitized by Google

be reenergized to the equipment, and the remainder of the casualty power cables are unrigged and restowed on the proper racks.

D-C ELECTRIC POWER SYSTEMS

Although a-c power systems have replaced d-c power systems in combat ships, d-c power is still used in auxiliary vessels having considerable deck machinery. The d-c power systems in auxiliary vessels are not ordinarily required to maintain the high degree of reliability required for combat ships. However, the degree of reliability is carried out within the limits of practicability and depends on the type and size of the vessel.

The d-c electric power systems installed in surface vessels are the (1) low-voltage system, (2) 120-volt, 2-wire system, and (3) 120/240-volt, 3-wire system.

LOW-VOLTAGE SYSTEM

The low-voltage (12-volt or 24-volt) system is installed in motor torpedo boats, small landing craft, and small boats. Power is supplied by generators that are driven by the propulsion engines or by small auxiliary engines. Storage batteries are used to supply power to the system when the generators are not operating.

120-VOLT, 2-WIRE SYSTEM

The 120-volt, 2-wire system is usually installed in ships in which the total electrical load is small or in ships in which the 120-volt load is the major part of the connected load. The power loads are usually supplied by feeders running directly from the switchboard. The lighting in the forward and after part of the ship is usually supplied by feeders running to lighting distribution boxes located near the centers of the forward and after loads.

120/240-VOLT, 3-WIRE SYSTEM

The 120/240-volts, 3-wire system was formerly installed in all large surface vessels. This system is still in use in older ships and in converted merchant ships with large deck machinery loads that warrant the use of d-c power. The 120/240 volt, 3-wire system is lighter in weight, smaller in size, and more efficient in operation than the 120-volt, 2-wire system.

In the 3-wire system the power is generated either by a 120/240-volt, 3-wire, d-c generator with an internally mounted balance coil or a converted 240-volt, 2-wire, d-c generator provided with an externally mounted transformer balancer (center tapped autotransformer) connected through slip rings to tapping points on the generator armature, which establishes a neutral. The present Navy practice is not to ground the neutral (or either leg) of a 3-wire system. The positive, neutral, and negative polarities of bus bars and terminals are indicated + (black), ± (white), and - red respectively.

Power distribution from the switchboards to the power loads is a 240-volt, 2-wire system. The 120-volt distribution from the switchboards to the distribution panels is a 120/240-volt, 3-wire system and from the distribution to the branch circuits is a 120-volt, 2-wire system.

POWER DISTRIBUTION SWITCHBOARDS

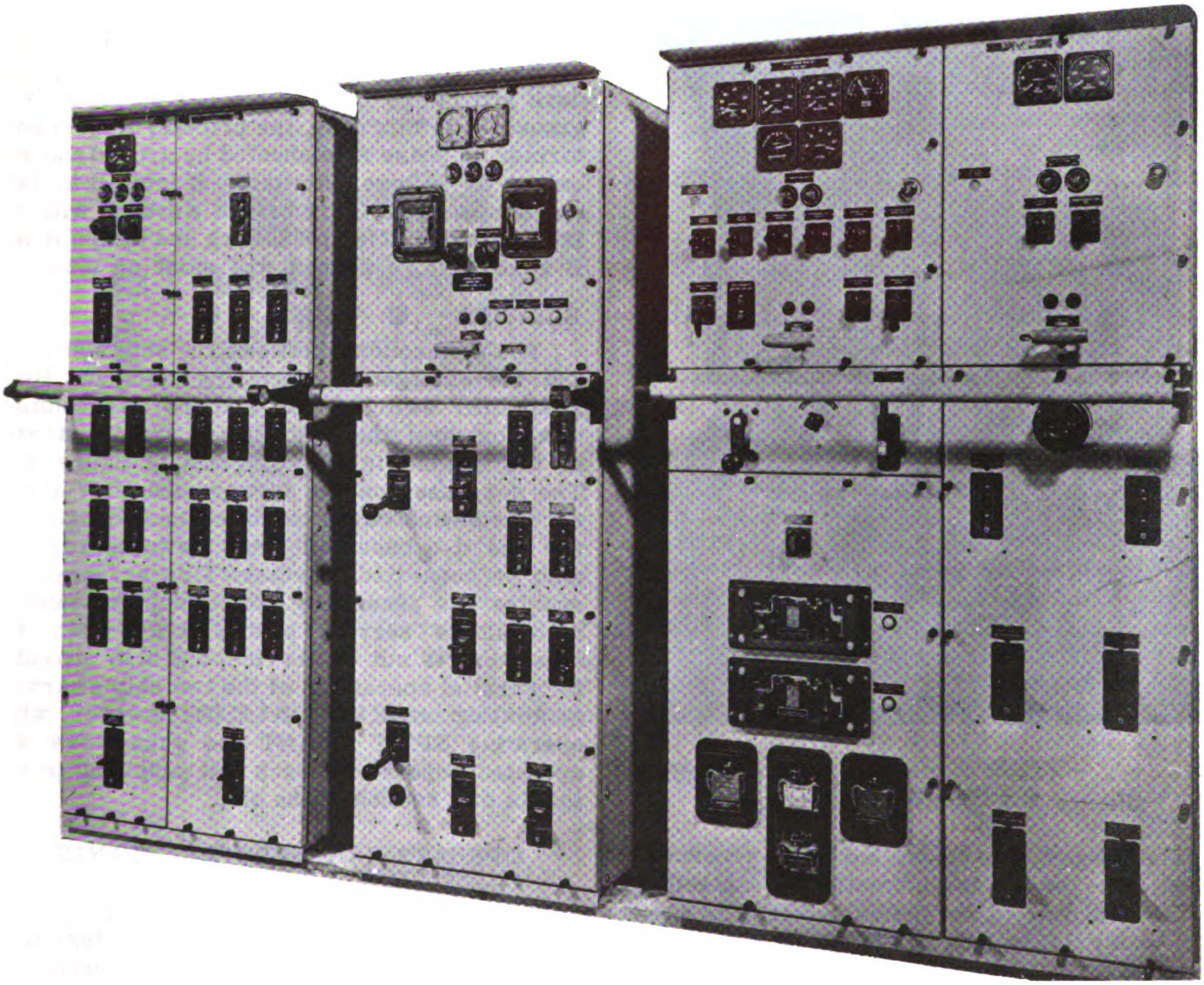
A switchboard may consist of a single section or of several sections that are physically separated and are connected by cables to form a switchgear group. This arrangement provides sufficient separation between sections to minimize damage from shock, to LOCALIZE damage from fire, and to permit easy removal of damaged sections for repairs or replacement.

On dead-front switchboards (fig. 3-2) 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 seperate control benchboard (fig. 3-3) 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

Digitized by Google



77.166

Figure 3-2.-Dead-front switchboard.

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

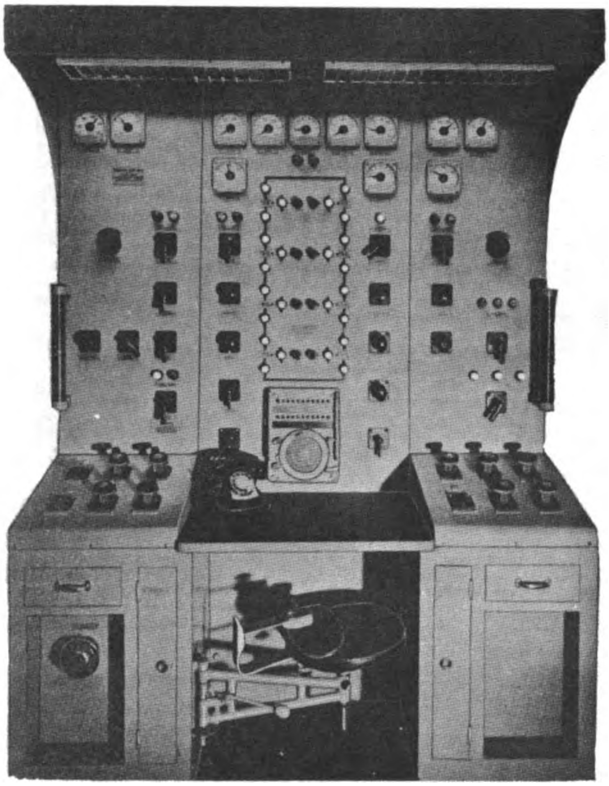
The ship's service switchboards in a destroyer, consist of switchgear groups 1S and 2S (fig. 3-4), located in the forward and after engine rooms, respectively.

The forward ship's service switchgear group (fig. 3-4A) 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. 3-4B) 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.

Digitized by Google



27.65.1
Figure 3-3.-Control benchboard.

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.

GROUND DETECTOR LAMPS

A set of three ground detector lamps (fig. 3-5) is connected (through transformers) to the main bus of each ship's service switchgear group and to the emergency bus, enabling the switchboard watch 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 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 3-6. 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.

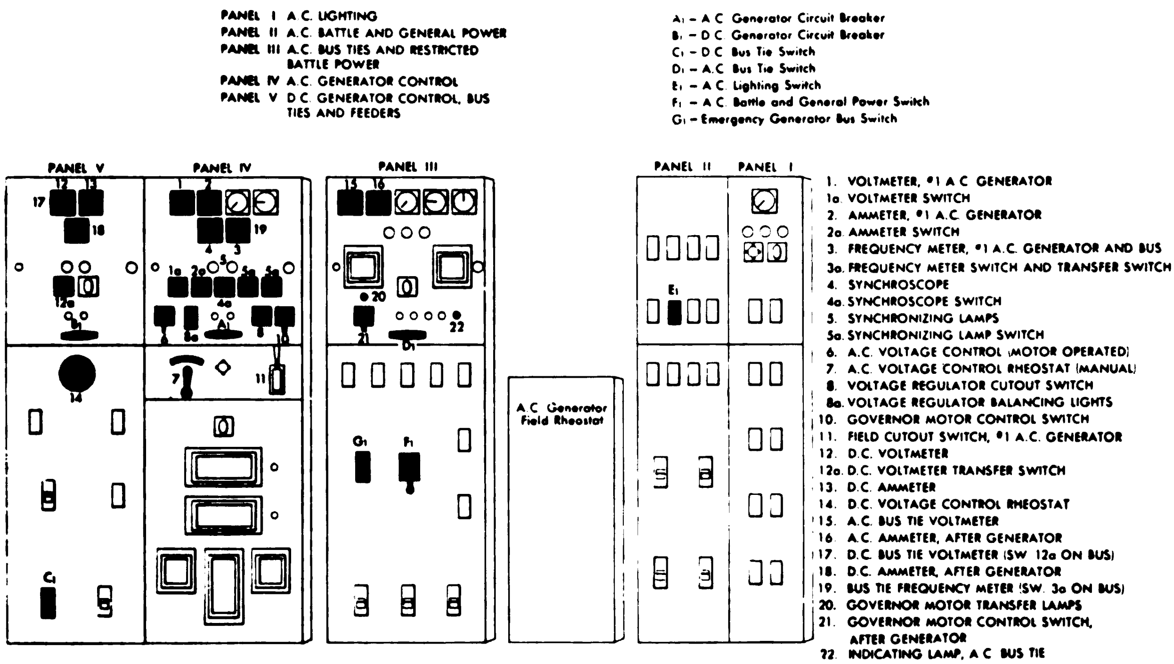
OPERATION OF ELECTRIC PLANTS

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 plant) or separately (split plant).

CROSS PLANT (PARALLEL)

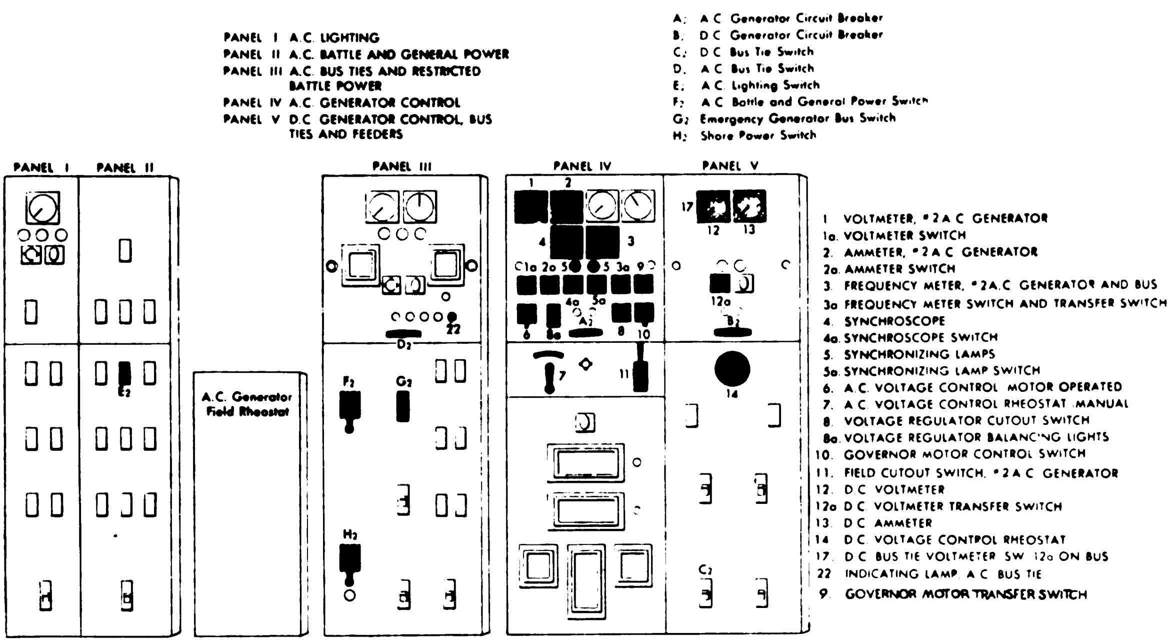
The setup for cross connected plant operation requires that bus-ties between the ship's service switchboards be closed with the generators running in parallel so that any switchboard or several switchboards can supply electric power to any other switchboard. However, when the plant is operating cross 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.

Digitized by Google



77.167.1

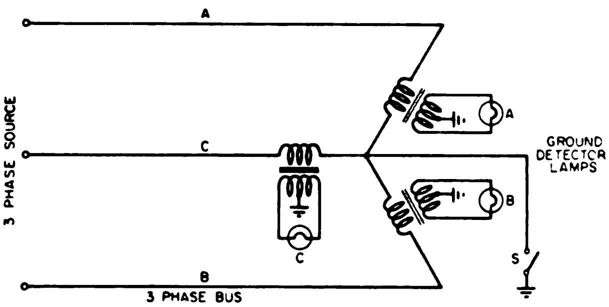
Figure 3-4A.—Forward generator and distribution switchboard (1S).



77.167.2

Figure 3-4B.—After generator and distribution switchboard (2S).

Digitized by Google



77.172
Figure 3-5.—A-c ground detector lamp circuit.

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 breakers are closed for both the normal and alternate supplies. Thus, if there is a casualty to one generator plant, power will be immediately available at the manual transfer switch for this vital equipment by means of the alternate power supply from the other generator plant.

The circuit breakers are closed on the bus-tie feeders between the ship's service switchboards and the emergency switchboards to permit the utilization of the emergency system as an additional means of distributing power from the ship's service generators. If a loss of ship's service power occurs on these bus-tie feeders automatic starting of the emergency generators provides emergency power for the vital loads.

Hence, during war cruising, the normal setup is to operate each generating plant separately, each one feeding its associated switchboard or switchboards. This setup provides independent generating plants, each receiving steam from an associated group of boilers, and one or more emergency diesel generators standing by to take over the emergency load. The diesel emergency generators are set for automatic starting.

EMERGENCY GENERATOR

Emergency diesel generators can be stopped only from within the space where the generator is located. Also, it is usually necessary to set up manually the lube oil alarm after the diesel starts.

The automatic starting of emergency diesel generators should be secured when shifting from ship to shore power, or vice versa. Emergency generators must not be operated in parallel with each other with ship's service generators, 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 and diesel should be set up for automatic starting, if desired.

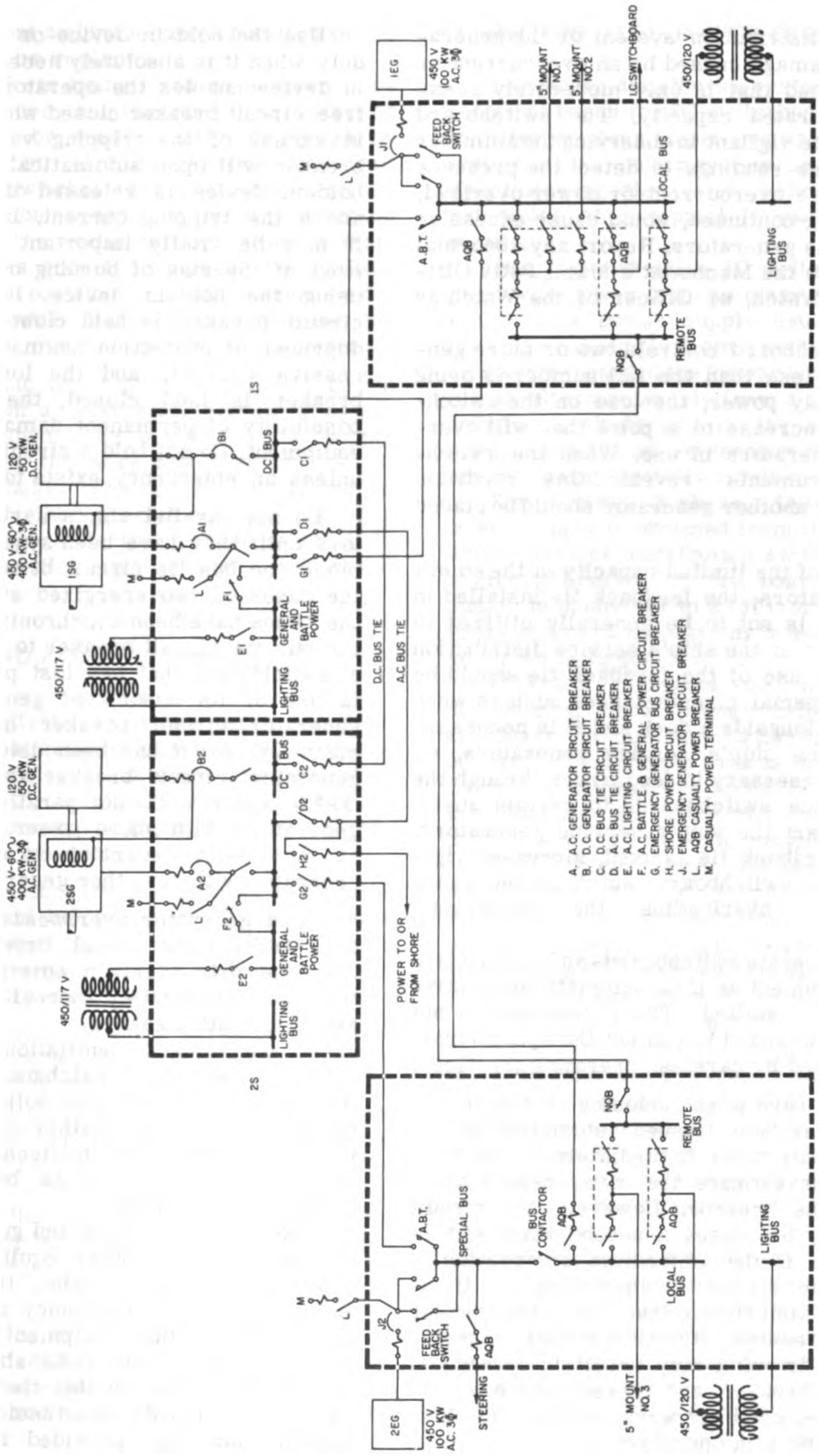
GENERAL RULES AND SAFETY PRECAUTIONS

In the operation of any shipboard electrical installation the assigned switchboard watch must 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 current 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 equipment supplied with electric power.

Operating personnel must realize that no automatically operated devices are installed to

Digitized by Google



77.169

Figure 3-6.—Ship's service and emergency switchboard interconnections.

Digitized by Google

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 watch must be vigilant in observing the ammeter and wattmeter readings to detect the presence of a moderate overcurrent or power overload, which, if long continued, would cause excessive heating of the generators. Report any abnormal indications to the Machinist's Mate, Petty Officer of the Watch, or Officer of the Watch as appropriate.

If a switchboard controls two or more generators and less than the full number is being used to supply power, the load on the switchboard may increase to a point that will overload the generators in use. When the switchboard instruments reveal this condition approaching, another generator should be placed in service.

Because of the limited capacity of the emergency generators, the feedback tie installed in some ships is not to be generally utilized to supply power to the ship's service distribution system. The use of the feedback tie should be limited to special circumstances such as when the ship is alongside a dock and it is necessary to secure the ship's service generators, or when it is necessary to feed power through the ship's service switchboards to certain auxiliaries to start the ship's service generators. When the feedback tie is used, increased vigilance of the switchboard watch is necessary to prevent overloading the emergency generators.

Always operate switchboards and distribution system equipment as if no automatic protective devices are installed. These devices are not designed or intended to protect the system from damage caused by careless operating practices.

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 may be closed a second time without investigation if the immediate restoration of power to the circuit is important and if the interrupting disturbance that tripped the breaker was 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 value. 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 circuit is deprived of protection against damage by excessive current, and the longer the 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.

Do not parallel ship's service a-c generators until they have been synchronized. Do not close the bus tie circuit breakers to parallel the buses on two energized switchboards until the buses have been synchronized. Do not close the bus tie circuit breaker to restore power to a switchboard that has lost power because of failure of its associated generator until the generator circuit breaker has been tripped manually, or it has been determined that the generator circuit breaker is already in the OPEN position. Do not parallel ship's service generators with shore power. Do not parallel an emergency generator or a casualty power generator with any other generator.

If a generator overspeeds, whether a-c or d-c, turbine or diesel driven, immediately trip the prime mover emergency overspeed trip and immediately thereafter trip the generator circuit breaker.

Do not adjust a ventilation opening (for the personal comfort of watchstanders) to a position that permits spray or solid water (entering the system through weather openings) from the ventilating system to be discharged on switchboards, distribution panels, bus bars, or other electrical equipment.

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 ensure that they are secure and will not become dislodged accidentally. The insulating mattings provided for covering the

Digitized by Google

deck in the front and in the rear of switchboards should always be in place.

When work is being done on a circuit, be careful to ensure 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 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.

IC AND ACO SWITCHBOARDS

The IC 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 IC 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 IC switchboards are provided. One switchboard is located in the forward IC room, and the other switchboard is located in the after IC room. Thus, each system or equipment receives its normal supply from the nearer IC switchboard. The after main IC 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 IC and action cutout (ACO) switchboards are installed. In new construction ships, IC switchboards are composed of power control distribution, and ACO sections.

IC SWITCHBOARD POWER SUPPLY

The power distribution systems and arrangements of buses for IC switchboards vary widely in different ships, depending upon the size of the ship, the main power system, and the FC system. The following discussion describes the general principles of a typical IC switchboard power supply.

The forward main IC 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 IC switchboard through the bus-transfer switch, as shown in figure 3-7.

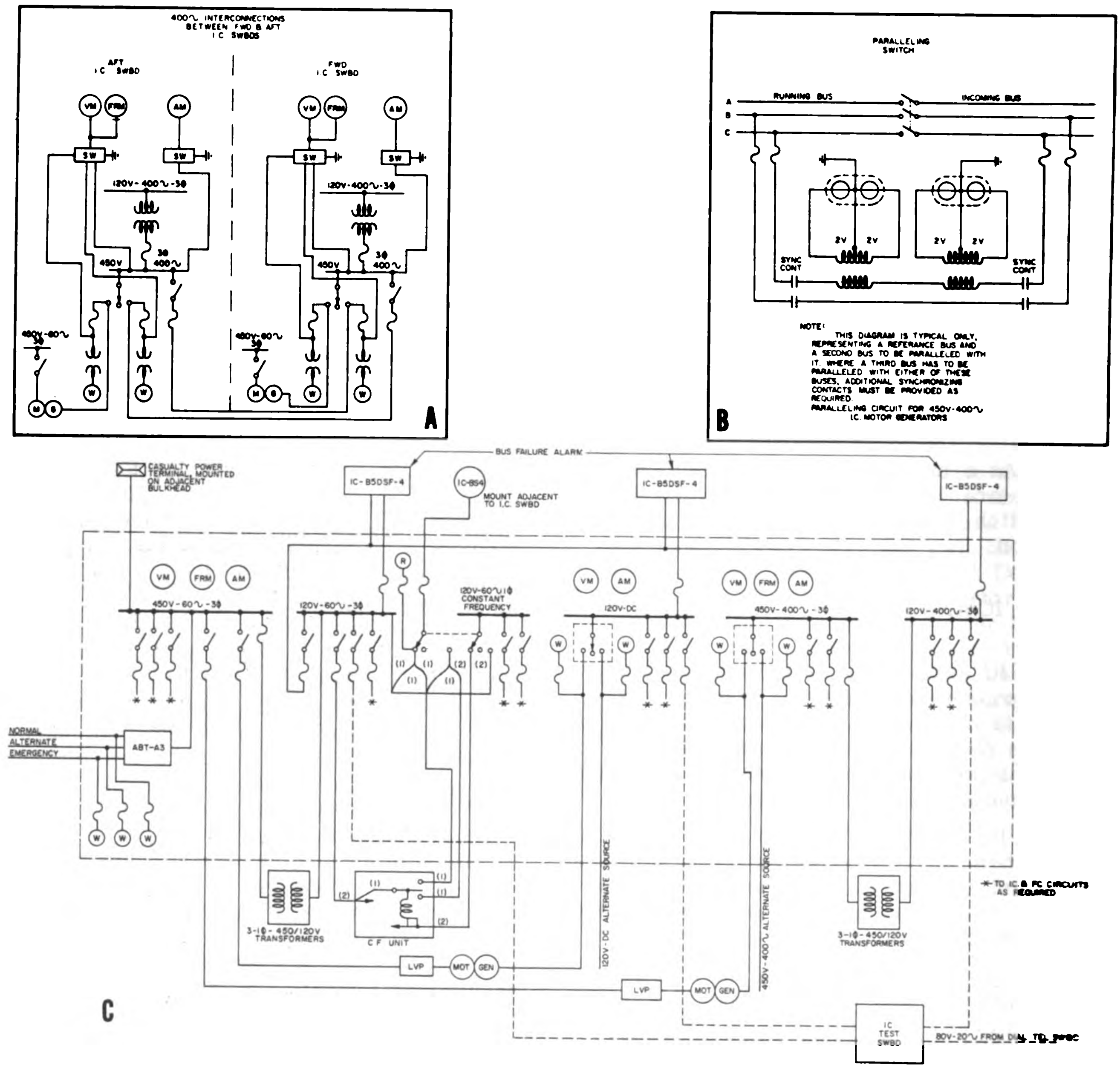
This bus energizes the various 450-volt, 60-cycle circuits through individual switches and fuses. In this installation the 450/120-volt 60-cycle transformer bank is energized directly from this bus through fuses. However, in some installations the transformers are energized through a switch and fuse combination.

The IC 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 general and restricted bus. This restricted bus supplies power to the most important circuits, and to the IC and FC 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 IC and FC buses upon transfer to the emergency supply. After the switches for less essential circuits on the IC and FC buses have been opened to reduce the load, the contactors supplying these buses are closed again.

In figure 3-7 the 120-volt, 60-cycle, bus furnishes power for the three electromechanical

Digitized by Google



140.17

Figure 3-7.—Schematic wiring diagram of IC switchboards.

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 IC and FC 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

Digitized by Google

IC room, the ship's service switchboard, or from another motor generator in the after IC 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. (fig. 3-7A.) 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 networks synchronizing lamps and switch (fig. 3-7B).

A casualty power terminal is provided adjacent to the IC switchboard in vessels having a casualty power system. Risers are not always provided in the IC room. It is necessary therefore, to rig portable cables to the nearest riser outlet. All IC 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 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 IC board except those energizing vital ship control circuits and FC circuits should be operated to the OFF position.

IC 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 IC switchboard is the oldest type of board and is found only in older ships. All switches for circuits up to 250 volts are of the live-front, lever type with fuses in exposed clips, mounted on insulating panels. Blown-fuse indicators are mounted over the fuses. For circuits above 250 volts, enclosed lever (type K enclosed) switches or circuit breakers are used on dead-front panels. The ship's cables are usually connected directly to the switch and fuse terminals in the rear of the switchboards.

SEMIDEAD-FRONT

The semidead-front IC 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.

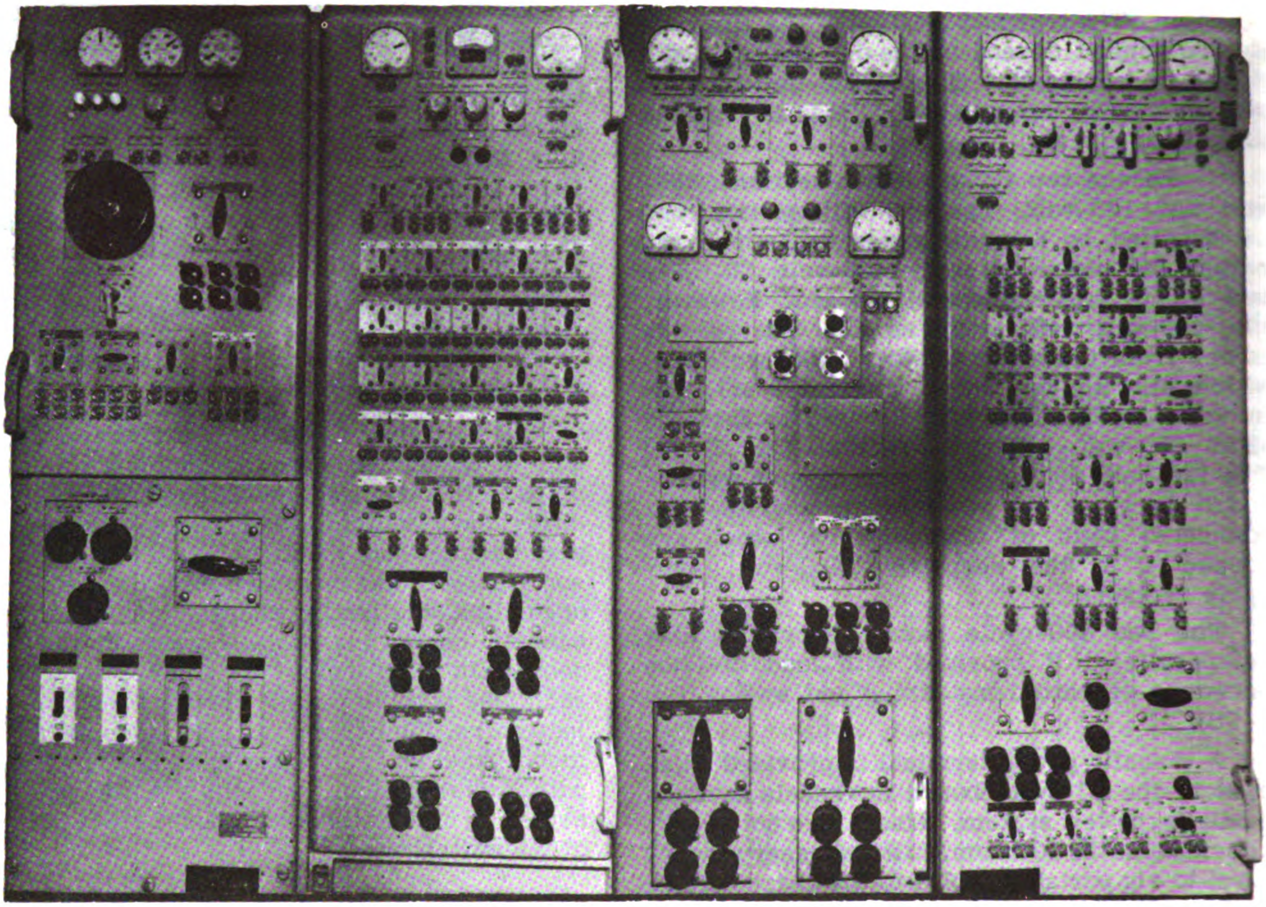
DEAD-FRONT

The dead-front IC switchboard 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.

DEAD-FRONT, FRONT-SERVICE

The latest type of IC switchboard is the dead-front, front-service IC board (fig. 3-8).

Digitized by Google



27.271

Figure 3-8.—Dead-front, front service switchboard

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.

Digitized by Google

ACO SWITCHBOARDS AND SECTIONS

The function of the action cutout (ACO) section is to permit isolation of various portions of IC 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 ACO switchboard (one or more sections) is located in the central station, which also functions as damage 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 IC room. The ACO therefore, is located in the IC room and is part of the IC switchboard.

Live-Front ACO Switchboard

ACO switchboards installed in naval ships are similar in construction to the several types of IC switchboards.

The live-front ACO 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 ACO Switchboard

The dead-front ACO switchboard 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 ACO Sections

The dead-front, front-service ACO sections are shown in figure 3-9A, 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 used on the ACO section to permit the selection of several different stations or supplies.

The inherent design of the equipment on most IC 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 ACO 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 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 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.

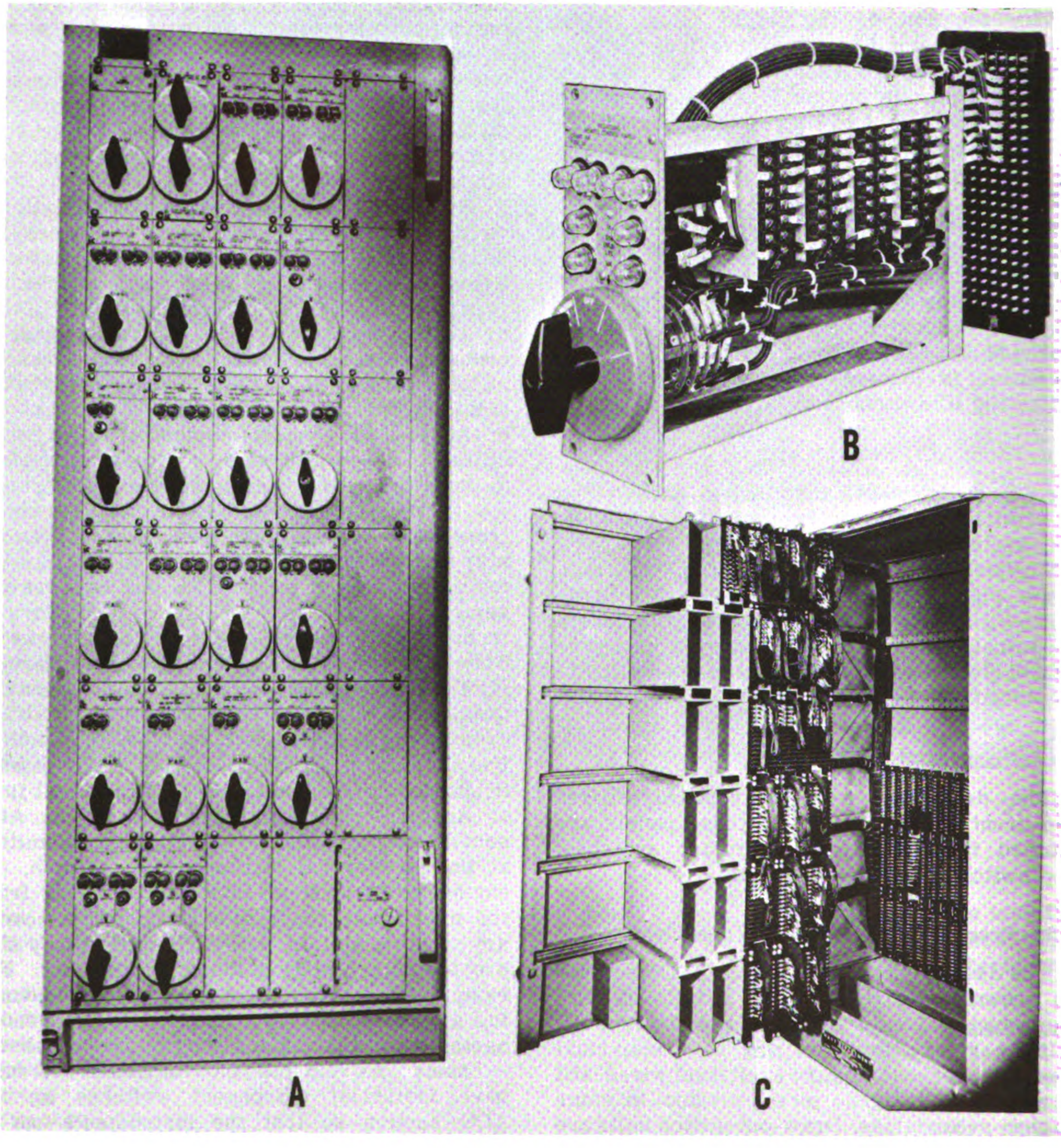
Another switch arrangement on the ACO section may provide for selecting a transmitter at one of several stations. For example, the engine-order system may be controlled from the pilot house, the open bridge, or the secondary conning station. The ACO section may also provide for isolating damaged circuits. 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 ACO section so that the instruments can be energized as needed or disconnected from the circuit in the event of trouble.

LOCAL IC SWITCHBOARDS

An IC switchboard is usually provided in each engineroom (motor or maneuvering room in electric-drive ships) to energize local IC circuits. The normal supply for each switchboard is from the nearer main IC switchboard.

Digitized by Google



55.316

Figure 3-9.—Dead-front, front service section. (A) Front view; (B) Action cutout unit; (C) Rear view, door open.

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 IC switchboard. However, in case of loss of power at the main IC switchboard or damage to the connecting cable, the local switchboards can still be energized from a local source. Automatic

Digitized by Google

bus transfer switches are provided on the IC 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 IC switchboard (fig. 3-10), 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 IC switchboard 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. Local IC switchboards are installed for Weapons Control, and Electronic Counter Measures systems on some ships.

BUS-TRANSFER SWITCHES

Type-K, 3-position, manually operated switches are used on IC switchboards of older design to transfer between the normal and emergency sources of power. More modern IC switchboards are provided with automatic rotary bus-transfer switches (fig. 3-11A), 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. 3-11B). The switch is operated by a solenoid (fig. 3-11C) which is energized from the normal power supply through a voltage-sensitive relay (fig. 3-11D). 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.

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.

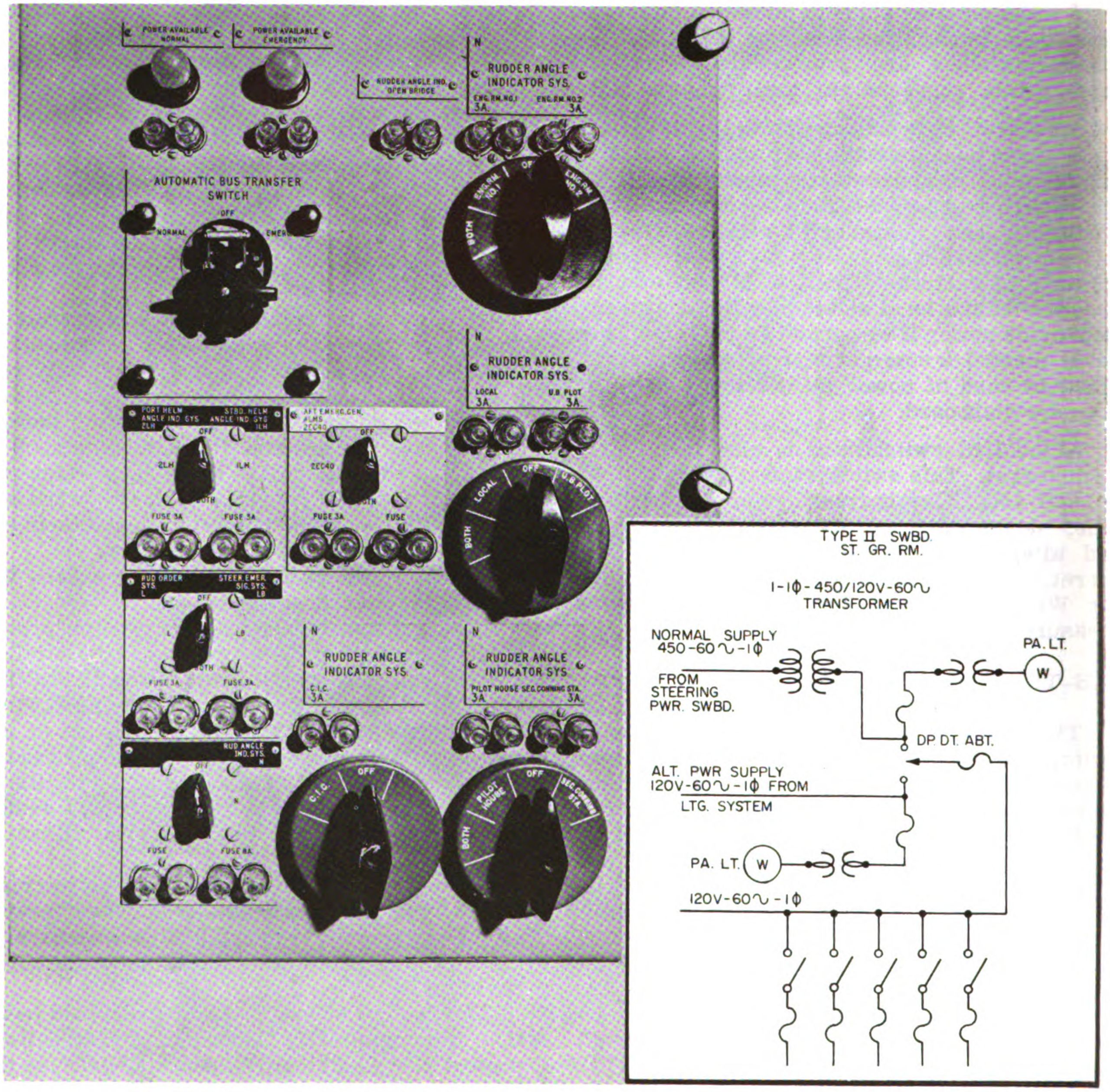
The automatic bus-transfer switch previously described is being replaced by a similar switch, which corrects some of the difficulties encountered in the original type. The new switch is constructed so that when the blades of the switch are closed, they will remain closed under conditions of vibration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

Digitized by Google



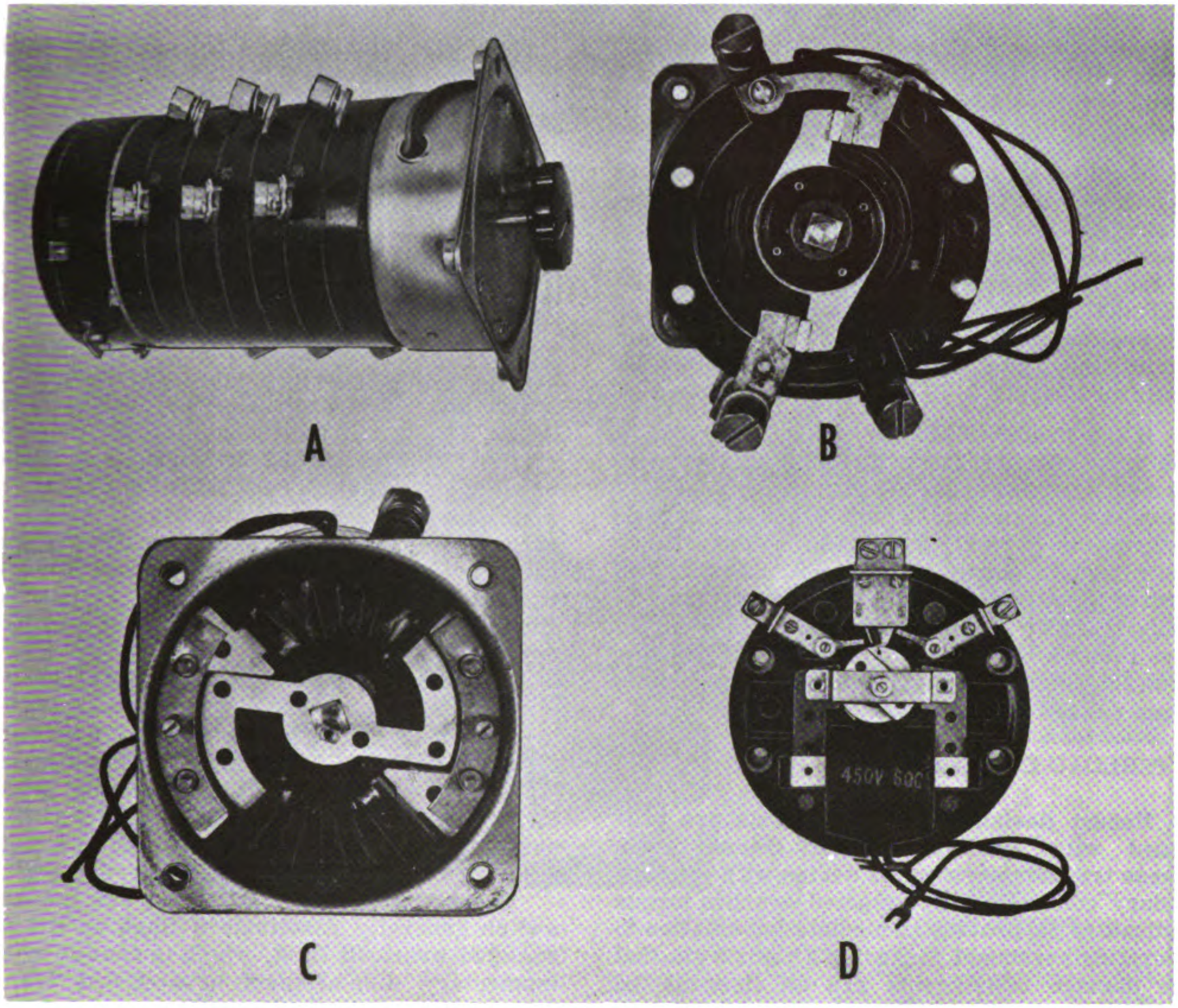
140.18

Figure 3-10.—Local IC switchboard, steering gear room.

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

Digitized by Google



140.19

Figure 3-11.—Automatic rotary bus-transfer switch. (A) External view; (B) Rotary contact; (C) Magnetic coil; (D) Voltage-sensitive relay.

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 IC switchboards from any one of the three sources. These sources are (1) normal (2) alternate, and (3) emergency (fig. 3-7). Each equipment consists of a 3-way, 450-volt, 600-ampere, drum-type

Digitized by Google

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 (normal) 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 load 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 ACO sections are provided with synchro overload transformers. These transformers are in series with the secondary connections of selected synchro torque indicators to provide immediate information to operating personnel regarding a casualty so that the damage 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. 3-12) 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 IC switchboard (fig. 3-12). 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 IC synchro circuits and for FC circuits is that for IC synchro circuits the overload transformers are usually set to provide a much greater relative displacement between transmitter and indicator before the overload lamp lights. FC synchro circuits are usually precision systems in which a relatively slight displacement between a transmitter and indicator may involve a serious error. Most IC 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.

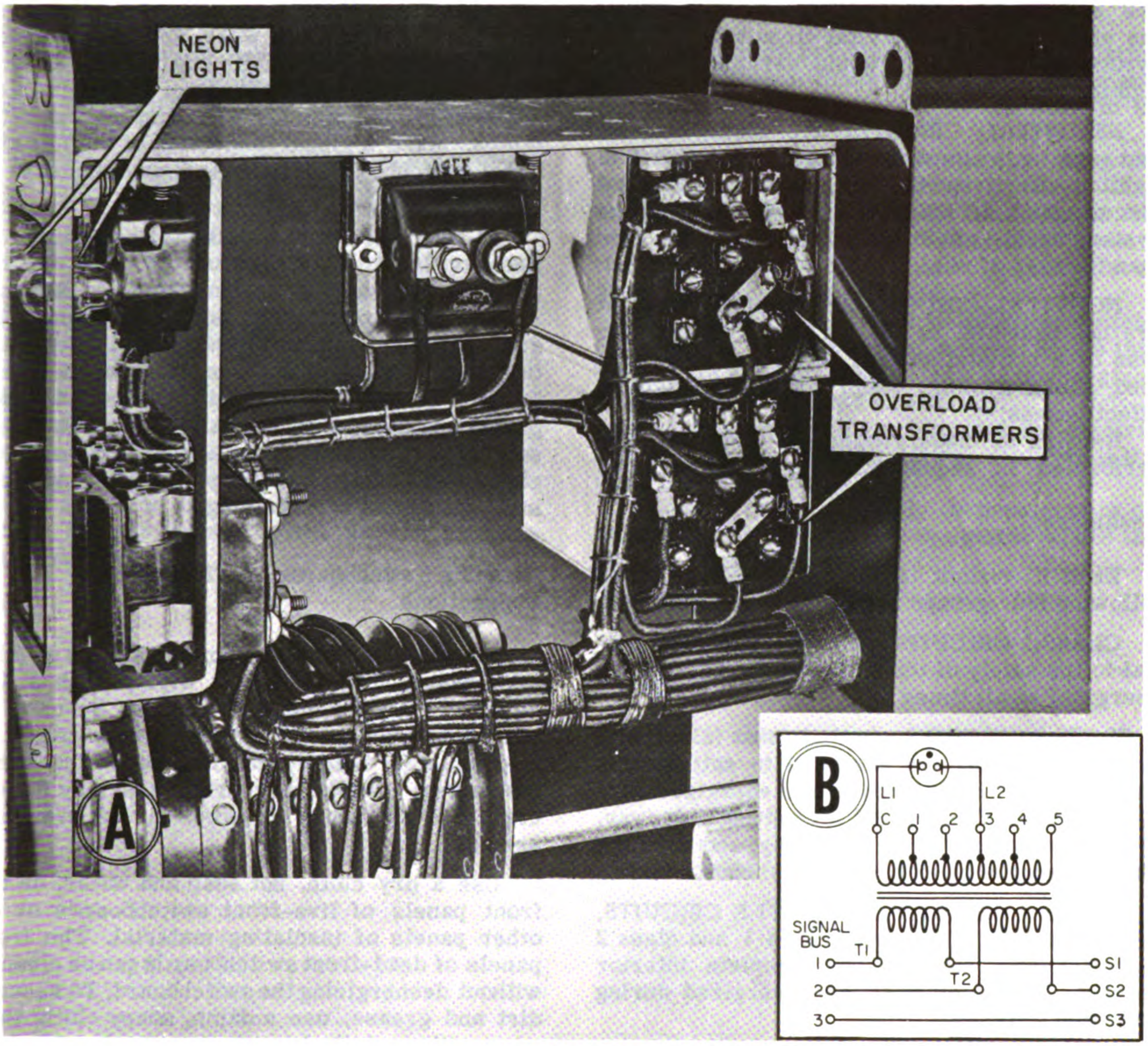
Operating personnel of IC switchboards should be very cautious when operating switches to disconnect indicators, particularly on vital circuits such as the engine order system. When practicable, operating personnel should investigate before operating the switch, as the overload indication may be a result 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 IC switchboards normally use two 6-volt lamps because 120-volt

Digitized by Google



55.317

Figure 3-12.—Synchro overload transformer. (A) External view; (B) Schematic diagram.

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.

CLASSIFICATION OF CIRCUITS

IC circuits are classified according to importance and to readiness.

Importance

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

Digitized by Google

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 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 IC circuits are performed in sequence of their importance.

Readiness

Each IC 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 IC 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

MAINTENANCE

Maintenance of IC switchboards consists of routine tests and inspections, cleaning, tightening connections, and calibrating meters.

Tests and Inspections

At least once each week, and after firing if possible, test all automatic bus transfer switches, and/or manual bus transfer switches. Test all bus failure alarms and inspect indicator lamps. Make a visual inspection of the interior of all switchboards for signs of loose connections or over heating.

At least once each quarter, clean and inspect the wiring of all switchboards as thoroughly as possible without deenergizing the boards.

Annually, or during shipyard overhauls, deenergize each switchboard, inspect and thoroughly clean all buses and wiring, and tighten connections. Check all switches for proper operation, check all mechanical fastenings for tightness, calibrate all meters, check all fuses for proper size, and take insulation tests of all wiring.

Cleaning Switchboards and Tightening Connections

Bus bars and insulating materials can usually be cleaned sufficiently by wiping with a dry cloth. A vacuum cleaner can also be used to advantage. Always insure that the switchboard is completely deenergized. Remember that some instrument transformer primaries may be energized even though all power circuit breakers are off.

Use a dry cloth, not soap and water, on the front panels of live-front switchboards or on other panels of insulating material. The front panels of dead-front switchboards can be cleaned without deenergizing the switchboard. To remove dirt and grease, use a damp, soapy cloth, then wipe with a cloth dampened with clear water, and dry with a dry cloth. Clean a small section at a time then wipe dry.

The inspection of a deenergized switchboard should not be limited to a visual inspection, but should include grasping and shaking each electrical connection and mechanical fastening to ensure that they are tight.

WORKING ON ENERGIZED SWITCHBOARDS

When military considerations require that electrical repair work be done on energized switchboards permission to do the work must be obtained from the commanding officer. The work

Digitized by Google

should be done only by adequately supervised personnel fully cognizant of the dangers involved, and the following precautions observed.

1. Provide ample illumination.

2. The person doing the work should not wear wristwatch, rings, watch chain, metal articles, or loose clothing which might make accidental contact with live parts or which might accidentally catch and throw some part of his body into contact with live parts. Clothing and shoes should be as dry as possible.

3. Insulate the worker from ground by means of insulating material covering any adjacent grounded metal with which he might come in contact. Suitable insulating materials are dry wood, rubber mats, dry canvas, dry phenolic material, or even heavy dry paper in several thicknesses. Be sure that any such insulating material is dry, has no holes in it, and no conducting materials embedded in it. Cover sufficient areas so that adequate latitude is permitted for movement by the worker in doing the work.

4. Cover working metal tools with insulating rubber tape (not friction tape) as far as practicable.

5. Insofar as practicable, provide insulating barriers between the work and any live metal parts immediately adjacent to the work to be done

6. Use only one hand in accomplishing the work, if practicable.

7. A rubber glove should be worn on the hand not used for handling the insulated tools. If the work being done permits, rubber gloves should be worn on both hands.

8. Station men by circuit breakers or switches, and man a telephone if necessary, so that the circuit or switchboard can be deenergized immediately in case of emergency.

9. A man qualified in first aid for electric shock should be immediately available while the work is being done.

These precautions apply to repair work on all energized circuits or equipment where the voltage exceeds 30 volts.

Digitized by Google

CHAPTER 4

CONSTANT FREQUENCY SYSTEMS

Constant frequency systems supply power to special IC and FC equipments utilizing synchronous motors. The first constant frequency systems installed in Navy ships utilized a rotary inverter. The inverter speed was closely controlled by a tuning fork amplifier so that the inverter output remained 60 cycles ±0.1%. Static type electronic systems utilizing electron tubes have replaced the rotary inverters. Electronic systems utilizing solid state devices will be replacing the electron tube types in the near future.

This chapter discusses two representative constant frequency systems that utilize electron tubes.

CONTROL, CONSTANT FREQUENCY C-2249/U

Control, Constant Frequency C-2249/U (fig. 4-1), is designed to supply 60 cycle, controlled frequency, a-c power for operation of synchronous devices aboard ship. This system is completely electronic and uses no rotating parts.

The input to the system is 55-65 cps, single phase, at 108-122 VAC. The single phase output is 60 cps ± .01%, at 120 VAC ± 7.5%.

A basic, accurate, stable frequency of 480 cps is generated by an electrically driven tuning fork in combination with a tube, in an oscillator circuit. The output of this oscillator drives a monostable multivibrator which generates a square wave at the frequency of the oscillator. A series of 3 bistable multivibrators divides this 480 cps square wave, down to 60 cps. Subsequent resistor-capacitor combinations filter the 60 cps square wave and the resultant 60 cps sine wave is amplified by a series of power amplifiers.

The system consists of the constant frequency circuits and the power supply circuits (fig. 4-2).

CONSTANT FREQUENCY CIRCUITS

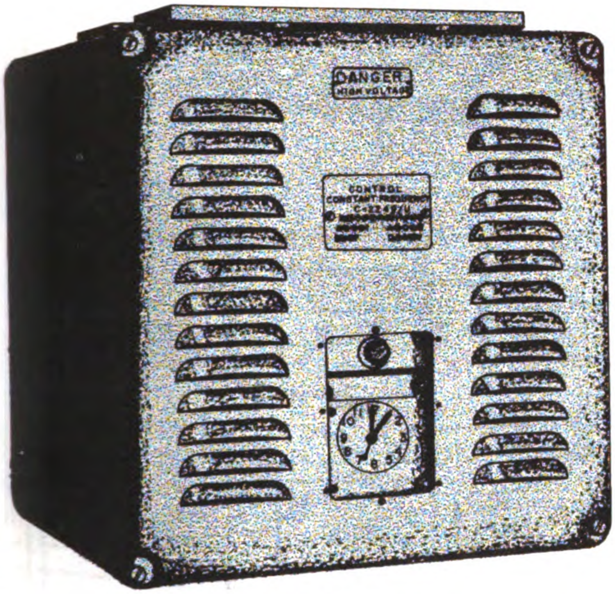
The tuning fork frequency standard Y1 (fig. 4-2) is enclosed in a hermetically sealed case. The fork vibrates at 480 cps within an accuracy of ± .01%. It also operates in conjunction with V1, a twin-triode amplifier (5751) electron tube in which the two sections are cascaded so as to maintain the fork in resonant vibration.

The 480 cps output of V1 is applied to square wave generator tube V2 which, like V1, is a twin-triode amplifier (5814) electron tube. Both halves of V2 are connected in a monostable multivibrator circuit. This circuit has one stable state in which the tube will remain until triggered by a negative input voltage of sufficient magnitude. The tube will continue in its unstable state until triggered by a negative voltage of sufficient magnitude or until a certain time, as determined by the time constant of the circuit, when it will return to its stable state. The 480 cps output of V1 acts as a triggering voltage for V2, resulting in a 480 cps square wave output from V2.

The 480 cps square wave output of V2 is applied to both halves of V3, a twin triode (5814) electron tube amplifier. This tube is connected as a bistable multivibrator. The negative-going steps of the 480 cps square wave output of V2 have no effect on this bistable multivibrator. However, each positive-going step of the 480 cps square wave output of V2 causes V3 to flip to the other stable state. Since two input pulses are required to cause the circuit to complete its cycle, i.e., for each tube to pass from the nonconducting state to the conducting state and then back again, the output from either plate of V2 is a square wave with a frequency of one-half that of the input, (240-cps).

This 240 cps square wave is applied to V4, a 5814 twin-triode which is connected in an identical circuit to that of V3 and produces a 120 cps square-wave output, i.e., one-half of the input

Digitized by Google



140.20

Figure 4-1.—Control, constant frequency C-2249/U.

frequency of 240 cps. This 120 cps square wave signal is divided by one-half again to 60 cps, by twin-triode V5 which is connected in an identical circuit to both V3 and V4.

Filter amplifier V6A in conjunction with series and parallel resonant RC circuits, is used to filter out the 60 cps sine wave from the square wave. Positive and negative (degenerative) feedback from the output to feedback amplifier V6B results in a 60 cps sine wave at the input to push-pull driver stages V7 and V8, pentode 6005/6AQ5W tubes. The 60 cps sine wave output of V6B is coupled to the grids of V7 and V8.

The plate outputs of tubes V7 and V8 furnish the 60 cps driving signal to the inputs of push-pull connected power amplifier tubes V9 and V10. The output from V9 and V10 is 60 cps ±.01% at 120 volts. Part of the output is fed back to tube V6B to shape the 60 cps sine wave and to provide adequate voltage regulation. An alarm relay is placed in parallel across the output to actuate an alarm when the 60 cps output fails. A clock is placed in parallel across the 60 cps output to indicate the long time accuracy of the output frequency.

POWER SUPPLY CIRCUITS

The constant frequency supply has four separate self-contained power supplies. These are: a filament voltage supply, a +1200 VDC supply, a regulated +150 VDC supply, and an unregulated d-c supply.

The filament voltages are supplied from secondary windings on transformer T4, and are 6.3 volts, 5 volts, and 2.5 volts. The +1200 VDC supply consists of 6 silicon diodes (CR1 through CR6) connected in a full-wave rectifier circuit with suitable filtering. Plus 1200 volts d-c is used for the plates of the 811A push-pull power output tubes (V9 and V10). The unregulated d-c supply comprises a 5R4WGA dual-diode (V11) connected in a full-wave rectifier circuit with suitable filtering. The +150-volt regulated d-c produced by OA2 voltage regulator tube V12 is used for the plates of tubes V1 through V5 and V6A. Plate voltage for tubes V6, V7, and V8 is supplied from the unregulated d-c.

HARRISON MODEL 744 CONSTANT FREQUENCY POWER SUPPLY

The Harrison model 744 constant frequency power supply (fig. 4-3), is a compact 100-watt, 120-volt, 60-cycle, single-phase, static, power supply. A block diagram of the system is shown in figure 4-4.

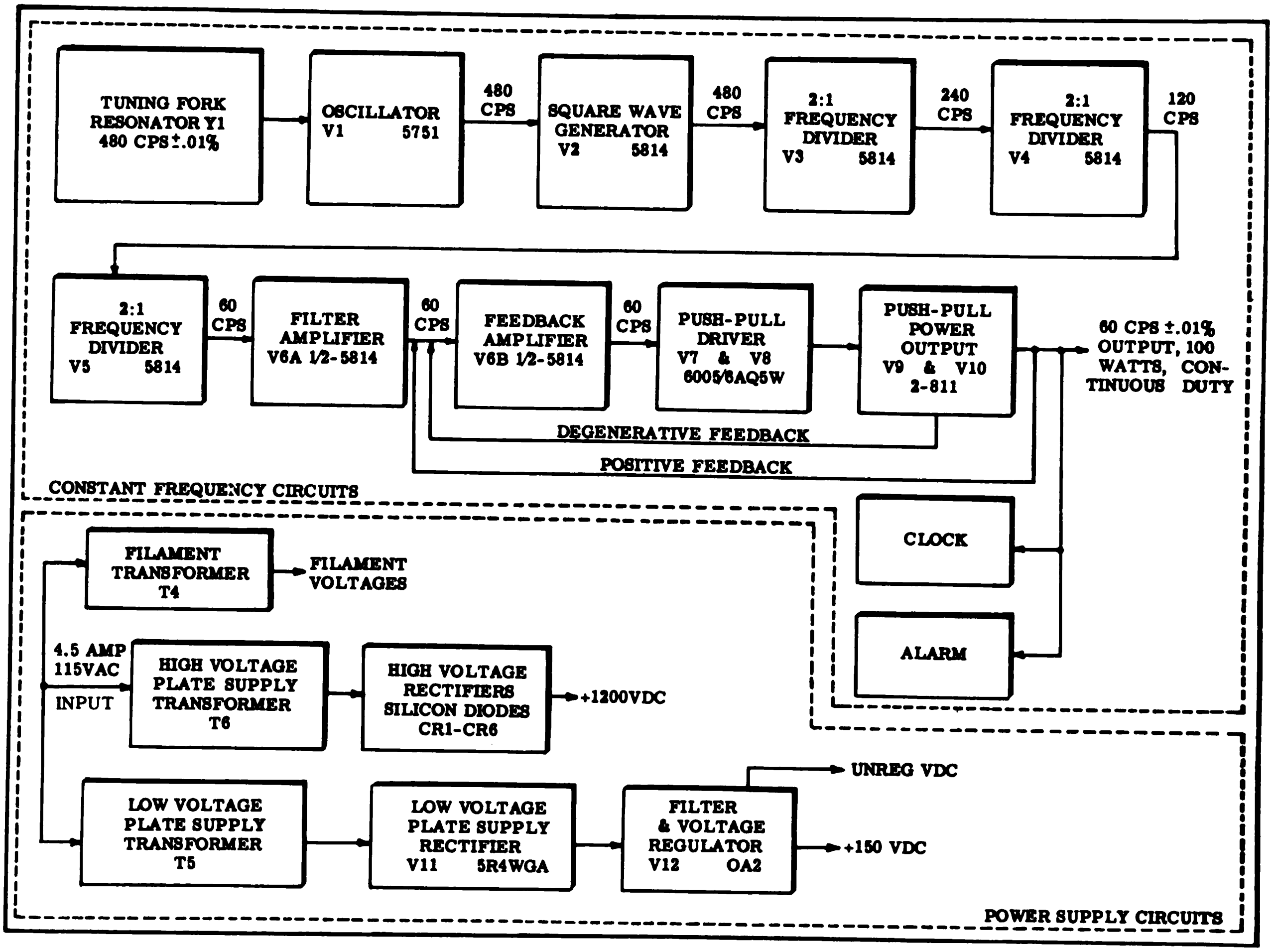
TUNING FORK ASSEMBLY AND OSCILLATOR

The tuning fork assembly and oscillator tube (fig. 4-5) comprise the frequency standard for the constant frequency power supply. The tuning fork assembly is a sealed unit with provisions in its circuitry for maintaining a frequency of 240 cps ±.005%.

Two coils are placed between the tines of the fork, one of which is in the plate circuit of V1B, the other is placed in the grid circuit of V1A.

The application of B+ to the circuit initiates oscillations. The initial surge of current through the coils which surround the tuning fork shock excite the fork into oscillations at a natural mechanical frequency of 240 cps. The motion of the tines of the fork in the magnetic field of the coils induces a small voltage in the grid circuit of V1A. This voltage, corresponds to the 240 cps natural frequency of vibration of the tuning fork. Tube V1A amplifies and inverts this voltage which is then coupled through C1 to the grid (pin 7) of V1B where further amplification and inversion takes place. This signal voltage, once again in phase with the oscillating fork but of larger amplitude, is fed back through the coil to sustain the circuit's oscillations.

Digitized by Google



140.21

Figure 4-2.—Control, constant frequency C-2249/U, block diagram.

The output of the oscillator amplifier is coupled through C2 to V2A, a buffer cathode follower (not shown). The output of the buffer is coupled to the square-wave generator.

Negative feedback is applied to the circuit through a varistor element in the cathode of V1A. This arrangement maintains the fork amplitude and frequency constant when the B+ is varied or when the gain of V1 changes.

The output of the tuning fork at terminal 5 (fig. 4-5), is a sine wave of approximately 1 volt amplitude.

SQUARE WAVE GENERATOR

The square-wave generator, V3, (fig. 4-6) is essentially a two-stage overdriven voltage amplifier. Tube V3A has zero bias, therefore the positive half of the sine wave applied to pin 2 drives V3A into saturation. The negative half of the input sine wave is highly amplified. The resultant signal developed across R-8 is applied through C-5 to V3B, pin 7. The action of V3B is similar to V3A and the resultant 240 cps square wave developed across R-10 is coupled to the first divider, V-4, through C-6.

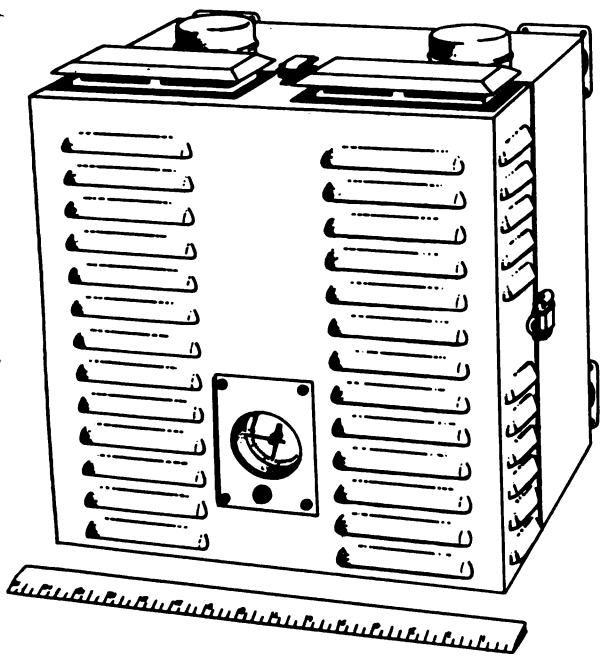
FIRST DIVIDER

The first divider, V4, (fig. 4-6) is a conventional bistable multivibrator triggered by negative pulses applied to the plates of the tube.

The square wave output is differentiated by C6 and R11. The resultant signal developed across R11 contains both positive and negative pulses.

In a bistable multivibrator one section is always in a state of high conduction. Positive pulses applied to the grids of V4, thru the corresponding plate load resistor R12 and R17 and the coupling capacitors C7 and C8, will not cause

Digitized by Google



27.267
Figure 4-3.—Harrison model 744 constant frequency power supply.

he multivibrator to flip. Only negative pulses vill cause operation. There is only one negative ulse fed to the grids of V4 per cycle of the inut square wave. Two negative pulses are reuired to cause V4 to complete one cycle f operation. The resultant square wave deeloped across R17 of V4A will have a fundanental frequency of 120 cps. Thus a frequency ivision of two to one has been accomplished.

This 120-cps square wave is applied to the econd divider, V5 through C10.

ECOND DIVIDER AND FILTER

The operation of the second divider V5 (fig. -7) is identical with the operation of the first livider V4.

The output of the second divider is a factor f 2 countdown of its 120 cps input, thus a 60 cps quare wave output is fed to the filter network hru C13 and R29.

The filter in figure 4-7 is a bridged "T" network designed to pass only 60 cps sine waves. It filters out all other harmonics of the square wave. Thus a pure sine wave is coupled to the voltage amplifier, V2B. The harmonic content of the 60 cps sine wave is less than 1%.

VOLTAGE AMPLIFIER

The Voltage Amplifier section consists of two tubes V2B and V6A, (fig. 4-8).

Tube V2B and its associated components constitute a conventional Class A, self biased amplifier. The unbypassed cathode resistor provides a degree of negative feedback and improves the circuit stability and reduces the distortion. Tube V2B is coupled to V6A through C20 and the gain control voltage divider network R38 and R39.

The signal from the gain control R38 is applied to V6A Pin 2, thru an isolation resistor R-40. This resistor is necessary to isolate the positive feedback loop from the divider network. Tube V6A is a class A, degenerative amplifier. The unbypassed cathode serves two purposes, self-degeneration, and degenerative feedback coupled from the output transformer T2. This feedback maintains a minimum of distortion on the output of the constant frequency power supply. The output of V6A is developed across R43 with C22 bypassing high frequency transients to ground. This output is applied to the phase splitter V6B thru C21.

PHASE SPLITTER

The phase splitter provides two outputs, differing in phase by 180 degrees, to the push-pull driver amplifier tubes. Tube V6B (fig. 4-8) constitutes the phase splitter. It is a basic paraphase amplifier with a gain of less than one. The outputs of the phase splitter are equal in amplitude and approximately 180° out of phase.

One output is developed at the V6B plate and is fed through C24 to the grid of V7. The other output is developed at the V6B cathode, and is coupled through C23 to the grid of V8.

DRIVER AMPLIFIER

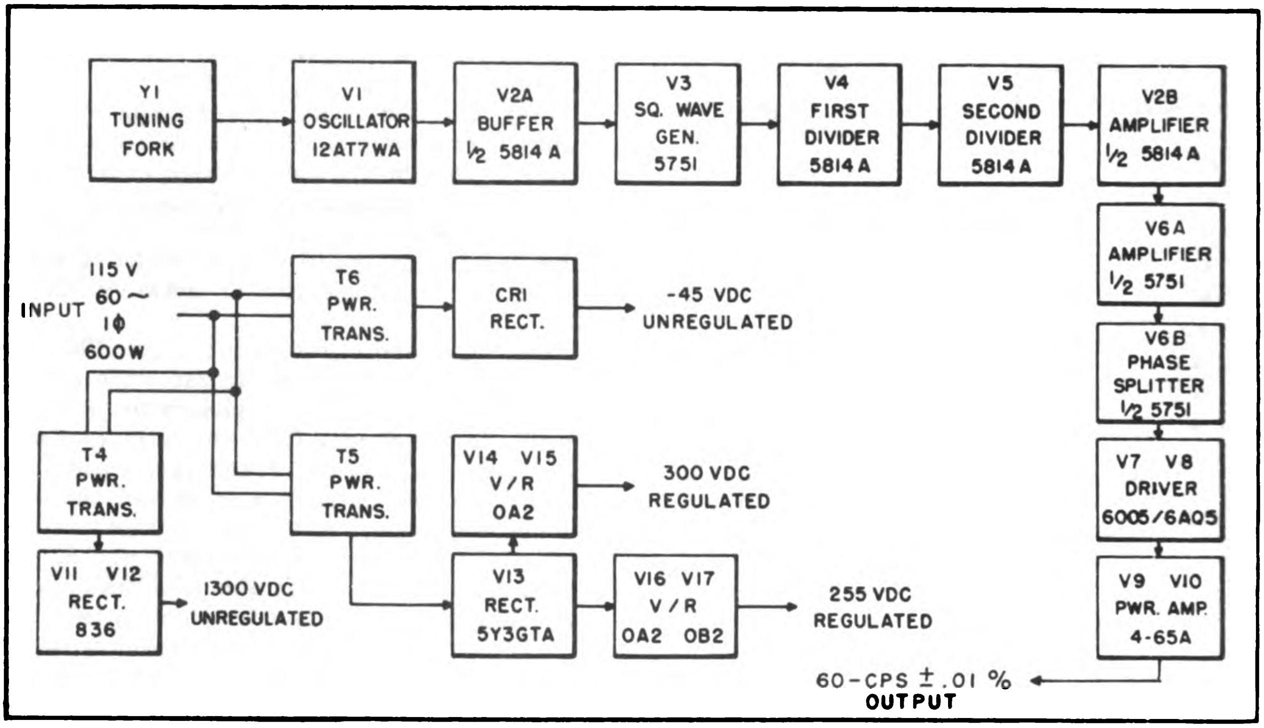
Tubes V7 and V8, (fig. 4-9) constitute a push-pull power amplifier. These tubes are capable of delivering the necessary power to drive the final push-pull power amplifiers, V9 and V10.

Cathode resistor R50 is bypassed by C25. This bypass capacitor improves the balance of the tubes used and removes the need for a balancing adjustment.

POWER AMPLIFIER

The final stage of the constant frequency power supply (fig. 4-10) consists of a pair of

Digitized by Google



140.22

Figure 4-4.—Functional block diagram.

4-65A tetrodes connected as a class AB push-pull amplifier. The input is coupled through transformer T1 directly into the grids of the tubes. Negative bias of 45V is supplied through the centertapped secondary to the V9 and V10 grids.

Resistor R53 is shunted across the secondary of transformer T1 to reflect a proper load for the push-pull drive circuit V7 and V8.

The 120 VAC voltage is transformer coupled to the output terminals by transformer T2. Plate voltage (+1300 volts), is applied through the centertap winding of the primary pin 2.

The secondary of the output transformer T2 consists of two separate windings. Winding 4 to 5 is the output winding rated at 120 VAC, single phase, 60 cps ±.01%, from zero to 100 watts at 0.95 power factor. Winding 6 to 7 is a feedback winding from which a sample voltage is applied to the cathode (pin 3) of V6. In addition to this negative feedback some positive feedback is obtained across resistor R54. This is in series with the output current obtained from winding 5 of transformer T2. The voltage thus obtained is fed back to the grid (pin 2) of V6 through isolation transformer T3. Potentiometer R55 controls the amount of positive feedback and is adjusted only at the start of the adjustment procedure.

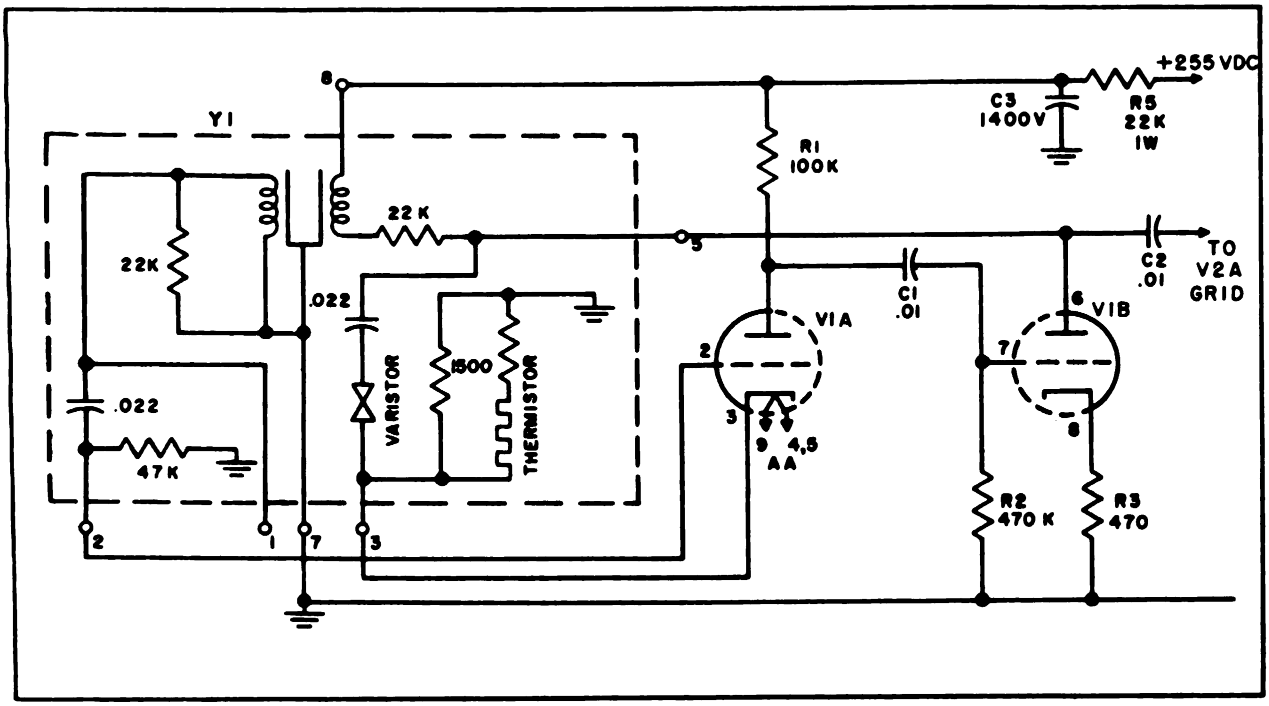
The positive feedback thus obtained maintains the output voltage constant with varying loads. For example, if load current increases, the normal tendency in circuits without feedback is for the output voltage to drop. However, the increase in load current serves to increase the voltage developed across series resistor R55. This increase is coupled to the grid (pin 2) of V6, and serves to increase the output voltage, thus compensating for the load variation. A decrease in output load requirements operates in exactly the opposite manner.

The output is monitored by an alarm relay K2 (not shown), whose contacts open when the output voltage of 120 VAC fails.

A synchronous clock, connected across the output voltage terminals, serves to indicate that the equipment is functioning and is a means of checking frequency accuracy. The clock is calibrated in seconds and reads from 0 to 60 seconds continuously.

The synchronous clock provides a means for measurement of the cumulative error in frequency by comparison with radio time signals

Digitized by Google

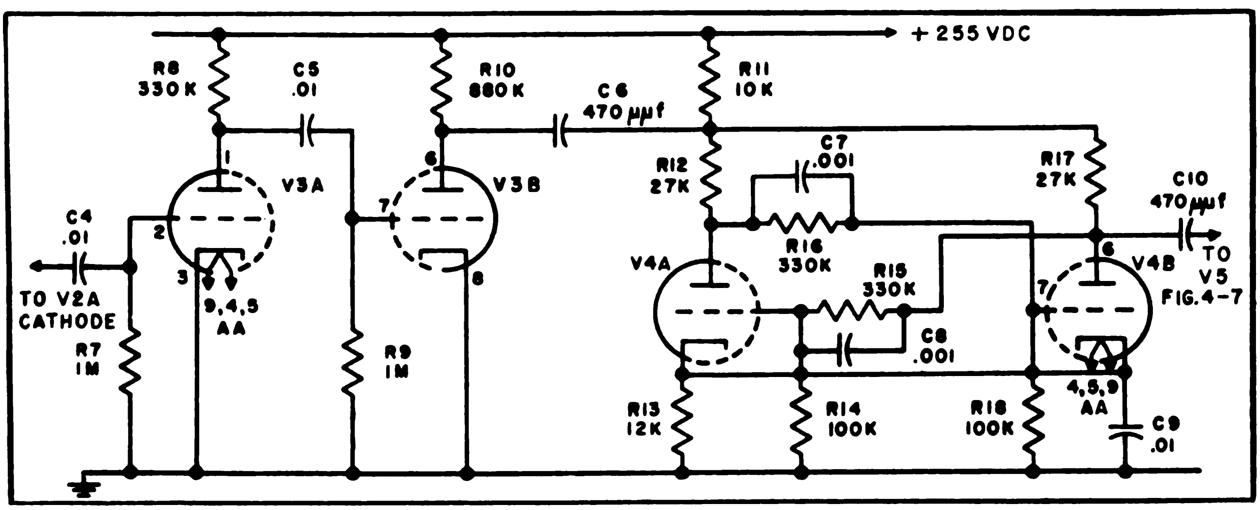


140.23

Figure 4-5.—Tuning fork assembly and oscillator.

from WWV or a calibrated chronometer. The decimal error is the reciprocal of the number of seconds required for the clock to gain or lose one full second. When operating normally, gain or loss of one second will require in excess of 10,000 seconds.

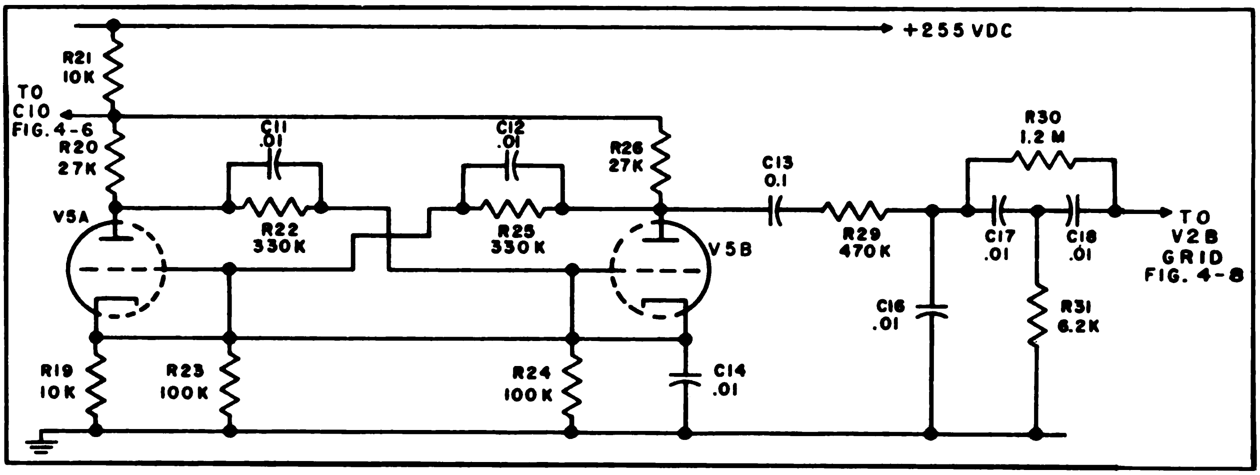
The clock is also usable as a timing device for oscilloscope comparison of the 600-cycle



140.24

Figure 4-6.—Square wave generator and first divider.

Digitized by Google



140.25

Figure 4-7.—Second divider and filter circuit.

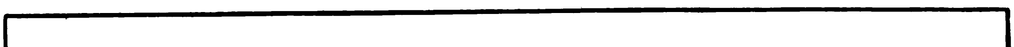
modulation of WWV against the 60-cycle output of the power supply.

POWER SUPPLY

The power supply consists of the high voltage supply, the low voltage supply, and the bias and filament supply.

High Voltage Supply

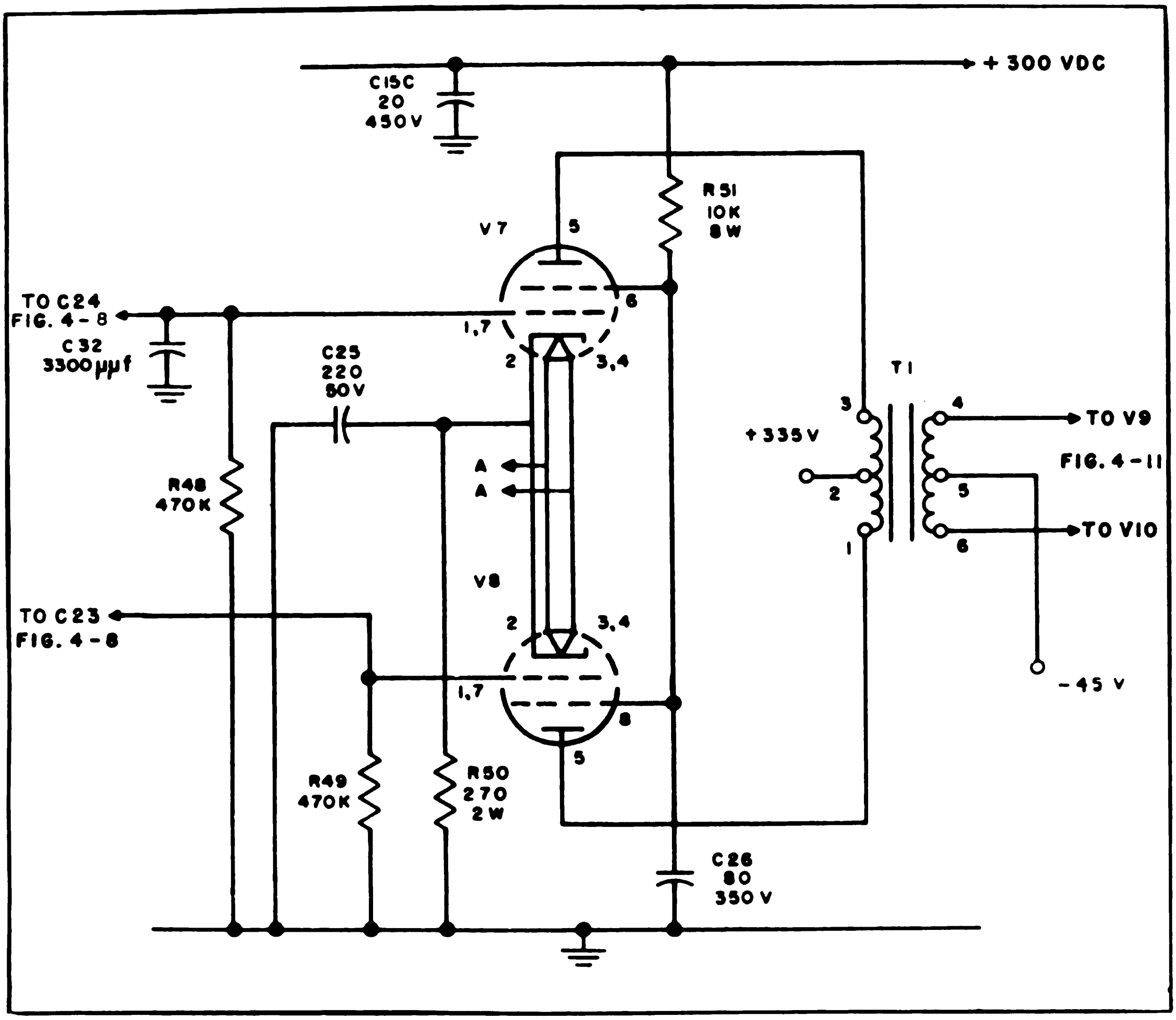
Upon energizing the unit, the application of 115 VAC to the primary of the high voltage transformer T4 (fig. 4-11) is delayed approximately 45 seconds by the thermal delay relay K1. This is necessary to prevent damage to the filaments



140.26

Figure 4-8.—Voltage amplifier and phase splitter.

Digitized by Google



140.27

Figure 4-9.—Driver amplifier.

of the 836 tubes V11 and V12. The delay allows the filaments to reach their operating temperature before they have to supply high current.

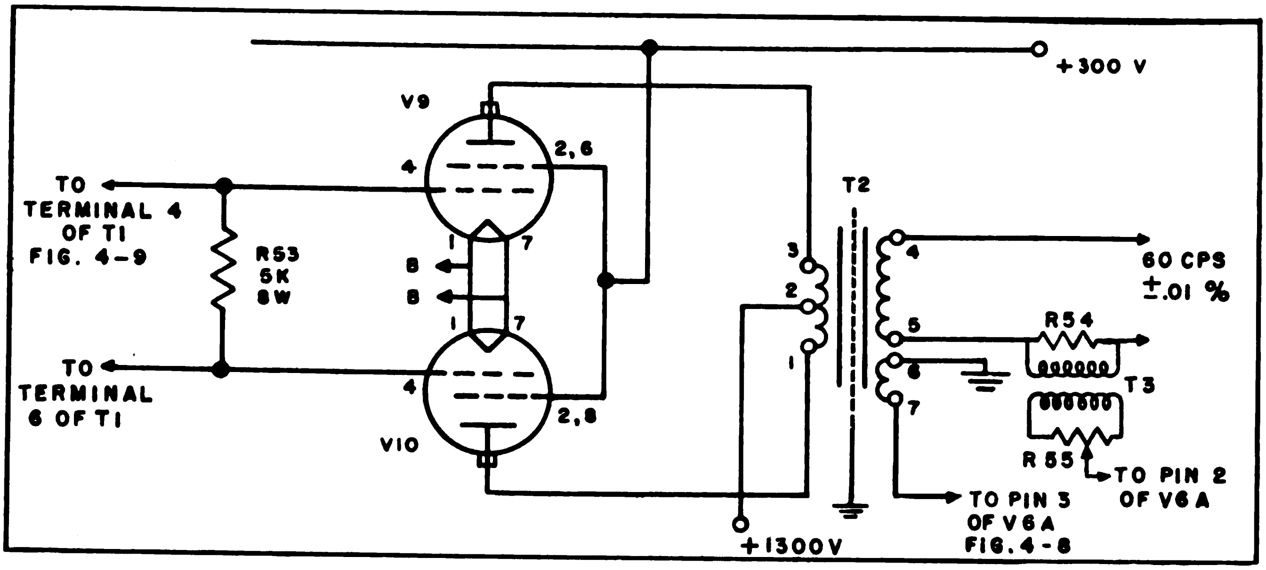
After relay K1 closes, 115 VAC is applied to T4 which in turn applies 1500 VAC to V11 and V12. The centertap (pin 4) of the secondary of T4 is tied to a common ground bus while the filaments are tied to the High Voltage filter L2 and C28 thru the centertap (pin 9) of the 2.5V winding of T6. Resistors R58, R59, and R60 are bleeder resistors across C28. The high voltage supply furnishes 1300 V positive to the centertap (pin 2) of T2, the power amplifier output transformer (fig. 4-10).

Low Voltage Supply

Upon application of 115 VAC to the constant frequency power supply, transformer T5 (fig. 4-11) is immediately energized. Filament and plate voltage is applied to V13. Rectifier V13 rectifies the plate voltage and provides pulsating d-c current to the choke input filter L1, C29, and R61. Resistor R61 acts as a bleeder resistor to discharge C29 upon deenergizing the equipment. The output voltage is supplied to the oscillator, buffer, square-wave generator, first divider, second divider, and amplifier V2B.

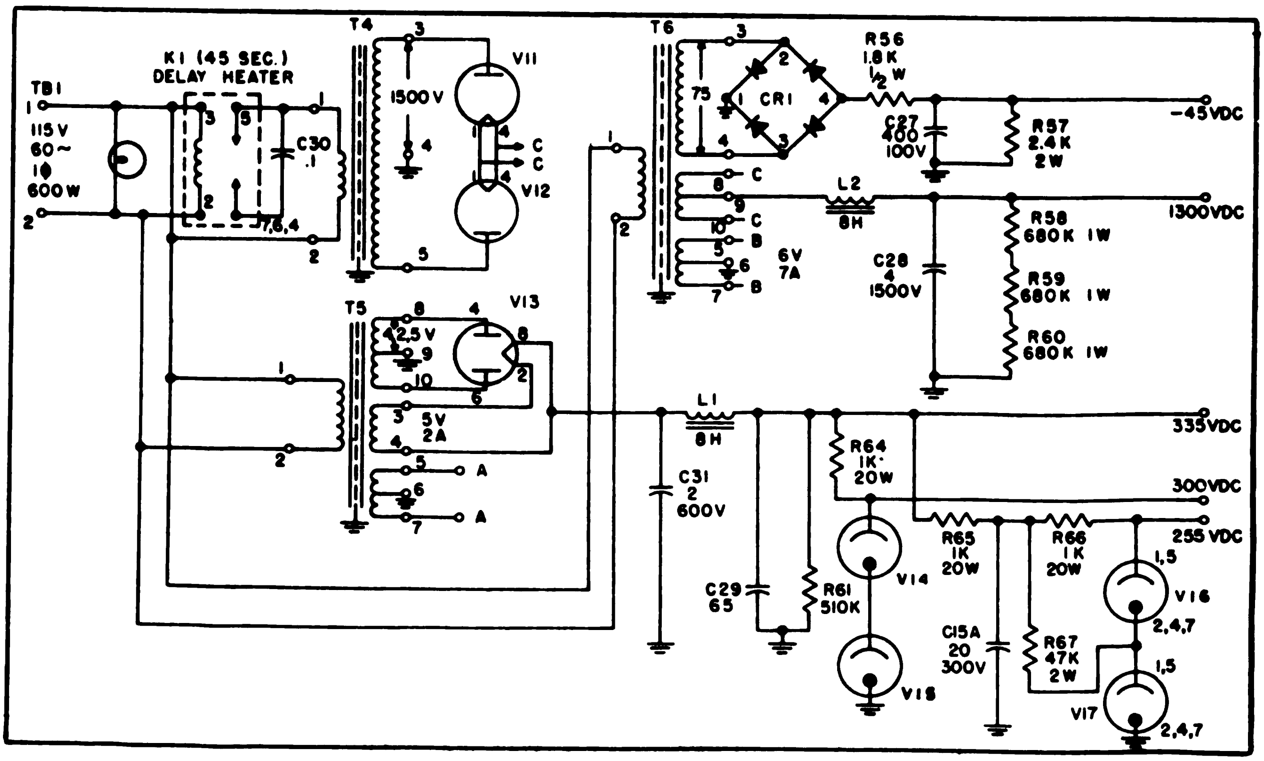
The 6.3V winding of T5 is applied to filaments of all stages except the power amplifiers V9 and

Digitized by Google



140.28

Figure 4-10.—Power amplifier.



140.29

Figure 4-11.—Power supply.

V10. Tubes V14, 15, and 16 are type OA2 voltage regulators. Tube V17 is an OB2 voltage regulator.

Bias and Filament Supply

The application of 115 VAC to the equipment also energizes transformer T6 (fig. 4-11) which supplies 6V at 7 amps to the power amplifier filaments (V9 and V10 fig. 4-10), and 2.5V at 10 amps to the high voltage rectifier tubes V11 and V12. The centertap to the 2.5V winding is the return path of the 1300V supply from L2.

Transformer T6 supplies 75 VAC to the bias rectifier CR1 whose output is filtered by R56, C27, and bleeder resistor R57. Resistor R57 serves to discharge C27 upon securing the unit. The output of this bias supply filter is negative 45 volts with respect to common ground and is delivered to the power amplifier grids V9 and V10 by way of the center tap in the secondary of the driver transformer T1 (fig. 4-9).

MAINTENANCE

Preventive maintenance for the C-2249/U and Harrison model 744 units requires only periodic mechanical inspections, electrical checks, and cleaning as prescribed by the manufacturer's technical manual, or the planned maintenance system manual. No lubrication of any kind is required. Frequent inspections should be made to ensure that all mechanical fastenings and electrical connections are tight. Clean the units with a soft hair brush. DO NOT use compressed air. Exercise care when making the required electrical checks, as voltages as high as 2000 volts are present. Use a high voltage probe when measuring voltages over 300 volts.

Digitized by Google

CHAPTER 5

TEST EQUIPMENT

This chapter discusses test equipments that you will be working with as an IC Electrician. Test equipments are, for the most part, precision equipments, and must be handled with care if they are to perform their designed functions accurately.

Some equipments may require special handling; however, there are precautions which apply to test equipments in general. Rough handling, moisture, and dust all affect the useful life of test equipments. Bumping or dropping a test instrument, for example, may destroy the calibration of a meter or short-circuit the elements of an electron tube within the instrument.

The effects of moisture are minimized in many of the more complicated electronic test equipments, such as signal generators, oscilloscopes, etc., by utilizing built-in heaters; these heaters should always be operated for several minutes before applying the high voltage to the equipment.

Meters are the most delicate parts of test equipments. These precautions should be followed:

1. Make certain that the amplitude of the input signal under test is within the range of the meter.
2. Keep meters as far away as possible from strong magnets.
3. When servicing a test equipment, disconnect the meter from the circuit before making resistance or continuity tests. This precaution will eliminate the possibility of burning out the meter.

As an IC 3 or 2, you will be required to use and perform preventive maintenance on certain test equipments. The repair and calibration of test equipments requires a thorough knowledge of their design and operating principles, and skill in the use of special tools and equipment. The Bureau of Ships and the Bureau of Naval Weapons have repair facilities available both ashore and afloat for test equipment repair and calibration. These facilities are listed in BuShips Instruction 9690.12 of 15 April 1963.

MULTIMETERS

During troubleshooting, a technician is often required to measure voltage, current, and resistance. To eliminate the necessity of obtaining three or more meters, the multimeter is used. The multimeter combines a voltmeter, ammeter, and ohmmeter in one unit. The following are guides for the proper use of multimeters:

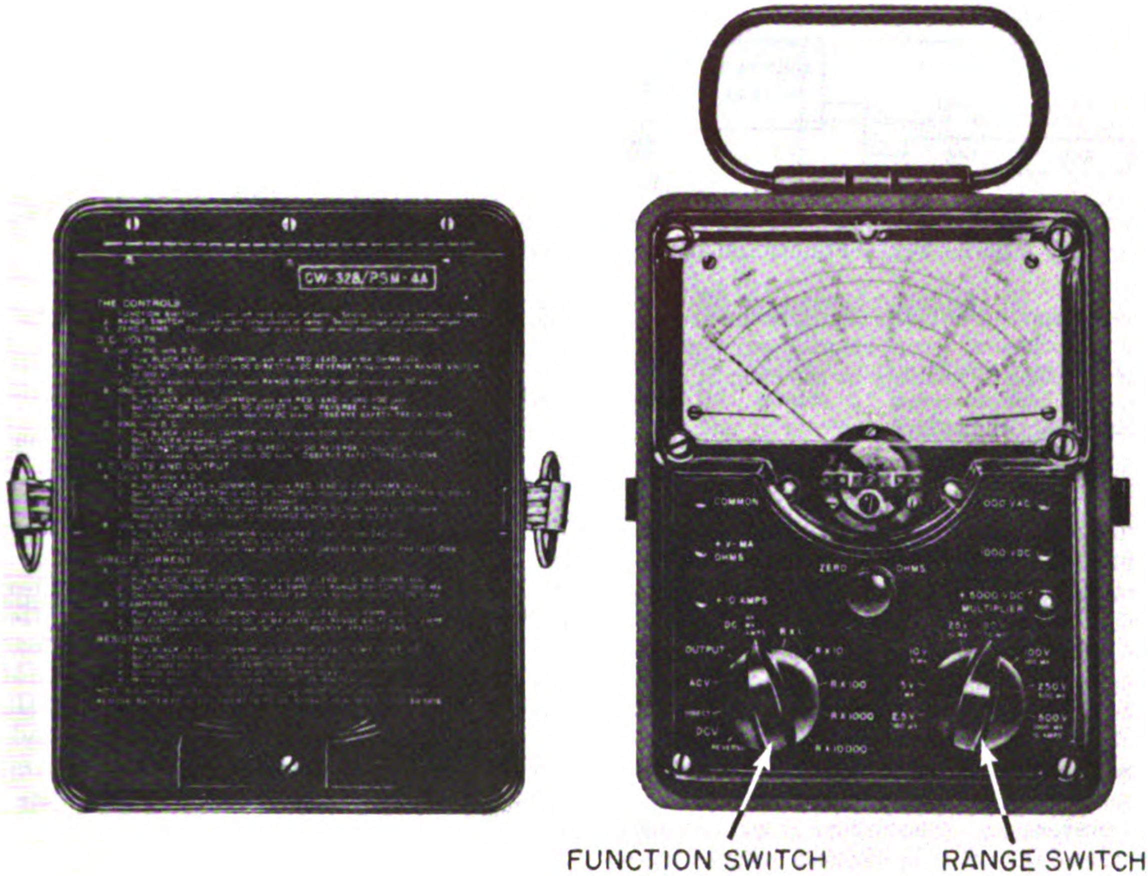
1. An ammeter is always connected in series—NEVER in parallel.
2. A voltmeter is connected in parallel.
3. An ohmmeter is NEVER connected to a live circuit.
4. Polarity must be observed in the use of a d-c ammeter or a d-c voltmeter.
5. Readings should be made directly from the front. When viewed from an angle off to the side, an incorrect reading will result because of optical parallax.
6. Always choose an instrument suitable for the measurement desired.
7. Select the highest range FIRST and then switch to the proper range.
8. In using an ammeter or voltmeter, choose a scale which will result in an indication as near midscale as possible.
9. In using an ohmmeter, select a scale which will result in a midscale reading.

Multimeters may be of the electronic or nonelectronic type. A representative multimeter of each type is discussed below.

MULTIMETER AN/PSM-4A

Multimeter AN/PSM-4A (fig. 5-1) is a portable, nonelectronic volt-ohm-milliammeter. It can be used to make d-c current, d-c resistance,

Digitized by Google



4.133

Figure 5-1.—Multimeter AN/PSM-4A, front view with cover open.

and d-c, a-c, and output voltage measurements. The complete unit includes test probes which may be used with their prod tips, or the tips can be fitted with alligator clips or with a telephone plug to simplify contact arrangements and connections. A high voltage probe is also included, which makes it possible to read voltages up to 5,000 VDC. This probe contains a warning light to indicate the presence of high voltage.

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

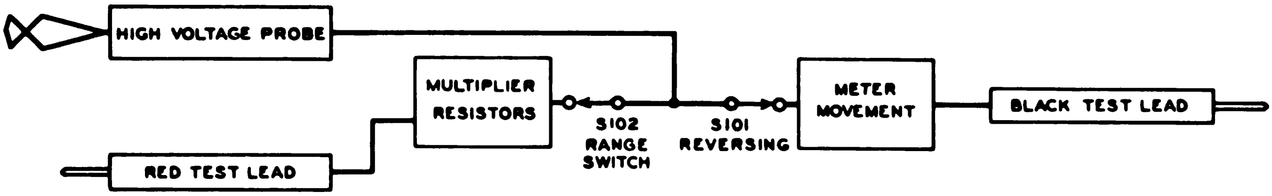
1. Direct currents up to 10 amperes.
2. Resistances up to 30 megohms.
3. D-c voltages up to 5,000 volts.
4. A-c voltages up to 1000 volts (RMS).
5. Output voltages up to 500 volts (RMS).

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

D-C Voltmeter Circuits

The block diagram of the circuit in Multimeter AN/PSM-4A which is used for measuring d-c voltages is shown in figure 5-2. The circuit is selected with function switch S101, in either its DIRECT or REVERSE DCV position (fig. 5-1). For voltages up through 500 volts, a range is selected with range switch S-102 (only one position shown in figure 5-2). For the 1000 volt range, the red test lead connects into the special 1000 VDC jack (fig. 5-1), and the range switch is not in the circuit. For the 5000-volt range the high voltage probe (not shown) connects the special 5000 VDC jack, and places its resistance in series with the meter movement. For any range, the total resistance in series

Digitized by Google



124.219

Figure 5-2.—Functional block diagram of d-c voltage circuits.

with the meter movement will regulate the meter current to provide a proportional current to indicate the amount of voltage in the circuit.

A-C and Output Voltage Circuits

The circuits which measure a-c and output voltages (fig. 5-3), are selected with the ACV and OUTPUT positions of function switch S-101. For voltages up through 500 volts, a range is selected with range switch S-102. For the 1000 volt range, the red test lead connects the special 1000 VAC jack, and the range switch, S-102, is not in the circuit. The a-c voltage impressed across the circuit between the red and black test lead tries to send current through the resistance of the circuit in both directions, but the rectifier allows only one direction of current flow through the meter movement. The meter is calibrated to indicate the RMS value of the a-c voltage applied to the instrument circuit.

D-C Current Circuits

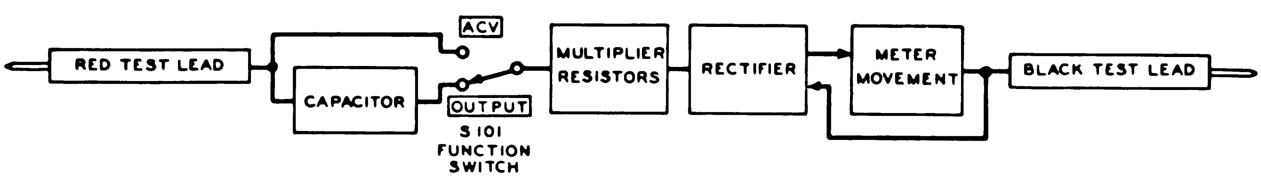
The circuit which measures d-c currents is selected with the d-c μA MA AMPS position of function switch S-101 (fig. 5-1). For currents up to 1000 milliamperes, the range is selected with range switch S-102 (fig. 5-4). For the 10 ampere range, the red test lead connects the special 10 AMPS jack, and range switch S-102 is not in the circuit. Each range provides a parallel shunt resistance for the meter movement, and the circuit current divides between these two parallel paths. The proportional part which passes through the meter movement indicates the total circuit current.

Ohmmeter Circuits

The ohmmeter circuit (fig. 5-5) and its ranges are selected with function switch S-101. The ranges are Rx1, Rx10, Rx100, Rx1000, and Rx10000. An internal battery furnishes the power for all resistance measurements. For each range, the circuit is arranged so the meter will indicate zero, ohms, and full scale deflection when the red test lead and the black test lead are shorted together. When you connect a resistance between the test leads, this resistance will be in series with the instrument circuit, and less current will flow through the meter movement. The amount of reduced meter deflection indicates how much resistance is between the test leads.

Function Switch S-101

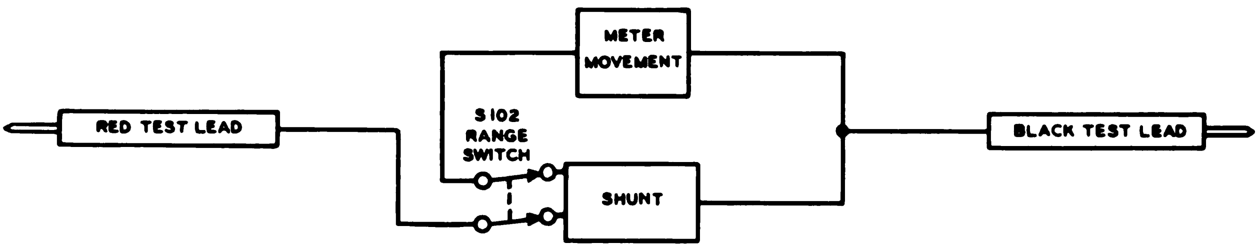
Function switch S-101, (fig. 5-1) located in the lower left-hand corner of the front panel, selects the type of circuit for which the instrument is connected. There are two positions for d-c volts: direct and reverse. The normal position is direct. When using the meter to make a d-c voltage measurement and a connection is made which causes the meter to read backwards (deflection of the pointer to the left), set switch S-101 to reverse and the pointer will be deflected up-scale. To read alternating current voltages, set switch S-101 to the ACV position.



124.220

Figure 5-3.—Functional block diagram of a-c and output voltage circuits.

Digitized by Google



124.221

Figure 5-4.—Functional block diagram of d-c current circuits.

A rectifier within the instrument rectifies the a-c voltage to an equivalent d-c value, and the meter indicates the RMS value of the applied voltage. To read the a-c portion of mixed a-c and d-c voltages, set switch S-101 at OUTPUT. Set switch S-101 at d-c μA MA AMPS to read direct current. As mentioned previously, switch S-101 also serves as a range switch for resistance measurements.

Range Switch S-102

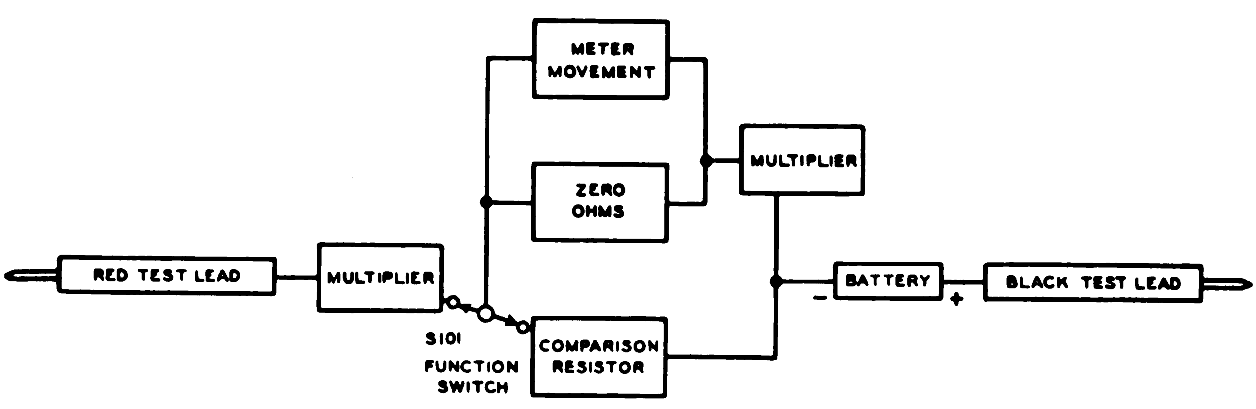
This eight-position range switch located in the lower right corner of the front panel permits the selection of voltage and current ranges. The full scale value for each range switch position is marked on the front panel.

Zero Ohms Control

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

Test Leads and Test Jacks

There are two test leads, W-101 and W-102, (fig. 5-6) which are needed for all measurements except those which require the 5000 VDC range. Test lead W-101 is red and test lead W-102 is black. Unless otherwise specified, connect black test lead W-102 in the common jack, J106, and connect the red test lead W-101 in the +V MA OHMS jack, J101. For the 1000 VDC range, place red test lead W-101 in the 1000 VDC jack, J-103. For the 1000 VAC range, place red test lead W-101 in the 1000 VAC jack, J104. Use the red test lead to contact the positive side of the source for d-c measurements and the black test lead to contact the negative side. For the 5000 VDC range, use black test lead, W-102 in the common jack, J-106, and use the high voltage test lead, W-103, screwed on over recessed post J-102,



124.222

Figure 5-5.—Functional block diagram of ohmmeter circuits.

Digitized by Google

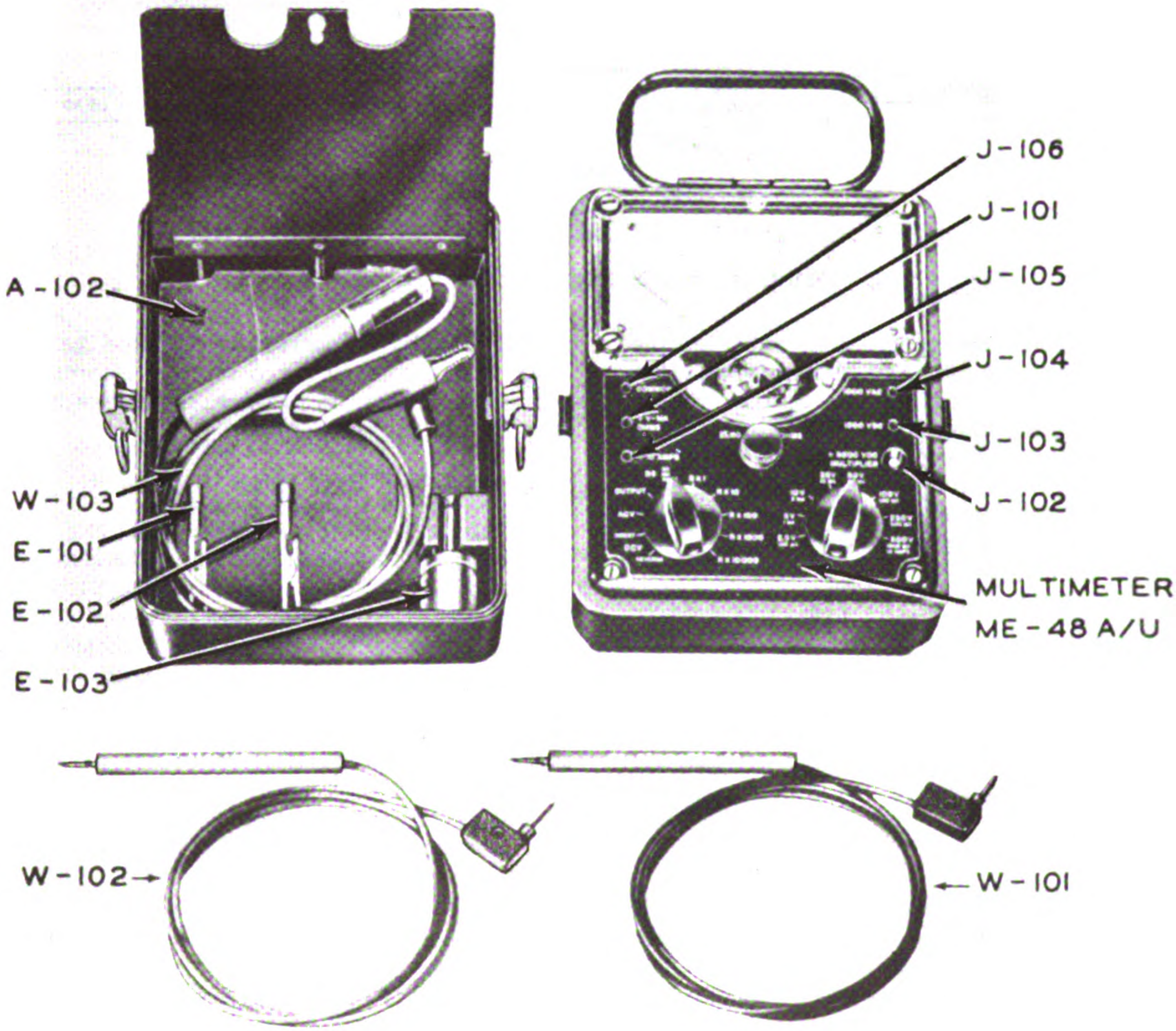


Figure 5-6.—Controls, jacks, leads, and accessories. 4.133

+5000 VDC multiplier. For the 10 ampere range, place red test lead, W101, in the special +10 AMPS jack, J105.

Accessories E-101, E-102, and E-103

There are two alligator clips, E-101 and E-102, which the operator may use to screw on over the end of test leads W-101 and W-102. This is for the convenience of the operator. There is a telephone plug, E-103, which may be used to connect both the test leads, W-101 and W-102, to contacts within a two-contact telephone jack. This permits easier connection to the jack contacts for any electrical measurement because the operator can make the measurement directly through an equipment panel without opening the case of the equipment. The red test lead W-101, connected in the red insulated jack (not shown) on the rear of telephone plug E-103, contacts the tip of the plug. The black test lead, W-102, connected in the black insulated jack (not shown) on the rear of the telephone plug, E-103, contacts the sleeve of the plug.

MULTIMETER ME-25B/U

Multimeter ME-25B/U (fig. 5-7) is a portable electronic combination d-c voltmeter and

Digitized by Google

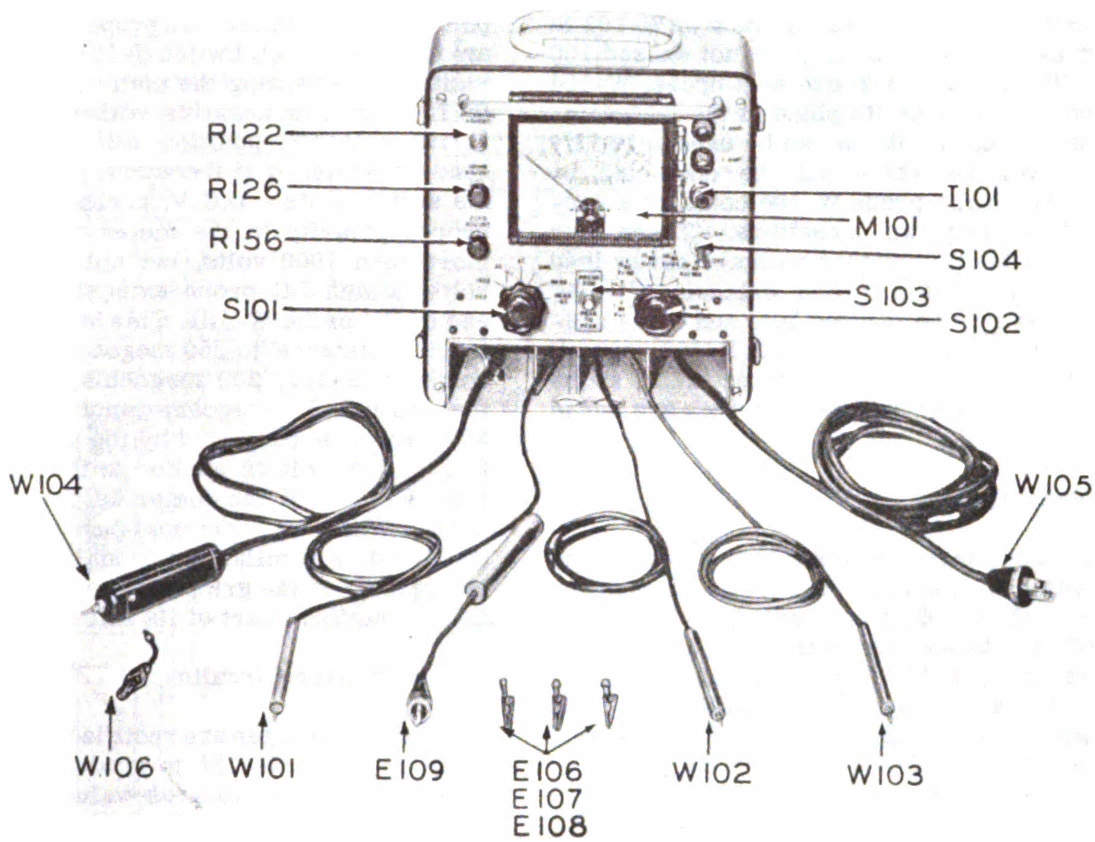


Figure 5-7.—Multimeter ME-25B/U, front panel control, leads, and accessories.

milliammeter, a-c and r-f voltmeter, and ohmmeter which can be used to make a large variety of electrical measurements over a wide range of values. For measurements of voltage and resistance, it is necessary to have a source of a-c power, 105 to 125 volts, single phase, 50 to 1000 cycles. For d-c current measurements, the meter does not require any outside source of power, but it is not necessary to disconnect the outside power source while making d-c current measurements.

Multimeter ME-25B/U is designed to make the following electrical measurements:

1. D-c voltages up to 5000 volts, with polarity reversal.
2. A-c voltages up to 1000 volts, both RMS and Peak-To-Peak.
3. R-f voltages up to 100 volts and 100 megacycles, both RMS and Peak-To-Peak.
4. Direct current up to 1000 milliamperes.
5. Resistance up to 1000 megohms.
6. Decibels from -12 to +42 db, where zero db is .001 watt in 600 ohms.

Test Leads

There are four probes with leads which are permanently attached. They are designated W-101, W-102, W-103, and W-104 (fig. 5-7). Probe W-101 (black) is used to contact d-c voltage and has a 5 megohm resistor, R-102, inside its probe handle. This resistor provides isolation between the instrument and the voltage source, and is part of the voltage divider network for all d-c voltage inputs. The lead is shielded to prevent any interference from stray fields. The shield is grounded inside the case of the meter. Probe W-102 (red) is a general purpose probe, and is used to contact the source of d-c current, resistance, and a-c voltage. Probe W-103 (black) is the ground or negative return lead used with either W-101 or W-102 for all their measurements. Probe W-104 (heavy black

Digitized by Google

lead) is used to contact the sources of r-f voltages, and it may be used in place of W-102 to contact a-c voltages if they do not exceed 100 volts. When it is not in use as a probe, W-104 must be returned to its place in the lead compartment so that its diode can be used to rectify any a-c voltage which will be contacted by W-102. The large probe W-104 contains a rectifying tube with two capacitors. These four probes and leads, together with a-c power lead W-105, high voltage probe extension E-109, diode probe ground lead W-106, and three alligator clips, E-106, E-107, and E-108, are all stored in the special lead compartments at the bottom of the front panel when they are not in use.

Front Panel Controls

The front panel controls (fig. 5-7), consist of a 7-position function switch, S-101; an 8-position range switch, S-102; a push switch, S-103, which is used to change the reading of a-c and r-f voltages from RMS to peak-to-peak; a power switch, S-104, labeled ON and OFF; pilot lamp I-101 which lights when power is on; an electrical zero adjuster for the bridge circuit, (R-156), called zero adjust; an OHMS ADJUST control (R-126), for full scale deflection with infinite resistance for ohms measurements; and a screwdriver controlled adjustment (R-122), which compensates for contact potential for a-c and r-f voltage circuits. Function switch S-101 has six positions which designate the type of measurement which can be made.

D-C Voltmeter Circuits

The d-c voltages up to 1000 volts are contacted with d-c probe W-101 and ground return common probe W-103. Resistors R-102 and R-103 (fig. 5-8), act as isolating resistors for the instrument to reduce the voltage applied to the tapped divider to one half the voltage contacted by the probes. Resistors R-107 through R-115 act as a voltage divider for the remaining voltage. Part of this voltage is tapped by range switch S-102, and is applied to the signal grid (pin 1) of bridge tube V-103. If the voltage which is contacted does not exceed the range to which switch S-102 is set, the maximum voltage change applied to the pin 1 grid of tube V-103 is 1/2 volt. This is sufficient to cause full scale deflection of meter M-101. Any smaller voltage input will cause a proportional fraction of 1/2 volt to be applied to the tube grid, and the meter pointer will be deflected a proportionally smaller amount. Function switch S-101 includes a provision for reversing the meter polarity. If probe W-101 contacts negative voltage, switch S-101 in its - D.C.V. position will make the meter read up-scale, or if it contacts positive polarity, the switch in its + D.C.V. position will apply the proper polarity to the meter. For measuring more than 1000 volts, but not more than 5000 volts, attach DC probe extension E-109 to the end of DC probe W-101. This increases the total input resistance to 250 megohms by connecting resistor R-101, 200 megohms, in series with the normal 50 megohm input circuit. When 5000 volts is contacted by the probe extension, E-109, 1/2 volt is applied to the signal grid of tube V-103 and the meter is deflected to full scale. When any fractional part of 5000 volts is contacted, a similar fractional part of 1/2 volt is applied, to the grid, and the meter reads the same fractional part of its full scale deflection.

A-C Voltmeter Circuits

The a-c voltages are rectified with tube V-101 in diode probe W-104 to produce a d-c voltage equal to the peak-to-peak value of the applied a-c voltage. The resulting d-c voltage is applied across the divider network. Range switch S-102 selects some portion of it to connect to the signal grid of bridge tube V-103. As this d-c voltage is proportional to the a-c voltage which is being measured, and the meter deflection is proportional to the d-c voltage, the meter indicates a-c voltage directly. The most common a-c voltage measurement consists of determining the RMS value of a sine wave form of voltage; for this reason, meter M-101 is calibrated in RMS values for a sine waveform. Pressing switch S-103 shorts out part of the meter calibrating resistance, providing 2.828 times as much meter deflection as is obtained with the same voltage input without pressing switch S-103. The reading thus obtained is the peak-to-peak value, and is correct for all waveforms provided they have a duty cycle of at least 4×10^{-6}. The duty cycle is the ratio between the pulse width and the time between like portions of successive pulses.

The a-c voltages can be measured with any of several combinations of probes. Diode probe W-104 can be used to contact the source of a-c voltage directly, providing the voltage has a value no greater than 100 volts, RMS. If the

Digitized by Google

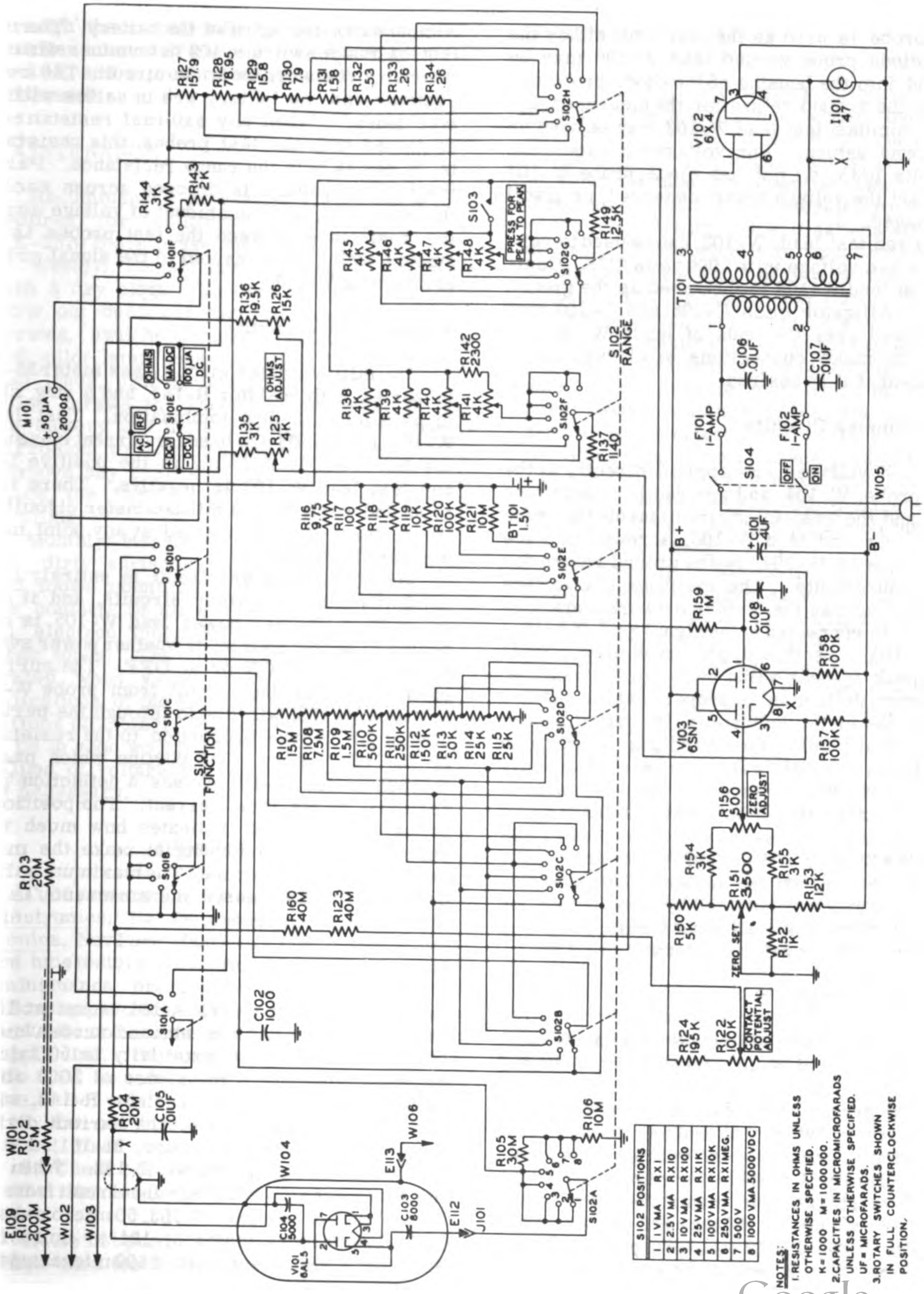


Figure 5-8.—Multimeter ME-25B/U, overall schematic diagram.

4.133

Digitized by Google

diode probe is used as the test lead, either the short diode probe ground lead W-106 may be screwed into the housing of the diode probe and used as the ground return for the measured signal, or common test lead W-103 may be used as the ground return. For voltages greater than 100 volts RMS, do not use diode probe W-104 to contact the voltage being measured, or it will be damaged.

The red test lead, W-102, can be used to contact any a-c voltage up to 1000 volts RMS. Common test lead W-103 is then used as the ground return. Alligator clips E-106 and E-107 may be screwed over the ends of leads W-102 and W-103 to make connections to circuits more convenient if it is desired.

R-F Voltmeter Circuits

All r-f voltages are applied directly to the diode probe, W-104, and are rectified with tube V-101 and the associated circuit inside the probe handle. Ground lead W-106, screwed in place on the side of W-104, is the ground return for r-f measurements. The resulting d-c voltage is applied across the divider network and a portion of it is connected to the signal grid of bridge tube V-103. As this d-c value is proportional to the peak-to-peak value of the applied voltage, and meter deflection is proportional to the d-c voltage, the meter indicates r-f voltage directly. If the voltage being measured has a true sine wave form, the RMS value can be read directly on meter M-101. However, if the wave form is any shape other than a sine wave, the RMS value has no meaning; press the switch marked PRESS FOR PEAK TO PEAK, S-103, to obtain a peak-to-peak reading on the meter. The peak-to-peak value which is obtained by pressing switch S-103 is correct for all wave forms, providing they have a duty cycle of at least 4×10^{-6}.

Ohmmeter Circuits

Resistance measurements are made with probes W-102 and W-103. When they are shorted together, the signal grid of tube V-103 is connected to ground potential and no meter deflection occurs. When the probes are separated with infinite resistance, the voltage at the signal grid of the bridge tube is 1.5 volts negative with respect to ground, and meter M-101 will read full scale deflection. Battery BT-101 furnishes 1.5 volts. The OHMS ADJUST potentiometer, R-126, is a meter sensitivity adjustment which compensates for aging of the battery. The setting of range switch S-102 determines which of the range resistors is in the circuit. The range resistor and the battery are in series with the test leads. When any external resistance is contacted with the test probes, this resistance is in series with the range resistance. Part of the battery voltage is dropped across each of the resistors, and the amount of voltage across the resistance between the test probes is the amount which is connected to the signal grid of bridge tube V-103.

Milliammeter Circuit

The milliammeter circuit uses meter M-101 in series with resistor R-144, and a ring shunt in parallel with this combination. Test leads W-102 and W-103 are used for current measurements. Test lead W-102 is the positive lead, and test lead W-103 is negative. There is no grounded point in the milliammeter circuit, so the meter can be connected at any point in the measured circuit.

The milliammeter circuit is entirely independent of the electronic circuits, and it does not matter whether power lead W-105 is connected to an a-c source, or whether power switch S-104 is set at ON or at OFF. The current, passing through the circuit from probe W-102 to probe W-103, will divide through the parallel circuit in inverse proportion to the resistance of the two paths. The portion which passes through meter M-101 causes a deflection proportional to the total current. The position of range switch S-102 indicates how much total current has to be flowing to make the meter read full scale deflection. The maximum voltage drop for milliammeter measurements is 250 millivolts for any range.

Microammeter Circuit

When function switch S-101 is set at 100 μ a-d-c resistor R143 is shunted across meter M-101. The meter sensitivity is 50 microamperes and has a resistance of 2000 ohms. When it is shunted with resistor R-143, which has an equal resistance, the current divides with half through the meter, M-101, and the other half through resistor R-143. When 100 microamperes flow through the circuit from test lead W-102 to test lead W-103, 50 microamperes will flow through meter M-101 to cause full-scale deflection. Any part of 100 microamperes

Digitized by Google

through the circuit will cause a proportionally smaller amount of current to flow through meter M-101, and a proportionally smaller deflection will result.

MAINTENANCE

Recommended preventive maintenance procedures for multimeters AN/PSM-4A and ME-25B/U are presented below.

Weekly: Inspect the front panel, and clean with a dry cloth. Use dry compressed air to blow out dust and dirt. Check the mounting screws, switches, jacks, control knobs, fuse and pilot lamp covers, meter dial cover, and test leads, probes, and power leads. Tighten loose screws and knobs as necessary. Inspect the battery and battery trough for any dirt or corrosion, or any swelling of the battery case. Remove any corrosion with crocus cloth. Replace the battery if it shows any signs of swelling.

Monthly: Inspect all resistors and capacitors for dirty surfaces, corrosion, discoloration, and loose mountings and connections. Inspect the contacts of all switches. Inspect and test all electron tubes (ME-25B/U). Replace any weak tubes. The multimeter must be recalibrated when V-103 is replaced. Check the indications of the multimeters against the indications of another piece of test equipment known to be in good working order, or against standard values of voltage and resistances. Recalibrate as necessary.

TUBE TESTERS

Tube testers are discussed in Introduction To Electronics, NavPers 10084 and Basic Electronics, NavPers 10087-A. The design of modern tube testers is such that no special preventive maintenance procedures are required. The following precautions apply to most tube testers:

1. Do not connect the tester into a d-c power supply line. Be sure the power line is 105 to 125 VAC at a frequency between 50 and 1600 cps.

2. Do not insert a tube in any test socket without first properly adjusting the controls.

3. Check all tubes for shorted elements first. If the tube is shorted, do not make any other tests.

4. Do not push the mutual conductance pushbutton when testing rectifier tubes.

Tube Tester Limitations

In general, tube testers do not completely indicate tube performance because they present a fixed impedance to the tube grid and plate which may or may not be that of the equipment in which the tube is to operate. Also, the tester takes no account of the interelectrode capacity of the tube. Military specifications allow a wide deviation of interelectrode capacity which makes an accurate prediction of tube performance with a tube tester difficult. The range of operating frequency affects performance also.

It is impracticable to design a complete testing instrument that will evaluate the performance of any tube in any circuit in which it is being used. A tube may test low on the tester and yet work perfectly well in the circuit or, on the other hand, it may check good in the tester and not function in the equipment. As a rule, therefore, only dead, shorted, or extremely weak tubes should be discarded purely on the basis of a tube tester check.

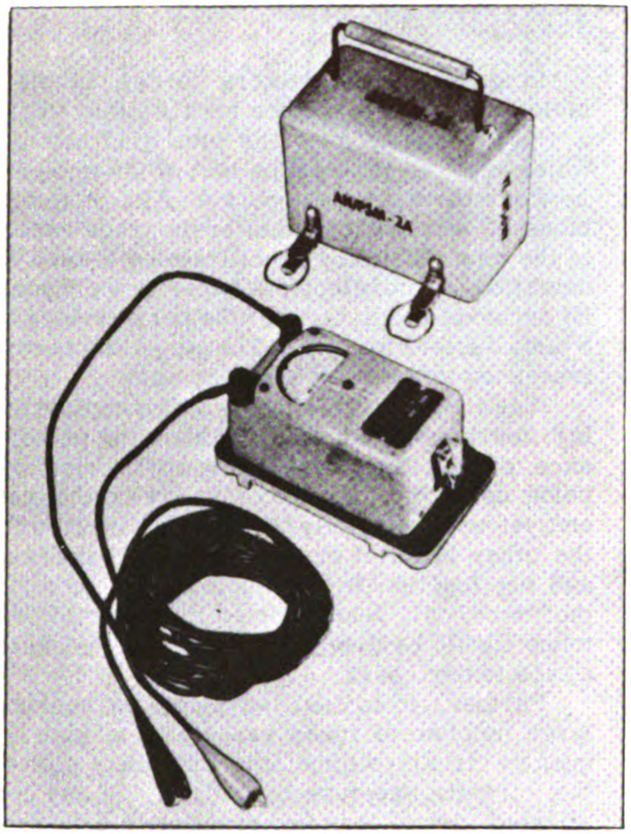
Further, it is NOT advisable to replace a large number of tubes especially in high frequency circuits without checking their effect on the circuit, one tube at a time. In any complicated circuit it is bad practice to arbitrarily replace a large number of tubes. It is better to replace them either tube by tube or in small groups. Be sure to replace each tube with an identical replacement.

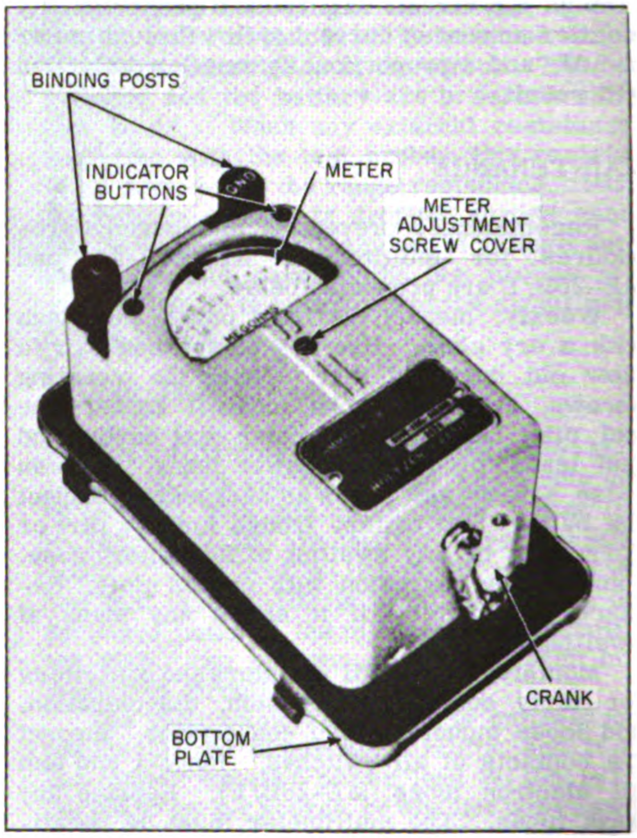
MEGGERS

Meggers (megohmmeters) are used primarily to test insulation resistance. A megger employing a 500 volt d-c generator is described in Basic Electricity, NavPers 10086-A. Another type of megger employing an a-c generator, a rectifier, and an ohmmeter circuit with a conventional d-c milliammeter (Insulation Test Set AN/PSM-2A) is illustrated in figure 5-9. It is designed to measure insulation resistance from 0 to 1000 megohms. The testing voltage is 500 volts d-c.

The meter pointer should read infinite resistance when there are no external connections to the output binding posts, L, and GND. If the pointer does not stand over the infinity mark, it is necessary to adjust the meter adjustment screw until the pointer stands over the infinity mark. When the meter terminals are short-circuited and the crank is turned at normal

Digitized by Google





1.55

Figure 5-9.—Insulation test set AN/PSM-2A.

operating speed (indicator buttons glowing steadily), the meter pointer should be over the zero mark.

The operation of the insulation test set is relatively simple.

1. Be sure that the apparatus, line, or circuit to be tested is disconnected from its power supply in accordance with safety instructions. Ground the apparatus, line, or circuit to be tested to discharge any capacitors connected to it.

2. Connect the spade-type terminal lug of the black lead to the GND binding post of the test set.

3. Attach the alligator clip of the black test lead to the side of the circuit (under test) nearest ground potential.

4. Connect the spade-type terminal lug of the red lead to the L binding post of the test set.

5. Attach the alligator clip of the red test lead to the conductor to be tested.

6. Turn the crank in either direction at the minimum speed required to provide steady illumination of the indicator buttons.

7. Read the megohms of resistance offered by the material being tested. If the resistance is more than 1000 megohms at 500 volts d-c, the meter will remain at rest over the infinity mark (∞), indicating that the resistance of the insulation being tested is beyond the range of the meter.

MEGOHMMETER, TYPE CV-60089

Electron tube megohmmeter Navy type CV-60089 (fig. 5-10) is recommended for testing IC circuits and components that must be tested at a lower potential than 500 volts. Supplied with the tester are three test leads, and a leather carrying strap. The tester, test leads, and carrying strap are enclosed in a heavy oak case.

The rheostat marked ZERO ADJUSTER controls the plate and grid potentials of the amplifier tube. This rheostat is used to adjust the

Digitized by Google

pointer to the zero or top mark division with the ground and line terminals short-circuited. The right-hand button marked PRESS TO READ is depressed whenever a reading is desired. This closes the filament circuit to the amplifier tube. There is no drain on the internal batteries unless this button is depressed.

For normal operation, the line and ground terminals are used. The line binding post is insulated with polystyrene fittings and is guard-ringed against leakage current. The guard ring on this binding post connects to the center post marked SHIELD. Where surface leakage influences readings, such as in cable testing, a guard ring or a leakage shield should be applied to the surface of the insulation and connected to the shield terminal.

To operate, connect one test lead to the ground terminal and one test lead to the line terminal. Short-circuit the clipped ends of the leads and depress the PRESS TO READ button. The pointer should deflect to the ZERO position. If adjustment is necessary, remove the zero adjuster cap and rotate the adjuster screw bringing the pointer to the ZERO position. Replace the zero adjuster cap nut and connect the leads across the unknown resistance. Depress the PRESS TO READ button and note the resistance reading.

When circuits or components under test contain a large electrical capacity the PRESS TO READ button must be depressed for a sufficient time to allow the capacitor to charge before a steady reading is obtained. The test voltage applied by the megohmmeter to the unknown resistance is approximately 50 volts when measuring resistances of approximately 10 megohms. The voltage is slightly greater than this when measuring higher resistances.

140.30

Figure 5-10.—Megohmmeter, Navy type CV-60089.

Maintenance

After considerable use, the test leads may become worn or frayed, usually where they enter the hard rubber sleeves of the forked terminal. When this occurs, the sleeve should be unscrewed and the lead cut off beyond the worn spot and resoldered to the terminal.

Batteries for supplying voltage for the operation of the CV-60089 megohmmeter are contained in the bottom of the bakelite panel. These batteries are subject to deterioration either from use or from age. When the meter pointer cannot be brought to full scale with the test prods shorted and the zero adjuster rheostat at maximum right-hand position, the batteries should be replaced.

The tube does not normally need replacing unless mechanically damaged. Never replace the tube unless all other component parts are in good working order.

If during an actual resistance testing operation, with the PRESS TO READ button depressed, the instrument pointer fluctuates due to an intermittent contact, remove the panel and clean the switch contacts with a piece of crocus cloth.

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

Digitized by Google

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 a 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 action of a high-speed machine can be analyzed under normal operating conditions.

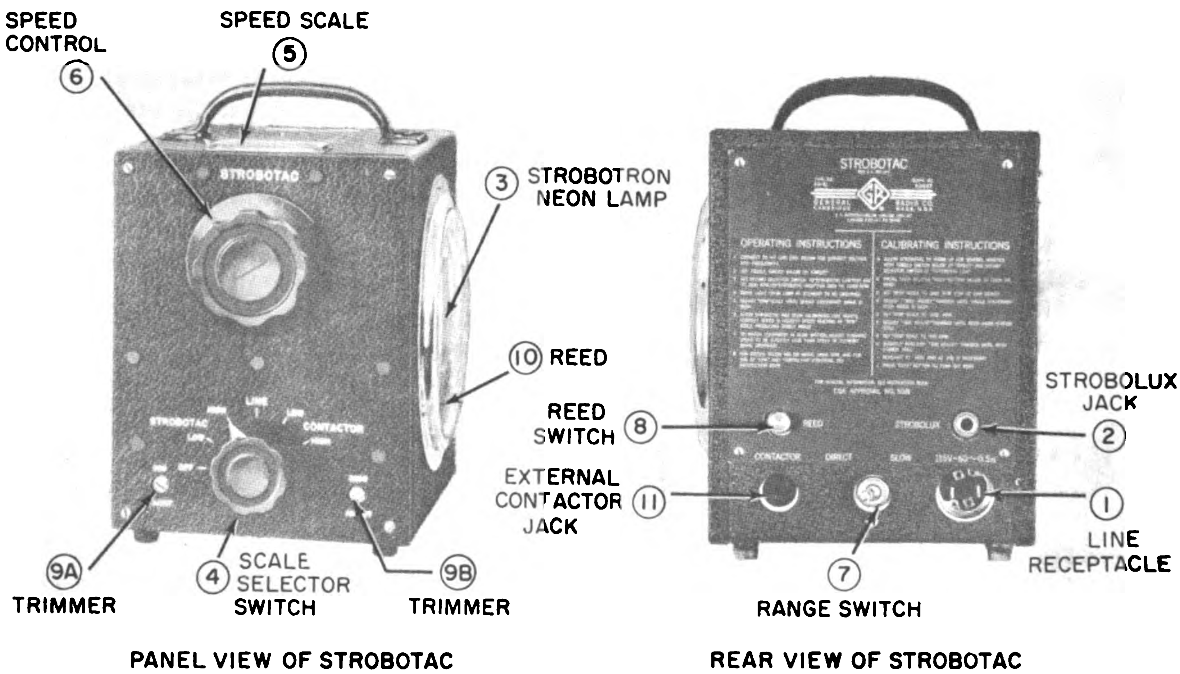
When the flashing rate of the light is adjustable, the control can be calibrated in flashes (or revolutions) per minute. The stationary image seen when the flashing rate of the lamp and the rotational rate of a shaft are equal permits very precise speed measurements to be made.

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 5-11 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.



140.31

Figure 5-11.—Strobotac.

Digitized by Google

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 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.

CATHODE-RAY OSCILLOSCOPE

Your ability to properly operate an oscilloscope will not only help you perform your duties but will provide a means of visually illustrating the operation of various electrical circuits to be studied as you advance in rate.

A typical cathode-ray oscilloscope is shown in figure 5-12. A description of the operating controls and their function is as follows:

FRONT PANEL CONTROLS:

INT-OFF—operates the power off-on switch and controls the intensity or brightness of the image on the screen.

FOCUS—adjusts the focus or sharpness of the trace on the cathode-ray tube.

HOR. and VERT. POS. (left-right, down-up)—used to adjust the position of the trace on the screen, either horizontally or vertically.

HORIZONTAL AMP. PANEL:

HOR. ATTEN—selects the source of signal, a-c with attenuation sweep, or d-c. The signal is then fed to the horizontal amplifier.

HOR. GAIN—controls the gain of the horizontal amplifier.

DC—connection for d-c input to the horizontal amplifier.

AC—connection for a-c input to the horizontal amplifier.

GND—connection for ground when using either a-c or d-c inputs to the horizontal amplifier.

SWEEP CIRCUIT OSC. PANEL:

COARSE FREQUENCY—provides a coarse adjustment of the sweep frequency.

VERNIER FREQUENCY—provides a fine or vernier adjustment of the sweep frequency.

SYNC. CIRCUIT PANEL:

SYNC. SELECTOR—provides for the selection of the synchronizing voltage source as follows:

LINE—signal is taken from input to power supply.

EXT.—signal is supplied by an external source connected to the EXT. terminal.

INT.—signal is taken from the input to the vertical amplifier.

LOCKING—selects the polarity and amplitude of the synchronizing voltage applied to the sweep circuit oscillator.

EXT.—input for external synchronizing voltage.

Z AXIS—connection for external voltage to be used in intensity modulation of the electron beam.

LINE—an external source of line supply frequency.

VERTICAL AMP. PANEL:

VERT. ATTEN.—provides for attenuation of a-c signals or d-c input without attenuation.

VERT. GAIN—controls the gain of the vertical amplifier.

DC—connection for d-c input to the vertical amplifier.

AC—connection for a-c input to the vertical amplifier.

GND—connection for ground when using either a-c or d-c inputs to the vertical amplifier.

OPERATION.—The operation of the 0S-8C/U cathode-ray oscilloscope for observation of

Digitized by Google

waveforms is relatively easy, in that the signal to be observed is applied to the a-c terminal of the vertical amplifier and that the horizontal sweep frequency need only be synchronized with it. The steps for operating the OS-8C/U are listed below.

1. The signal to be observed is connected to the a-c input terminal of the vertical amplifier, and the ground connection of the input signal is connected to the GND terminal.

2. The INT-OFF control is turned clockwise to switch the power on. After the oscilloscope has warmed up, adjust the brightness or intensity of the trace to a comfortable level.

3. Set the COARSE FREQUENCY control to the lowest frequency.

4. Set the SYNC. SELECTOR switch to the INT. position.

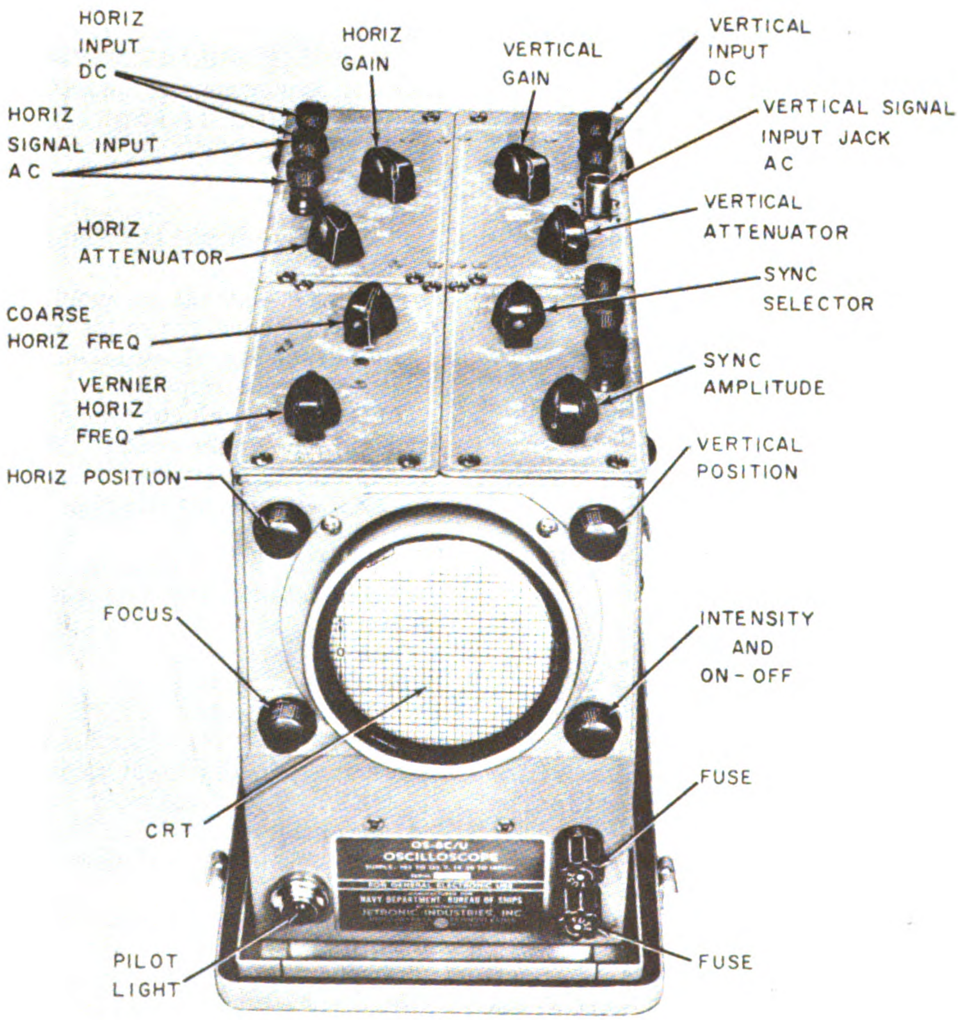
5. Set the VERT. GAIN and the VERT. ATTEN. controls for suitable deflection.

6. Set the HOR. GAIN control for desired pattern width.

7. Slowly rotate the VERNIER FREQUENCY control until the desired pattern appears and is steady.

8. If the number of cycles is too great, the COARSE FREQUENCY control is adjusted a step higher until the desired number of cycles appear and are steady. This may require readjustment of the VERNIER FREQUENCY control.

9. The trace can then be locked in synchronization by adjusting the LOCKING control.



1.86B

Figure 5-12.—Oscilloscope controls and input connections of the OS-8C/U oscilloscope.

Digitized by Google

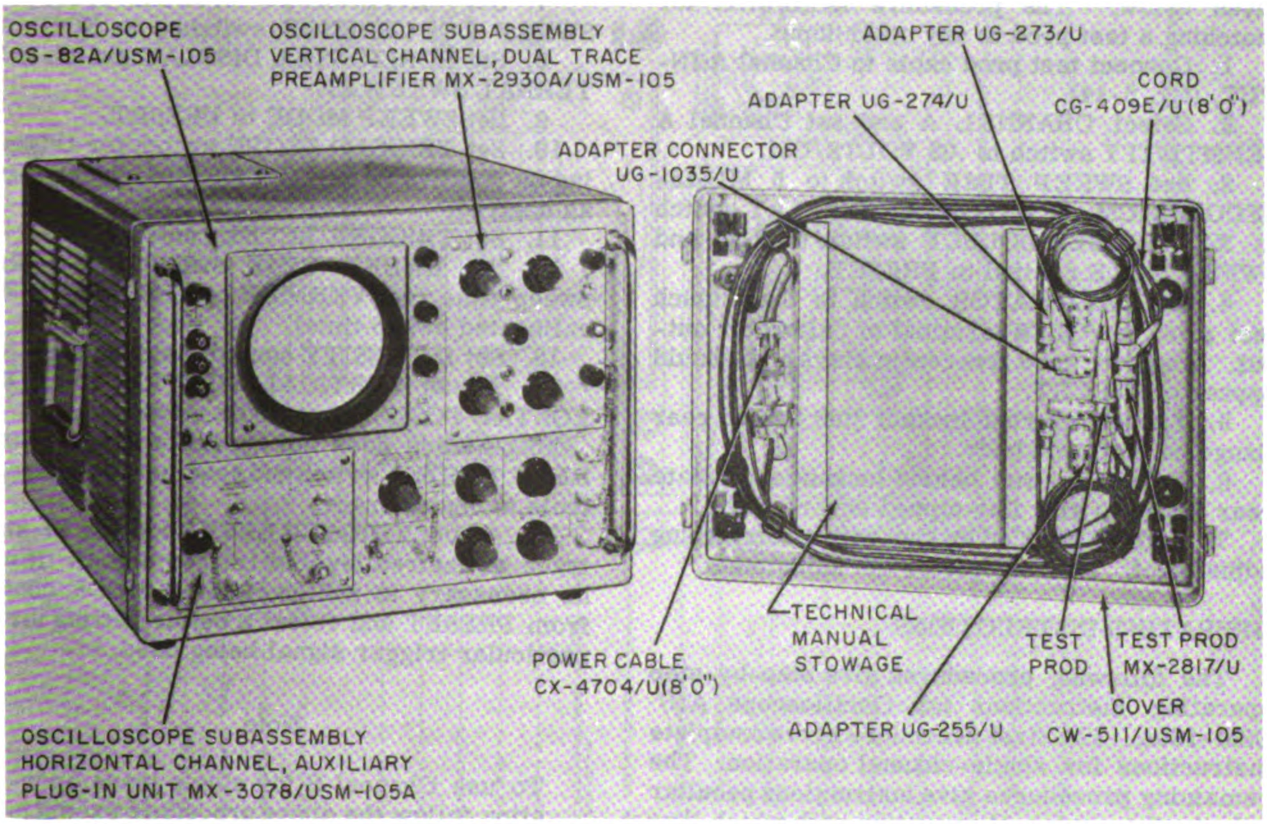
either positive or negative, until the pattern appears steady and fixed.

When it is desired to use an external synchronizing voltage, it can be connected into the EXT. synchronization terminal. The SYNC SELECTOR must be turned to EXT. The other controls are adjusted as above. When it is desired to use line voltage for synchronization, the SYNC. SELECTOR is turned to LINE and the other controls are adjusted as above.

OSCILLOSCOPE AN/USM-105A

Oscilloscope AN/USM-105A (fig. 5-13) is a general purpose, high-speed laboratory type oscilloscope designed for shipboard use. It produces a graphical display of simple and complex voltage variations which contain frequency components ranging from zero to 14 megacycles. To simplify operation and the interpretation of the display, the instrument provides calibrated vertical sensitivities, triggered internal sweeps, calibrated sweep times, calibrated expanded sweeps, beam finder, and calibrator.

Oscilloscope AN/USM-105A consists of a major unit and two plug-in units. The major unit, Oscilloscope OS-82A/USM-105, contains the power supplies, horizontal amplifier, sweep generator, main vertical amplifier, cathode ray tube (CRT), calibrator, and the controls associated with these circuits. Oscilloscope Subassembly, Vertical Channel, Dual Trace Preamplifier MX-2930A/USM-105 is a plug-in preamplifier to the main vertical amplifier. The dual trace preamplifier contains two separate voltage channels each with its own controls. An electronic switch, controlled from the front panel, connects one channel or the other to the main vertical amplifier and thereby determines the vertical presentation on the CRT. To produce a dual trace, the electronic switch alternates channels, either on alternate sweeps, or



1.86.5

Figure 5-13.—Oscilloscope AN/USM-105A.

Digitized by Google

continuously at a one-megacycle rate. Oscilloscope Subassembly, Horizontal Channel, Auxiliary Plug-in Unit MX-3078/USM-105A permits single-sweep operation and external intensity modulation.

TEST PRODS

The test prods are used to decrease circuit loading. The one megohm input impedance of the vertical and horizontal circuits plus the shunt capacity of a cable connecting the oscilloscope to the test circuit may degrade the operation of the circuit under test. The test prod increases input impedance to 10 megohms shunted by 10 picofarads. The test prod also introduces a 10:1 voltage division which must be considered when translating waveform deflection on the CRT into volts.

The test prod has an adjustable compensating capacitance so the prod can be matched exactly to a particular input of the oscilloscope. The procedure for matching a test prod to the Channel A input of the dual-trace preamplifier is given below. The procedure is similar for matching a test prod to any other input.

1. Connect test prod cable to Channel A INPUT, (fig. 5-14).
2. Select CHANNEL A and set Channel A SENSITIVITY switch to .02 VOLTS/CM.
3. Set SWEEP TIME switch to .5 MILLISECONDS/CM, HORIZONTAL DISPLAY switch to X1, TRIGGER SOURCE switch to INT, and SWEEP MODE control to PRESET.
4. Set CALIBRATOR switch to 1 and touch test prod to VOLTS terminal of calibrator output. A square wave five centimeters high should appear on the CRT.
5. Loosen knurled locknut just behind rear flange on test prod body.
6. Hold test prod behind locknut and rotate rear flange to give flat-topped square wave.
7. Tighten knurled locknut without disturbing adjustment. This completes the adjustment.

OPERATING INSTRUCTIONS

The following procedures give step-by-step operating instructions for Oscilloscope AN/USM-105A. The first procedure gives complete instructions for single-channel operation. The remaining procedures give instructions peculiar only to the modes of operation with which they are concerned.

Before making any test or measurements, allow the instrument about 5-minutes warmup. Rotate INTENSITY control fully counterclock- wise before turning instrument on to preven accidental burning of the CRT face during warm- up.

Use the test prods and other accessorie furnished with the oscilloscope as necessary

Single Trace Operation-Internal Sweep

1. Connect vertical signal to INPUT of Chan nel A.
2. Set Vertical Presentation switch to Chan nel A.
3. Set SENSITIVITY switch for Channel A a desired. (Set VERNIER to CALIBRATED fo calibrated sensitivity.)
4. Set input coupling for a-c or d-c couplin as desired.
5. Set POLARITY switch to +UP or -UP a desired.
6. Set TRIGGER SOURCE as desired. external trigger is used, connect it to trigge source INPUT.
7. Set INTENSITY MODULATION an SWEEP OCCURRENCE switches to NORMAI
8. Set HORIZONTAL DISPLAY switch to IN TERNAL SWEEP X1.
9. Set SWEEP MODE to PRESET.
10. Set TRIGGER SLOPE switch for trigger ing on positive or negative slope of trigger sign as desired.
11. Set TRIGGER LEVEL control to 0.
12. Set SWEEP TIME switch for desire sweep time (set VERNIER control to CAL FO calibrated sweep time).
13. Set INTENSITY control as desired.
14. Adjust VERTICAL POSITION and HOR ZONTAL POSITION controls as desired.
15. If trace does not appear on screen, pres BEAM FINDER switch and readjust position con trols to center trace.
16. Adjust TRIGGER LEVEL control to sta trace at desired level of trigger signal. It ma be necessary to switch SWEEP MODE contr from PRESET and select a better setting for th particular trigger signal being used.

Note

To use Channel B for single trace operation follow the above procedure except to substitute Channel B controls and terminals for the Channel A controls and terminals called out in the procedure.

Digitized by Google

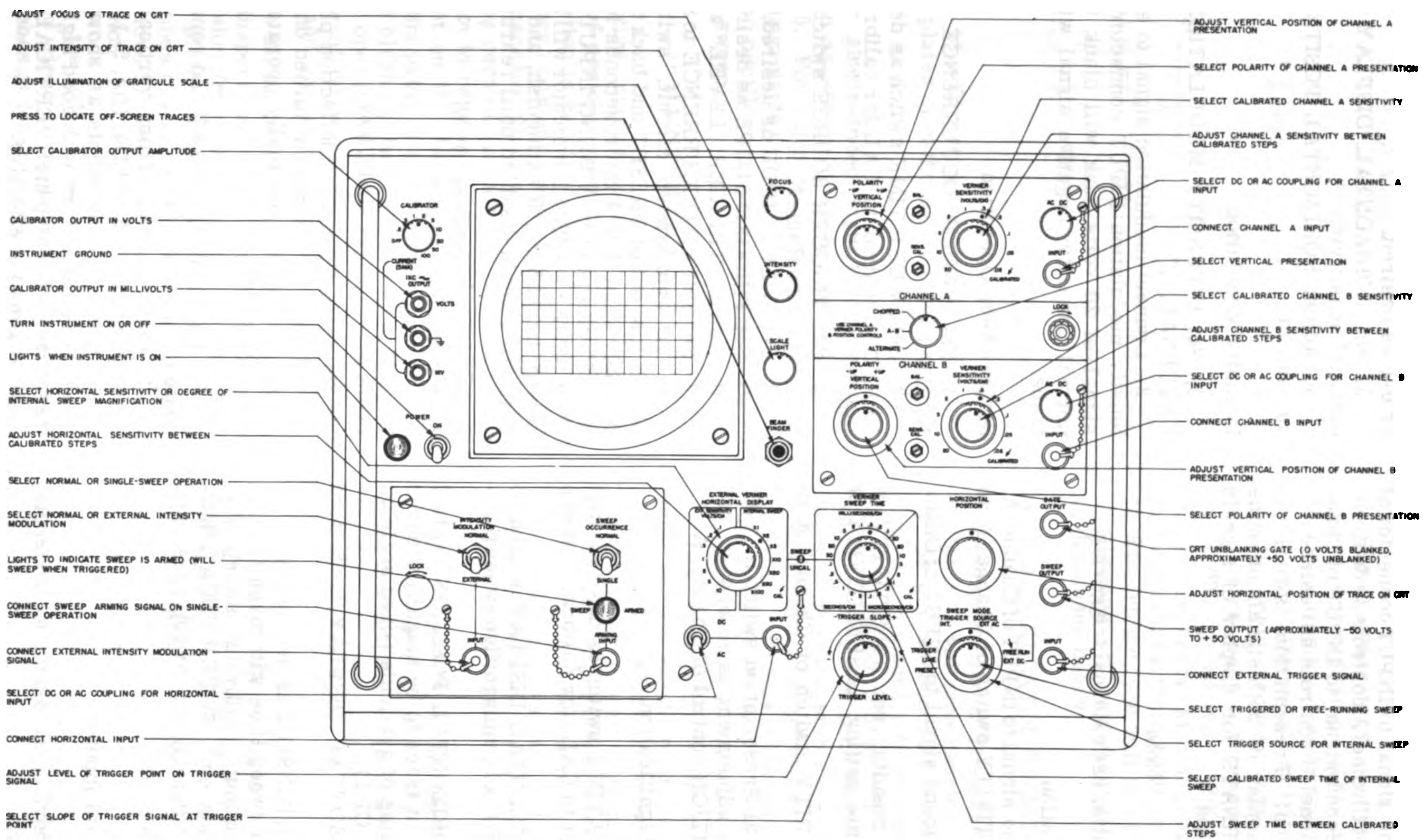


Figure 5-14.—Front panel controls and connectors.

Dual Trace Operation

1. Connect one signal to INPUT connector of Channel A and set Channel A controls as desired.
2. Connect second signal to INPUT of Channel B and set Channel B controls as desired.
3. Set Vertical Presentation switch to CHOPPED for display of both signals on same sweep, to ALTERNATE for display of signals on alternate sweeps.

Note

For best results, use external triggering.

Differential Operation

1. Connect one signal to INPUT of Channel A.
2. Set SENSITIVITY switch of Channel A as desired.
3. Connect second signal to INPUT of Channel B.
4. For best results, set SENSITIVITY of Channel B to same setting as SENSITIVITY of Channel A.
5. Set POLARITY switch of Channel A to +UP.
6. Set Vertical Presentation switch to A-B.
7. If vertical adjustment is necessary, use VERTICAL POSITION control of Channel A.

Internal Sweep Magnification

1. Set SWEEP TIME switch as desired. (Set VERNIER control to CAL for calibrated sweep time.)
2. Set HORIZONTAL DISPLAY switch to INTERNAL SWEEP X1 (unmagnified sweep position).
3. Adjust HORIZONTAL POSITION control to place portion of trace to be magnified under vertical center line of graticule (lined scale on the screen of the CRT).
4. Set HORIZONTAL DISPLAY to desired magnification.
5. Readjust INTENSITY as necessary.
6. If selected sweep time with magnification is less than minimum calibrated sweep time (0.02 microseconds/cm), SWEEP UNCAL indicator will light indicating that sweep time is no longer calibrated.

External Horizontal Input

1. Connect horizontal signal to horizontal INPUT connector.
2. Set horizontal input coupling switch to a-c or d-c as desired.
3. Set HORIZONTAL DISPLAY to desired external sensitivity.
4. Adjust HORIZONTAL POSITION control as desired.

Intensity Modulation

1. Set INTENSITY MODULATION switch to EXTERNAL.
2. Connect modulation signal to external intensity modulation INPUT connector. Positive signal of 20 volts peak will blank trace from normal intensity; negative signal will brighten trace.

Single Sweep Operation

1. Set SWEEP OCCURRENCE switch to NORMAL.
2. Set SWEEP TIME switch as desired. (Set VERNIER control to CAL for calibrated sweep time.)
3. Set TRIGGER SOURCE switch according to trigger signal used.
4. Set SWEEP MODE as desired.
5. Set TRIGGER SLOPE as desired.
6. Adjust TRIGGER LEVEL as desired.
7. Set SWEEP OCCURRENCE to SINGLE.
8. To arm sweep circuit, switch SWEEP MODE just out of PRESET and back to PRESET, or apply pulse 1 to 4 microseconds long and +15 to +25 volts peak to ARMING INPUT connector.
9. SWEEP ARMED indicator will light. After sweep, indicator will extinguish, and sweep circuit will remain disabled until rearmed.

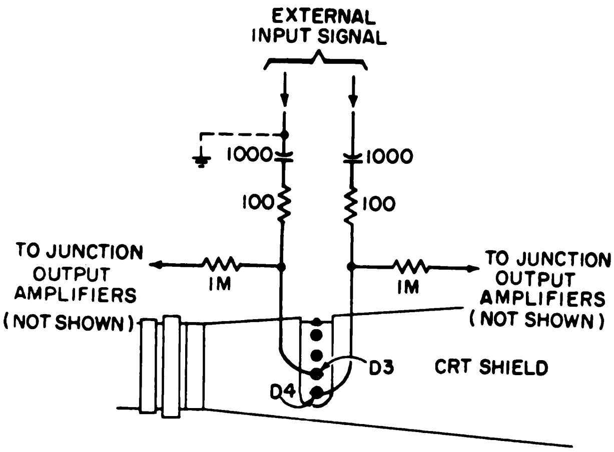
Connecting Signal Directly to CRT Deflection Plates

CAUTION

Do not contact CRT deflection plate terminals with instrument turned on. These terminals are normally operated about +200 volts.

1. Turn oscilloscope off and remove access plate on top of cabinet.
2. Remove leads from vertical deflection plate terminals D3 and D4, (fig. 5-15).
3. Connect components as shown in figure 5-15. Use capacitors with good high-frequency response. Front-panel VERTICAL POSITION control remains effective.

Digitized by Google



124.224
Figure 5-15.—Direct connection to deflection plates of cathode-ray tube.

4. For single-ended input, ground common signal lead as shown by dashed ground lead in figure 5-15. For balanced input leave both signal leads ungrounded.

5. Turn oscilloscope on. Use external signal to trigger sweep.

MAINTENANCE

Preventive maintenance for oscilloscopes consists of periodic cleaning and inspections. No lubrication is required. Use dry compressed air, or a dry cloth and a soft brush for cleaning. It may be necessary to use a dry-cleaning solvent to clean the ceramic insulators, but care should be taken not to remove the special paint. Do not use solvent on the chassis as it may soften the tropicalizing paint. Compressed air or a brush is best for cleaning the electron tubes. Keep all tubes that operate at a high temperature clean, as a layer of dust will interfere with the heat radiation and raise the operating temperature.

Remove all tubes from their sockets periodically and inspect the pins and sockets. Remove any corrosion from the pins with crocus cloth. Check the plate connections of the high voltage rectifier tubes to ensure that they are clean and tight. Remove all fuses and check for looseness and corrosion.

Inspect the AN/USM-105A air filter frequently and clean if necessary. Check the fan motor brushes at least monthly.

SIGNAL GENERATORS

Signal generators are test equipments that generate a-c signals. They are used for signal tracing, aligning tuned circuits, making sensitivity measurements, and frequency measurements. Audio frequency signal generators (audio oscillators) have a frequency range of from 20 to 20,000 cycles (up to 200 kc in some cases). Radio frequency signal generators have frequency ranges from 10 kc to 10,000 mc. As an IC Electrician, you will be concerned with audio oscillators. A representative audio oscillator is discussed below.

AUDIO OSCILLATOR TS-382D/U

Audio Oscillator TS-382D/U (fig. 5-16) generates a-c voltages ranging from 20 to 200,000 cycles per second at amplitudes which may be varied continuously from zero to 10 volts. The set contains thermostatically controlled heaters which reduce the time required for the instrument to reach a stable operation temperature. The heaters also permit satisfactory operation in arctic climates. The audio oscillator operates from a 115 volt a-c source, at a line frequency of 5- cps to 1600 cps.

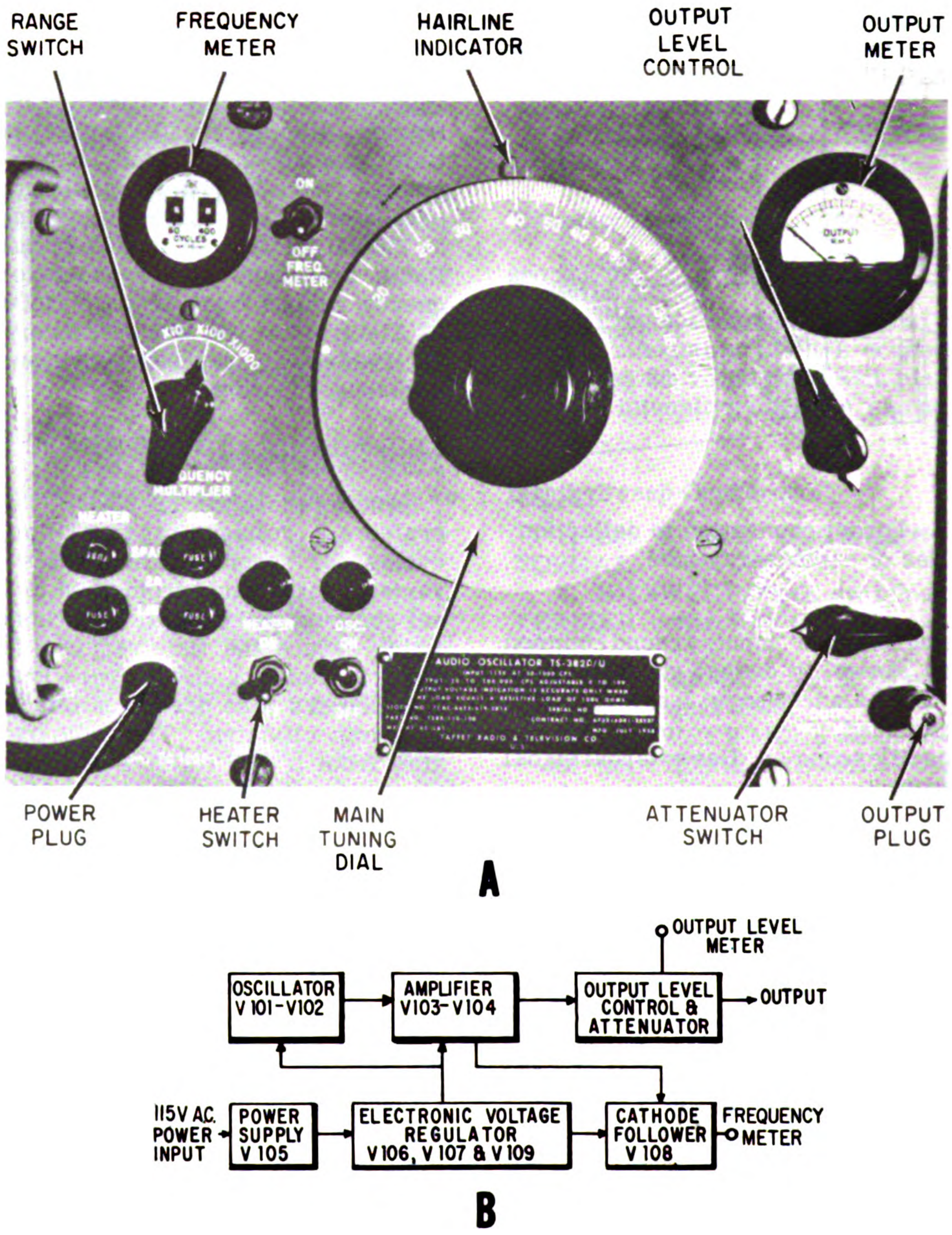
The circuit (fig. 5-16B) consists of an oscillator section which generates the audio voltage, an amplifier which isolates the oscillator from the external circuit and amplifies the audio voltage, an output level metering circuit with an attenuator, a power supply, an electronic voltage regulating system, and a cathode follower which isolates it from the remainder of the circuit.

OSCILLATOR.—The oscillator section includes tubes V101 and V102 (fig. 5-17) and consists basically of a two stage resistance coupled amplifier which is caused to oscillate by the use of positive feedback.

OUTPUT AMPLIFIER.—The output section consists of a two-stage resistance coupled amplifier employing tubes V103 and V104. Negative feedback is used to minimize distortion and provide uniform output. The output is constant within two db, over the frequency range covered by the instrument.

OUTPUT SYSTEM.—The output system consists of an output level meter (M101), a gain control (R138), and a six-section ladder type

Digitized by Google



20.338

Figure 5-16.—Audio oscillator TS-382D/U; (A) Front panel; (B) Block diagram.

attenuator, consisting of R152, R154, R155, R156 and R157. The output meter operates from a full wave type rectifier circuit in which germanium crystals are used as rectifying elements. The gain control is inserted in the circuit immediately preceding the output meter in order to set the voltage level at the input to the ladder attenuator. The ladder attenuator is calibrated on the basis of the instrument working into its rated load of 1,000 ohms.

POWER SUPPLY.—The power supply is designed to deliver filament voltage to all the tubes and to supply well filtered d-c voltage to the plates and screen grids. The power transformer T101 supplies all filament voltages in addition to

Digitized by Google

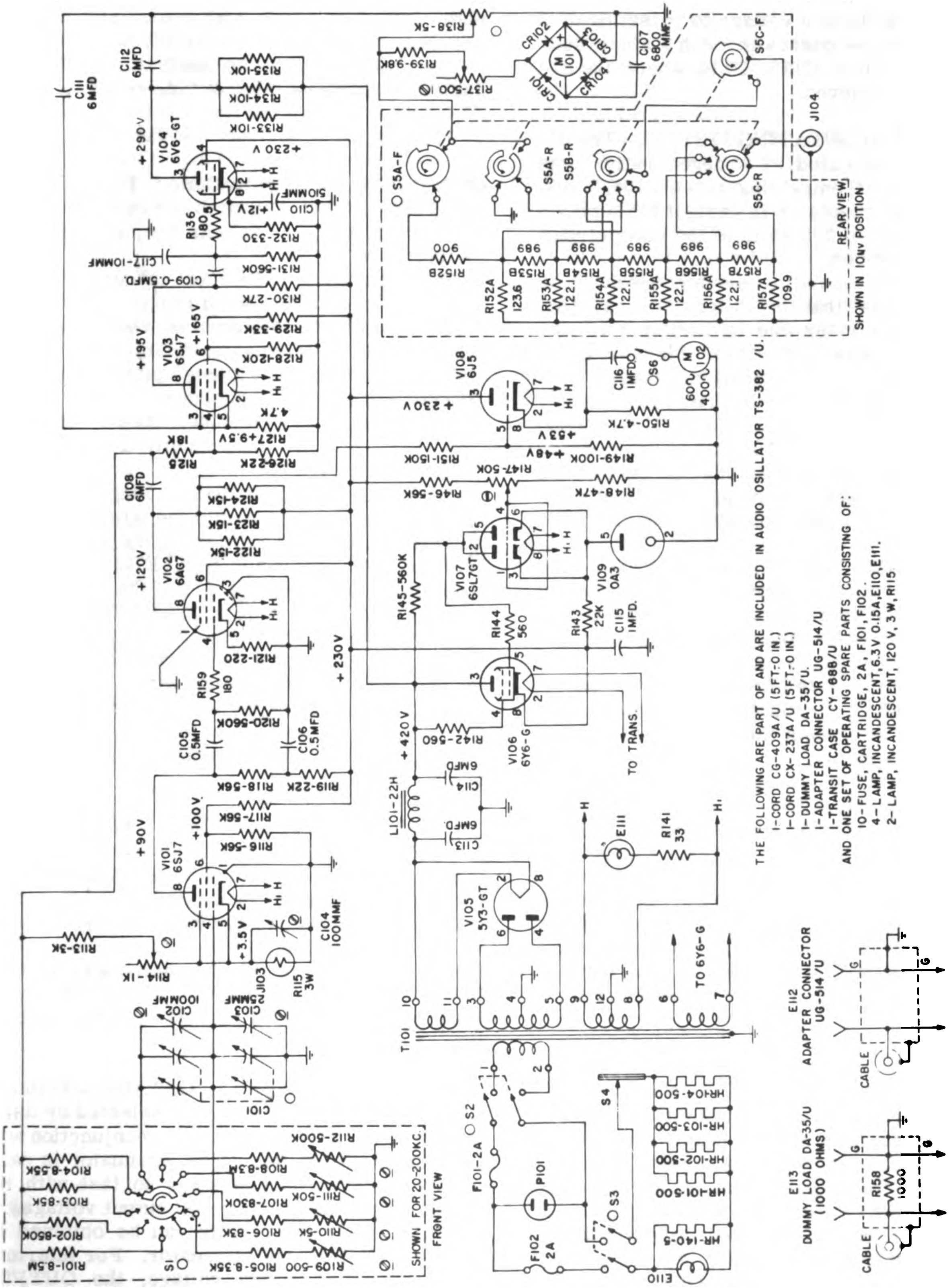


Figure 5-17.—Audio oscillator TS-382D/U, schematic diagram.

Digitized by Google

high voltage to the full wave rectifier V105, which converts the a-c voltage to pulsating d-c. The rectified wave passes through a single section pi filter L101, C113, C114 where the a-c component is removed.

VOLTAGE REGULATING SYSTEM.—The filtered d-c is regulated by a degenerative type voltage regulator employing tubes V106, V107, and V109. The regulator is designed to supply a constant voltage of 230 volts to the plate circuit of the various tubes.

The voltage regulating system operates as follows: Assume that the voltage across R146, R147, and R148 rises due to variation in line voltage or changes in the load. The voltage on the control grid of V107 then increases. This increased current causes the plate voltage to decrease, and as the control grid of V106 is connected to the plate of V107, the voltage of this control grid also decreases. The current through V106 then decreases, restoring the proper voltage (230 volts) across R146 and R148.

FREQUENCY METER.—A vibrating reed type meter permits accurate check of the output frequency of the oscillator at 60 cps and 400 cps. The meter has been factory adjusted to an accuracy of three-tenths of one percent. This meter, M102 is isolated from the second oscillator tube V102 by a cathode follower stage V108 to prevent shifts in frequency when the frequency meter is in operation.

STAND-BY-HEATER.—Five strip heaters HR101, HR102, HR103, HR104, and HR140 are used to decrease the time required for the unit to reach stable operation and to permit satisfactory operation in colder climates. These strip heaters are controlled by a built-in thermostat, S4, calibrated to maintain the temperature at 20° C. An ON-OFF switch S3, and an indicator light are included in the heater circuit.

Operation

Audio Oscillator TS-382D/U should be allowed a warm-up period of at least 15 minutes, in order to reach a stable operating temperature. Audio frequency output is taken from the oscillator at the output connector on the lower right hand side of the front panel (fig. 5-16A). The output cable may be used either with the adapter connector (UG-514/U), or the dummy load (DA-35/U) marked 1,000 OHM LOAD, for high impedances. Use of the dummy load with high impedance external loads maintains the accuracy of the metering circuit calibration.

The controls of Audio Oscillator TS-382D/U, and their functions, are as follows:

Control	Function
OSC: On, Off	Oscillator Power Switch
HEATER: On, Off	Switch for stand-by heater
RANGE X1, X10, X100, X1000	Selects frequency range
Main Tuning Dial	Selects frequency within each range
OUTPUT LEVEL (METER)	Indicates voltage input to attenuator
OUTPUT LEVEL (CONTROL)	Adjusts voltage input to attenuator
ATTENUATOR	Reduces output voltage in sub-multiples of ten.

STARTING PROCEDURE.—Plug the female end of the power cable into the power socket in the lower left-hand corner of the front panel. With the OSC switch and HEATER switch in OFF positions, plug the male end of the power cable into a 115 volt a-c source. Check the line voltage with a voltmeter to be sure that it is correct. Throw the OSC switch to ON position and check to see that the pilot lamp directly above the switch lights. Allow the instrument to warm up for at least 15 minutes. At low ambient temperatures, it is advisable to turn the HEATER switch to the ON position.

SELECTING FREQUENCY.—Any frequency from 20 to 200,000 cps may be selected by setting the main tuning dial and the range switch so that the two readings, when multiplied together, equal the desired frequency. For example, to select an output frequency of 52,000 cps, set the main tuning dial to 52 and the range switch to X1000. Do not force the main tuning dial beyond its normal travel as it may destroy the calibration of the instrument.

SELECTING OUTPUT VOLTAGE.—Voltages from zero to 10 volts may be selected by using the OUTPUT LEVEL control in conjunction with the attenuator switch. The attenuator is calibrated in seven decade steps so that with the output meter set to 10 volts, output voltages of 10 volts to 10 microvolts can be obtained by simply switching the attenuator. For intermediate values of output voltage, the OUTPUT

Digitized by Google

LEVEL control is varied so that the output meter reads the desired voltage. The attenuator switch is then set so that its value, multiplied by the output meter reading, gives the desired output voltage level. For example, to obtain an output voltage of 0.04 volts, set the meter by means of the OUTPUT LEVEL control to read 4 volts, and set the ATTENUATOR switch to the .01 position. The output voltage will then be the meter reading multiplied by the attenuator setting, or 0.04 volts.

STOPPING PROCEDURE.—The oscillator is turned off by throwing OSC switch to OFF position. If the heaters have been used, they should also be turned OFF. Remove the power plug first from the supply line and then from the front panel, remove the output cable, and replace the unit in its transit case.

Maintenance

The following periodic inspections are recommended for Audio Oscillator TS-382D/U at the intervals indicated:

Weekly: Inspect front panel of Audio Oscillator, check fuseholders, indicator lamp assemblies, power plug, output plug, cables, dummy load, and adapter connector.

Monthly: Check tightness of knobs.

Semiannually: Inspect front panel, tubes, and tube socket, switches, variable capacitors, thermostat contacts, terminal boards, and chassis.

To check that the Audio Oscillator is operating properly, set the main tuning dial to 60, and the range switch to X1 (the lowest frequency range). This sets the frequency of the oscillator at 60 cps. Turn the tuning dial back and forth slightly until the reed in the Frequency Meter marked 60 cycles/sec vibrates with maximum amplitude. This point should be correct within one division.

Similarly, the output at 400 cps may be checked by setting the main tuning dial to 40 and the range switch to X10. The main dial setting should be correct within one and a half divisions when the 400 cycle per sec reed vibrates with maximum amplitude. Turn FREQ. METER switch to OFF position after checking the frequency calibration.

Use a clean, dry lint-free cloth or a dry brush for cleaning. All control knobs should be tightened using an Allen wrench. Do not loosen the three set-screws on the main tuning dial plate behind the knob on the main dial as the frequency calibration of the instrument will be destroyed.

Should the contacts of the RANGE switch, or the ATTENUATOR switch become covered with a heavy accumulation of dust, dry compressed air of not more than five pounds pressure may be used, followed by careful cleaning with a small camel's hair brush. Care must be exercised when using the brush, not to damage any of the resistors mounted on these switches.

No lubrication of any kind is required for Audio Oscillator TS-382D/U. The main tuning capacitor and the associated panel bearing have been lubricated at the factory and do not require further lubrication.

Do not tamper with any of the alignment adjustments as these will affect the frequency calibration of the instrument. Removal of any tube other than those in the power section involves recalibration of the oscillator. Tubes V105, V106, V107 and V109 may be replaced without recalibrating the instrument.

Digitized by Google

CHAPTER 6

SOUND-POWERED TELEPHONES

Telephones provide a rapid and efficient means of communication between the many stations aboard ship. A satisfactory telephone system must be reliable and not susceptible to damage during battle; it must make possible rapid completion of calls; and it must be easy to maintain. 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.

In addition to sound-powered telephones, some ships are provided with automatic dial-type telephones. The dial telephone system is used for administrative purposes and is not depended upon under battle conditions. The dial telephone system is discussed in chapter 9 of this training course. This chapter discusses sound-powered telephones and associated circuits and equipment.

SOUND-POWERED UNITS

The sound-powered transmitter (microphone) and receiver units in some telephones are identical and interchangeable. Other telephones have sound-powered units that differ slightly. The principle of operation, however, is the same for both the transmitter and receiver.

As illustrated in figure 6-1, a unit consists 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 end is such that an air space remains after the armature is inserted between them. This air space has an intense magnetic field, which is supplied by the two magnets that are held in contact with the pole tips.

The armature is clamped rigidly at one end near one of the pairs of poles and is connected

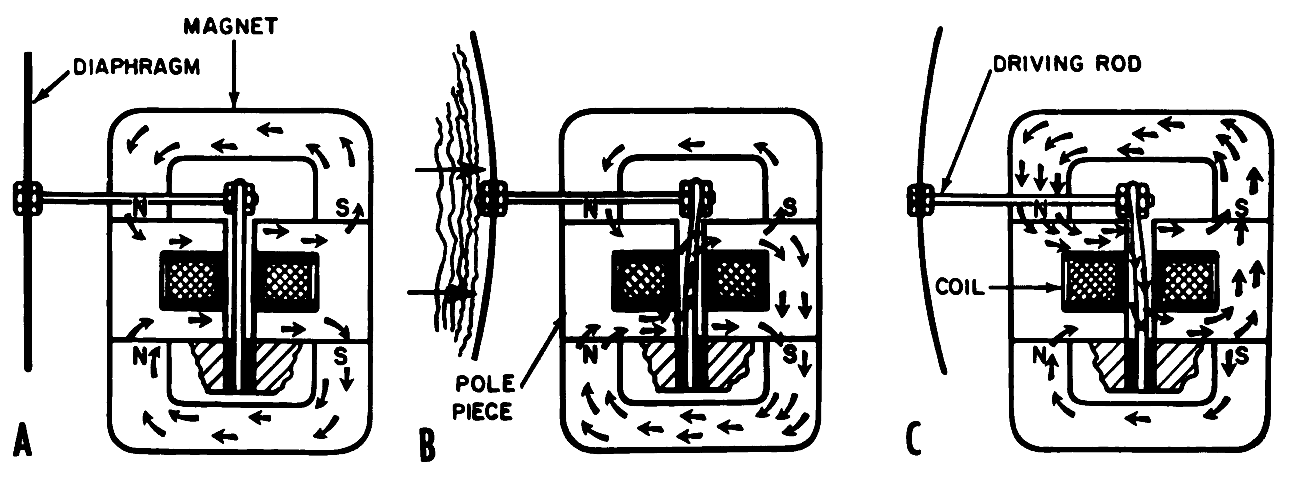


Figure 6-1.—Sound-powered transmitter unit.

Digitized by Google

at the other end to the diaphragm by the drive 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.

PRINCIPLES OF 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 6-1A. 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 6-1B, 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 6-1C, 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 6-1B.

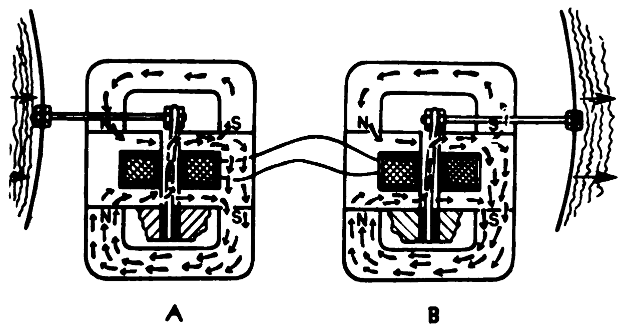
Sound waves striking the diaphragm cause it to vibrate back and forth. The armature bends first to one side and then to the other, causing an alternating polarizing flux to pass through it, first in one direction and then in the other. These lines of force passing through the armature vary in strength 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. 6-2). The resultant current through the coil magnetizes the armature with alternating polarity. An induced voltage in the coil of the transmitter (fig. 6-2A) causes a current to flow in the coil of the receiver (fig. 6-2B) 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. 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 Navy ships are handsets and 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 military specifications regardless of the manufacturer. Military Specification MIL-T-0015514D(SHIPS) of 24 March 1964 contains specifications for two types of handsets, and three types of headsets.

Digitized by Google



27.288

Figure 6-2.—Operation of sound-powered transmitter and receiver units.

HANDSETS

The type H203/U handset replaces the type TA, and is designed for general use, primarily one-to-one talking. The sound-powered transmitter and receiver units are interchangeable. A nonlocking, normally open, spring return, push switch, S1, (fig. 6-3), disconnects the sound-powered units from the line in the open position, and connects the units to the line in the closed (depressed) position. Capacitor, C1, is connected in parallel with the sound-powered units for tone compensation.

The type H-204/U handset is specially designed for use on a line loaded with other handsets or headsets. The switching arrangement keeps the set off the line when it is not in use. When transmitting, the transmitter unit is across the line and the receiver unit is across the line in series with a 3 db padding resistor. When receiving the receiver unit is directly across the line.

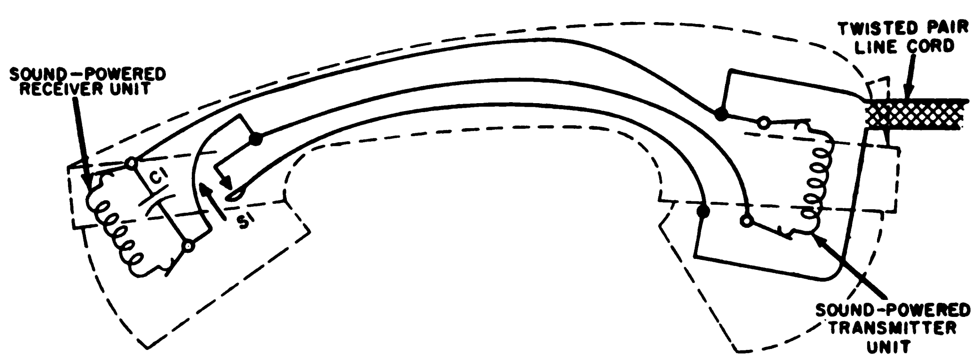
The sound-powered transmitter and receiver units are not interchangeable; however the receiver units are interchangeable with the type H-203/U sound-powered units.

HEADSETS

The type H-200/U headset replaces the type SA, and is designed for general use. The set consists of two sound-powered receiver units with protective shells and ear cushions, one sound-powered transmitter unit with protective shell provided with a push switch, one mouthpiece, one chest plate assembly with junction box provided with capacitors and terminal facilities, one headband assembly and neck strap, and one cord assembly and plug. Closing the press-to-talk switch, S1, (fig. 6-4), connects the sound-powered transmitter unit across the line. The receiver units are permanently connected across the line when the set is plugged in.

When a sound-powered telephone set is used on the output side of a sound-powered telephone amplifier, a small d-c voltage is placed across the set. The purpose is to provide an amplifier squelching circuit to avoid acoustical feedback when the local set is transmitting. Capacitor C1 (fig. 6-4), blocks the d-c from the receiver units. The press-to-talk switch allows the d-c to flow when transmitting, and operates a sensitive switch in the amplifier. The two capacitors are in series across the line. The sound-powered transmitter and receiver units are not interchangeable.

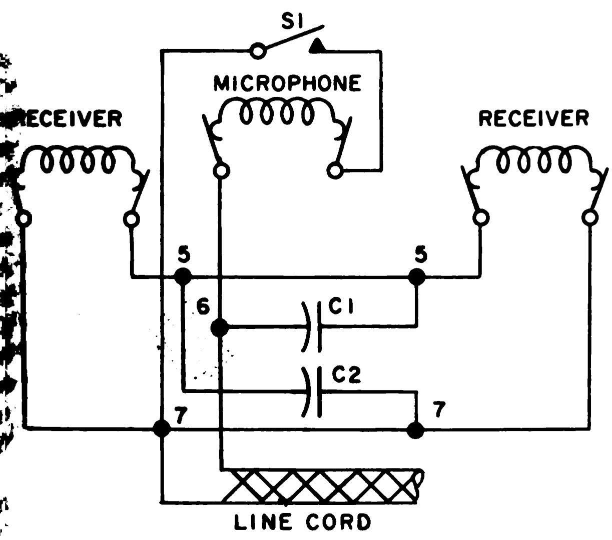
The type H-201/U headset is a specially designed set for use by plotters, console operators, etc. The transmitter is suspended from the headband by a boom. The boom may be adjusted to place the transmitter in front of the wearer's mouth. The junction box with terminal facilities, capacitors, and the normally



3.198

Figure 6-3.—Sound-powered telephone handset, wiring diagram.

Digitized by Google



140.33

Figure 6-4.—Sound-powered telephone headset type H-200/U, wiring diagram.

open, spring return, push switch, is fitted with a clip that allows it to be attached to the wearer's belt. The sound-powered units are not interchangeable.

The type H-202/U headset is a specially designed set for use in areas having high noise levels. The receiver units are housed in noise attenuating shells consisting of plastic caps lined with sound absorbing material. The sound-powered units are not interchangeable.

HANDLING AND STOWAGE

The connecting wires secured to the various portions of telephone sets have but one purpose—to transmit electric current. They are not provided as straps for supporting the equipment nor should they be subjected to a jerk or fall. When a plug is removed from a jack, the BODY of the plug should be pulled—never the CORD. Connections should be made so that a minimum of physical strain is put on the electric conductors. If the talker must remove the telephone set from his head, he should hang the set by the head band and the neck strap—not by any of the connecting wires.

The unit is made as waterproof as possible, but it should not be exposed unnecessarily to the weather. Moisture and good telephone service do not go hand-in-hand. Remember that several conductors, which actually carry the messages to and from the telephone, lie underneath the rubber covering on the various 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

Digitized by Google

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 coiled 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 for breakage. No special care, other than intelligent handling, is needed for handsets as they are much less subject to trouble than are headsets.

REPAIRS

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 familar 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.

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. 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.

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 difficult 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.

Inspection

A routine inspection of sets should be made before repairs are begun to determine whether physically 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.

Open and Short Circuits

The principal types of trouble that occur in sound-powered telephones are (1) short circuits or open circuits and (2) loss of sensitivity. A short circuit in a single unit renders an entire telephone circuit inoperative because it parallels all of the other units.

Use a low voltage ohmmeter to test for opens and shorts to avoid damage to the sound-powered units. Continuity tests may be made from the chest plate junction box on the types H-200/U, H-201/U, and H-202/U headsets. The normal d-c resistances of the sound-powered transmitter and receiver units are 10 ohms and 62 ohms respectively.

Loss of Sensitivity

Loss of sensitivity, or weakening of the transmission sound, is a gradual process and seldom is reported until the set becomes practically inoperative. When a sound-powered telephone is in good condition electrically yet the sound is weak, the transmitter unit should be replaced. If this procedure does not remedy the trouble, the receiver units should be replaced.

Headsets may be tested for loss of sensitivity by depressing the talk switch, and blowing into the transmitter. If the set is operating properly, a hissing noise is heard in the receiver units caused by the air striking the transmitter. One receiver unit is listened to, and then the other. In most cases, the loss in sensitivity is in the transmitter unit and might be caused by a displacement of the armature from the exact center of the air gap between the pole pieces.

Each sound-powered handset is tested on location because it is connected permanently to a box. The simplest test is to blow air into the transmitter. To test each individual handset it is not necessary to press the talk button because the transmitter and receiver are permanently connected in parallel. If no sound is heard, either the transmitter or the receiver is defective. The easiest method to determine whether the transmitter or the receiver is defective is to have someone talk into another phone on the line and to listen to both the transmitter and the receiver of the handset. If the

Digitized by Google

talker's voice is heard on one of the units but not the other, the unit on which the voice is not heard is the defective one and should be replaced. If the talker's voice cannot be heard on either unit, and the telephone circuit being used for the test is known to be free of trouble, the fault may be traced to the line cord, switch, or internal handset circuits.

Replacing Cords

When it is necessary to replace a defective cord between the junction box and the transmitter or receivers of headsets, tinsel cord should be used. Stocks of tinsel cord cut to the proper lengths for use with the various types of headsets and fitted with terminals are stocked at supply depots and should be requisitioned for use. Bulk tinsel cordage is also stocked at supply depots as standard stock. 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. 6-5).

If tinsel cord is not available, use standard DCP-1/2 cord between the junction box and the receivers and transmitter. Use DCOP 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.
6. Place the threaded entrance bushing, metal washer, and rubber gasket on the new cord and insert the cord into the entrance port (fig. 6-5). The cord should be long enough to allow slack after it is connected.
7. Secure the tie cord so that it takes all the strain off the connections; otherwise the wires might be pulled from their terminals.
8. Connect the wires to their terminals.
9. Screw the entrance bushing on the entrance port, drawing the bushing up tightly to secure the cable and to seal the port.
10. Close the unit after all connections have been visually checked.
11. Test the completed unit for operation.

SOUND-POWERED TELEPHONE SYSTEMS

There are three types of sound-powered telephone systems:

1. The primary battle telephone system—circuits JA to JZ (table 6-1)—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 circuits X1J through X61J, 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.

Table 6-1.—Sound-Powered Telephone Circuits

Circuit	PRIMARY CIRCUITS Title
JA	Captain's battle circuit
JC	Weapons control circuit
10JC	Missile battery control circuit
JD	Target detectors circuit
JF	Flag officer's circuit
1JG	Aircraft control circuit
2JG	Aircraft information circuit
2JG1	Aircraft strike coordination circuit
2JG2	Aircraft strike requirement and reporting circuit

Digitized by Google

Table 6-1.—Sound-Powered Telephone Circuits—Continued

Circuit	PRIMARY CIRCUITS Title
2JG3	Aircraft information circuit CATTC direct line
3JG	Aircraft service circuit
4JG1	Aviation fuel and vehicular control circuit
4JG2	Aviation fueling circuit forward
4JG3	Aviation fueling circuit aft
5JG1	Aviation ordnance circuit
5JG2	Aviation missile circuit
6JG	Arresting gear and barricade control circuit
9JG	Aircraft handling circuit
10JG	Airborne aircraft information circuit
11JG	Optical landing system control circuit
JH	Switchboard cross connecting circuit
JL	Lookouts circuit
JM	Mine control circuit
JN	Illumination control circuit
JO	Switchboard operators' circuit
2JP	Dual purpose battery control circuit
4JP	Heavy machine gun control circuit
5JP	Light machine gun control circuit
6JP	Torpedo control circuit
8JP	ASW weapon control circuit
9JP	Rocket battery control circuit
10JP	Guided missile launcher control circuit
10JP1	Starboard launcher circuit
10JP2	Port launcher circuit
11JP	FBM checkout and control circuit
JQ	Double purpose sight setters circuit
JR	Debarkation control circuit
JS	Plotters' transfer switchboard circuit
LJS	CIC information circuit
2JS	NTDS coordinating circuit No. 1
3JS	NTDS coordinating circuit No. 2
20JS1	Evaluated radar information circuit
20JS2	Evaluator's circuit
20JS3	Radar control officer's circuit
20JS4	Weapons liaison officer's circuit
21JS	Surface search radar circuit
22JS	Long range air search radar circuit
23JS	Medium range air search radar circuit
24JS	Range height finder radar circuit
25JS	ABW radar circuit
26JS	Radar information circuit
31JS	Track analyzer No. 1 air radar information check
32JS	Track analyzer No. 2 air radar information check

Table 6-1.—Sound-Powered Telephone Circuits—Continued

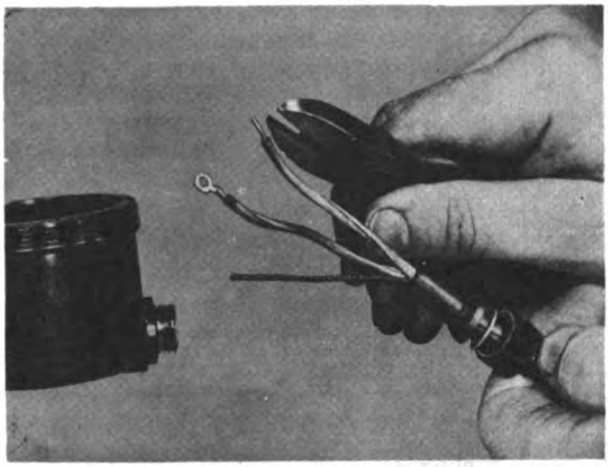
Circuit	PRIMARY CIRCUITS Title
33JS	Track analyzer No. 3 air radar information check
34JS	Track analyzer No. 4 air radar information check
35JS	Raid air radar information circuit
36JS	Combat air patrol air radar information circuit
61JS	Sonar information circuit
80JS	ECM plotters' circuit
81JS	ECM information circuit
82JS	Supplementary radio circuit
JT	Target designation control circuit
1JV	Maneuvering and docking circuit
2JV	Engineers' circuit (engines)
3JV	Engineers' circuit (boiler)
4JV	Engineers' circuit (fuel and stability)
5JV	Engineer's circuit (electrical)
6JV	Ballast control circuit
JW	Ship control bearing circuit
JX	Radio and signals circuit
2JZ	Damage and stability control
3JZ	Main deck repair circuit
4JZ	Forward repair circuit
5JZ	After repair circuit
6JZ	Midships repair circuit
7JZ	Engineer's repair circuit
8JZ	Flight deck repair circuit
9JZ	Magazine sprinkling and ordnance repair circuit forward
10JZ	Magazine sprinkling and ordnance repair circuit aft
	AUXILIARY CIRCUITS
XJA	Auxiliary captain's battle circuit
X1JG	Auxiliary aircraft control circuit
X1JV	Auxiliary maneuvering and docking circuit
XJX	Auxiliary radio and signals circuit
X2JZ	Auxiliary damage and stability control circuit
	SUPPLEMENTARY CIRCUITS
X1J	Ship administration circuit
X2J	Leadsman and anchor control circuit
X3J	Engineer watch officer's circuit
X4J	Degaussing control circuit
X5J	Machinery room control circuit

Digitized by Google

Table 6-1.—Sound-Powered Telephone Circuits—Continued

Circuit	SUPPLEMENTARY CIRCUITS
X6J1	Electronic service circuit
X6J7	ECM service circuit
X6J11-14	NTDS service circuits
X7J	Radio-sonde information circuit
X8J	Replenishment-at-sea circuit
X9J	Radar trainer circuit
X10J	Cargo transfer control circuit
X10J1	Cargo transfer circuit-Lower decks
X10J10	Cargo transfer circuit-Upper decks
X11J	Captain's and admiral's cruising circuit
X12J	Capstan control circuits
X13J	Aircraft crane control circuits
X14J	Missile handling and nuclear trunk crane circuit
X15J	SINS information circuit
X16J	Aircraft elevator circuit
X17J	5-inch ammunition hoist circuit
X18J	Machine gun ammunition hoist circuits
X19J	Missile component elevator circuit
X20J	Weapons elevator circuits
X21J	Catapult circuit
X22J	Catapult steam control circuit
X23J	Stores conveyor circuit
X24J	Cargo elevator circuit
X25J	Sonar service circuit
X26J	Jet engine test circuit
X28J	Dumbwaiter circuit
X29J	Timing and recording circuit
X34J	Alignment cart service circuit
X40J	Casualty communication circuit
X41J	Special weapons shop service circuit
X42J	Missile assembly and handling circuit
X43J	Weapons system service circuit
X44J	ASROC service circuit
X45J	Special weapons security circuit
X50J	Fog foam circuit
X61J	Nuclear support facilities operations and handling circuit

The various sound-powered telephone systems are classified further into (1) switchboard circuits, (2) switch-box circuits, and (3) string-type circuits.



140.34
Figure 6-5.—Preparing a new tip on a tinsel cord.

SWITCHBOARD CIRCUIT

A switchboard circuit is a circuit having cut-out switches on a switchboard. Most large combatant ships have several sound-powered telephone switchboards installed in different centrally located and protected control stations, such as IC rooms and plotting rooms. Each switchboard (fig. 6-6) usually has several switchboard circuits and a line-disconnect switch for each line. The older type (fig. 6-6A) is replaced with the newer switchboard (fig. 6-6B) which has a switchjack (fig. 6-6C) at each position. The switchjack consists of a line switch and jack. The purpose of the line switch is either to connect or disconnect a station from its circuit. The jack either parallels that phone with another circuit or parallels two circuits. Paralleling is accomplished by means of a PATCHING CORD, which is a short length of portable cord having a jack plug at each end.

Opening the line switch disconnects a station from its circuit. Inserting one end of a patching cord into the jack of this station and the other end of the cord into the jack of another station, makes the first station parallel with the circuit of which the second station is a part. Leaving the line switch of the first station closed makes

Digitized by Google

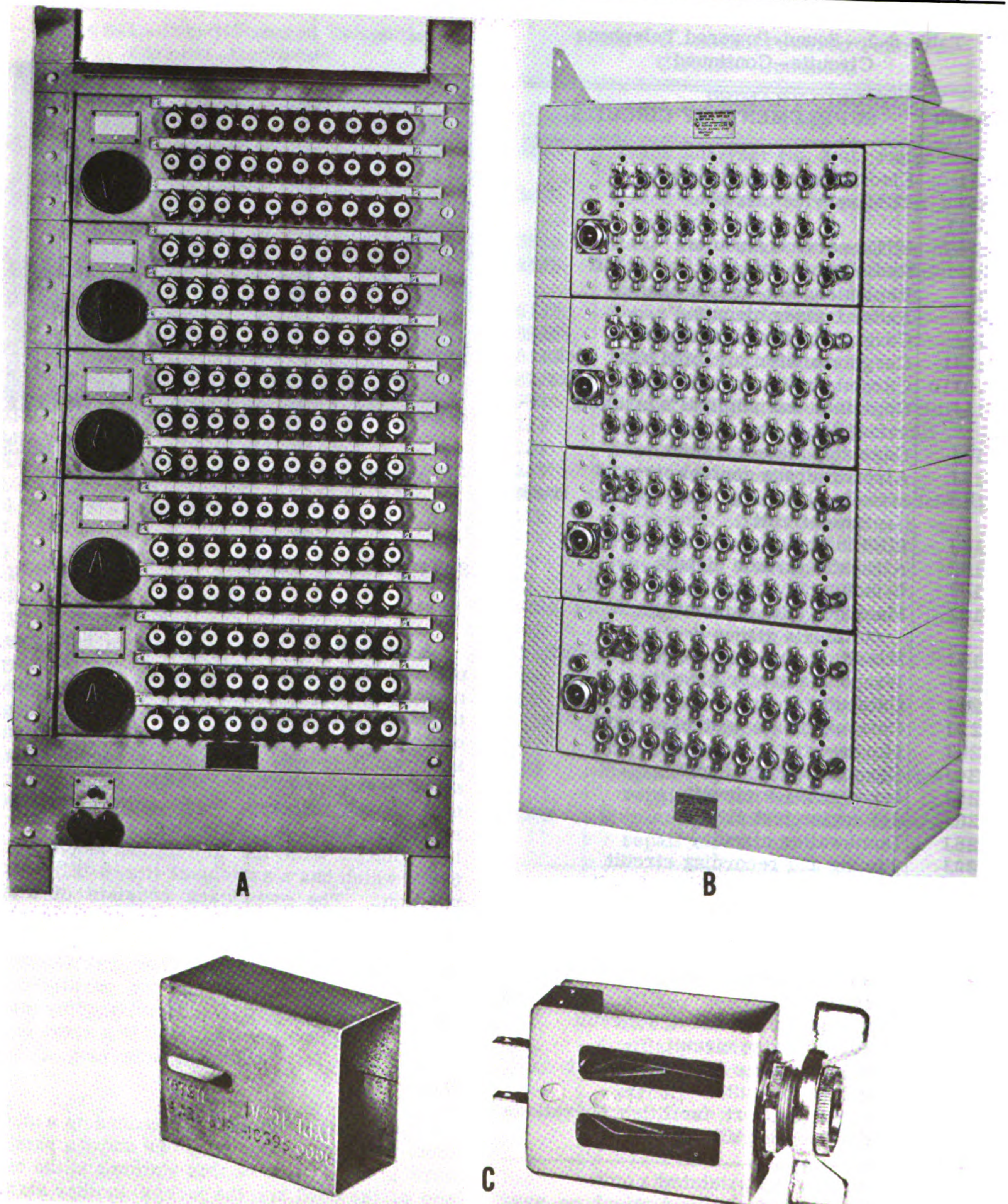
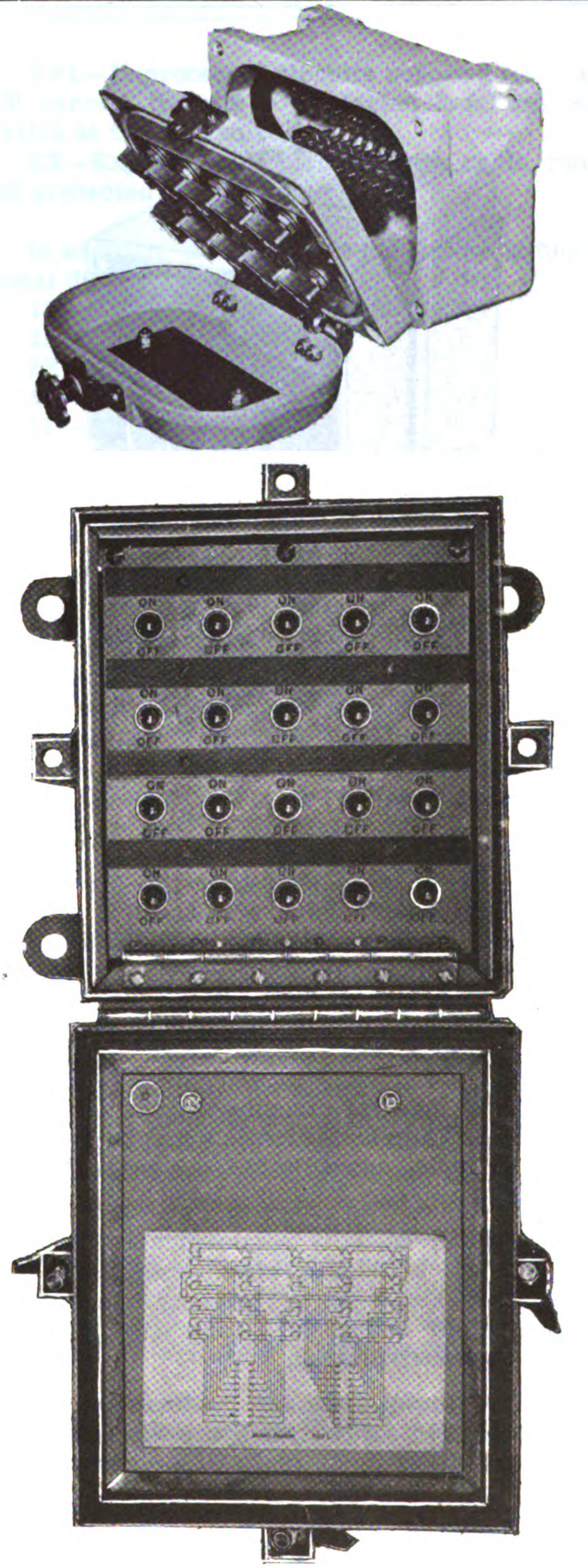


Figure 6-6.—Sound-powered telephone switchboards. 27.290X

Digitized by Google

the two circuits parallel. Any line may be connected to any other circuit, line, or combination of circuits on the switchboard by manipulation of patching cords and individual line cutout switches.

Transfer switches at some switchboards, such as gunnery-control switchboards, provide a means of quickly disconnecting a number of telephones from one circuit and connecting them to another. For example, the telephone circuits may be shifted from the number 1 computer to the number 2 computer or from one plotting room to another.



27.291X
Figure 6-7.—A.C.O. switch boxes. (Top) new; (Bottom) old.

SWITCHBOX CIRCUIT

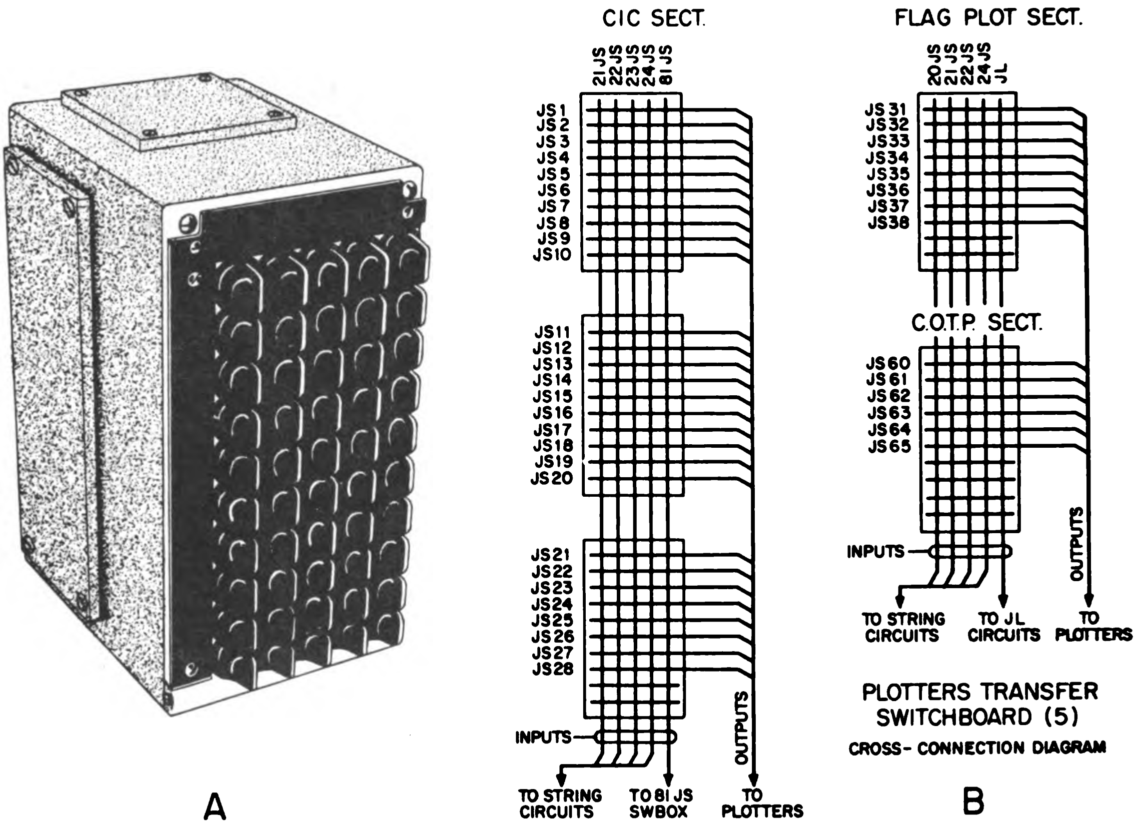
A switchbox circuit consists of several line cutout switches mounted in a switch box. Usually, there is only one switchbox for each circuit. Telephone switch boxes function primarily as small ACO switchboards. The switch boxes are located at the principal station on the circuit, and contain either 10 or 20 switches used for connecting incoming lines to a common circuit bus (fig. 6-7). Each station on the circuit is connected to one of the line switches. Some of the switches may be used as tie switches connected to the circuit bus in other switch boxes. When these tie switches are closed, the circuits in the two boxes are paralleled.

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 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. 6-8).

Digitized by Google



36.69

Figure 6-8.—Plotters transfer switchboard, type SB-82/SRR. (A) External view; (B) Wiring diagram.

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. These switches are discussed in chapter 2 of this training course.

MAINTENANCE

Preventive maintenance for sound-powered telephone circuits consists of routine tests and inspections, and cleaning. All circuits should be tested at least weekly to ensure that they are

Digitized by Google

working properly. Cleanliness is essential to the proper operation of sound-powered telephone switchboards due to the low voltages and currents involved. Dirt and dust between closely spaced contacts can cause cross-talk. Use a portable blower or vacuum cleaner to clean switchboards and switchboxes at least monthly.

Insulation tests should be made periodically on all sound-powered telephone cables. A separate test should be made for each circuit. Test each conductor to ground, and between each pair of conductors.

When making the insulation tests, all line switches must be closed, and all tie switches between circuits open. Headsets must be unplugged, and all sound-powered telephone amplifier chassis removed from their cases. All handset pushbuttons must be open.

The minimum allowable insulation resistance reading depends upon the length and temperature of the cable as discussed in chapter 2 of this training course. Lengthy cable runs on large ships may read as low as 50,000 ohms and be satisfactory.

Keep the cap covers for all sound-powered telephone jackboxes on, when the jackbox is not being used.

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.

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.

For example, 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 16 ringing stations (fig. 6-9). 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.

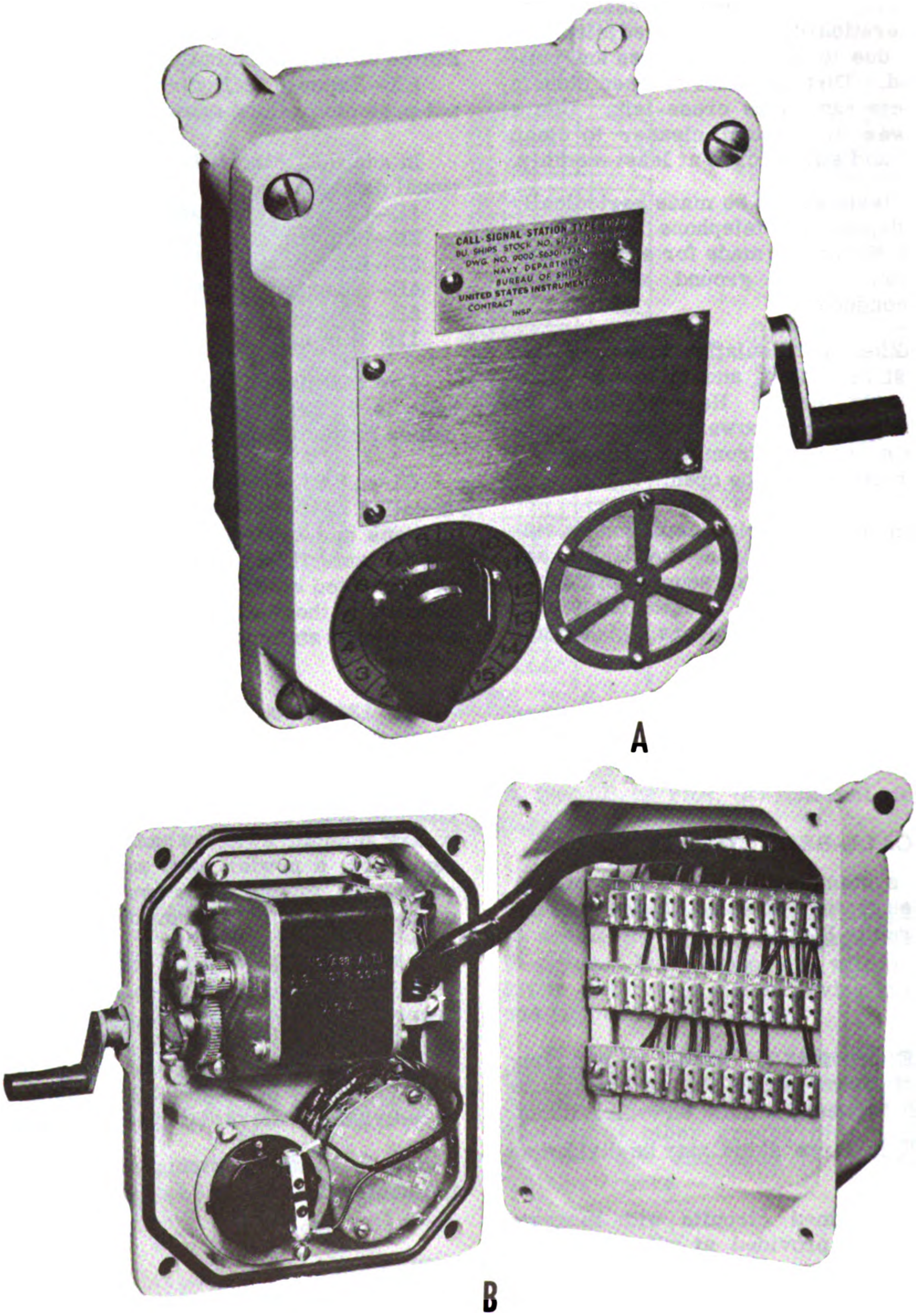
The operator simply turns the selector switch to the station to be called and cranks the generator handle. The howler (a modified sound-powered telephone receiver unit at the selected station) will give a high distinctive howl. The attenuator may be used to adjust the sound level of individual howlers at their respective stations.

The elementary wiring diagram (fig. 6-10) illustrates the simplicity of the circuit.

CIRCUIT A

Circuit A is for the convenience of the ship's officers in calling pantry attendants and orderlies. Calls are provided from all cabins; staterooms, except those equipped with ship's

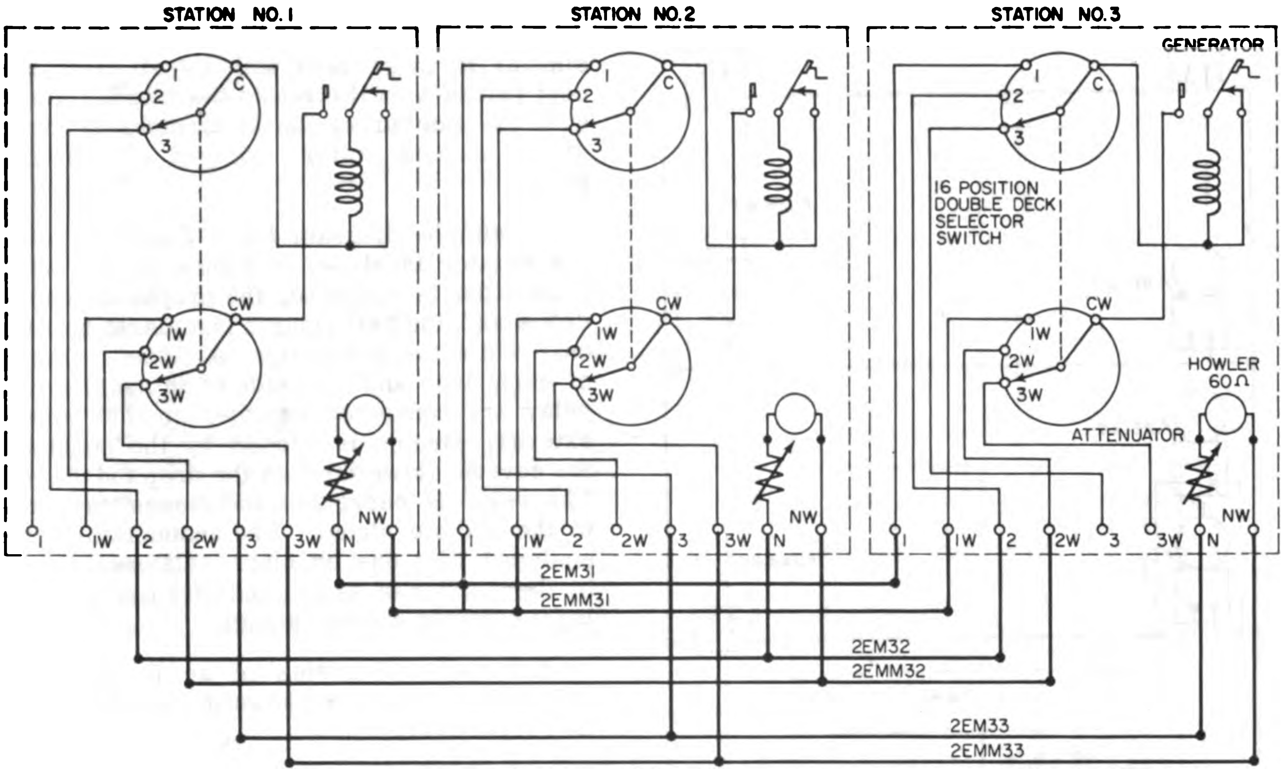
Digitized by Google



74.66X

Figure 6-9.—Magneto ringing station. (A) External view; (B) Internal view.

Digitized by Google



140.35

Figure 6-10.—Sound-powered magneto call system.

service telephones; and wardrooms to the respective pantries and orderlies. Circuit A calls are provided also from all sick-bay berths and isolation wards to the attendant's desk in the sick bay. Circuit A consists of bells or buzzers at the orderly and pantry stations and nonwatertight pushbuttons in the various cabins, staterooms, and messrooms. Where a station is to be signaled by more than one pushbutton, a drop-type annunciator is installed in addition to the bell or buzzer.

Three simplified call-bell circuits are shown in figure 6-11. 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.

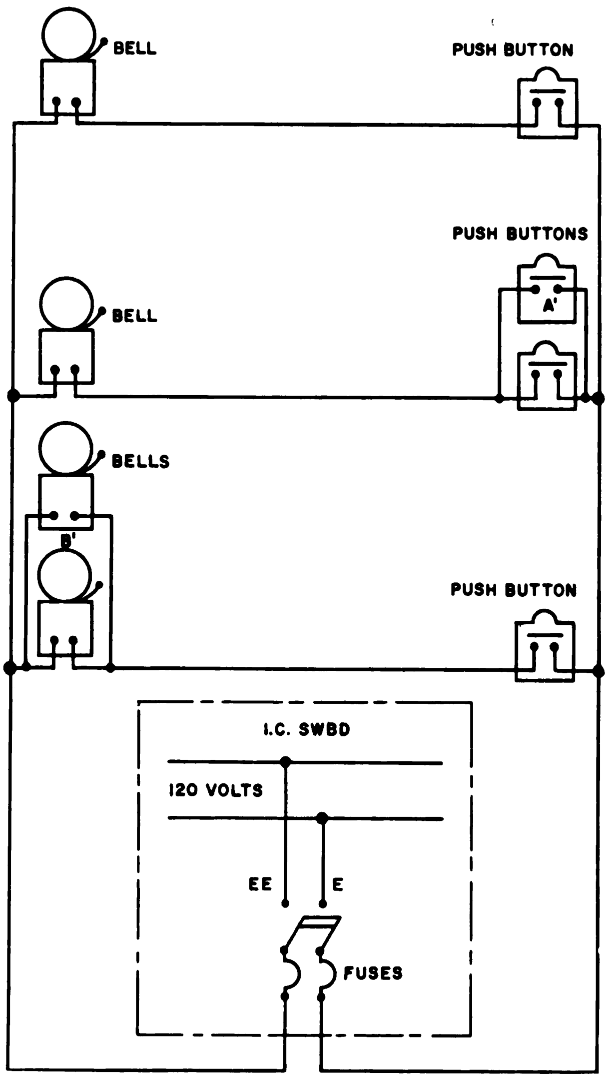
The lower branch circuit, with two bells in parallel with each other and in series with one pushbutton, is used to operate two bells from one location.

Note that the bells or signaling devices (fig. 6-11) 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.

Digitized by Google



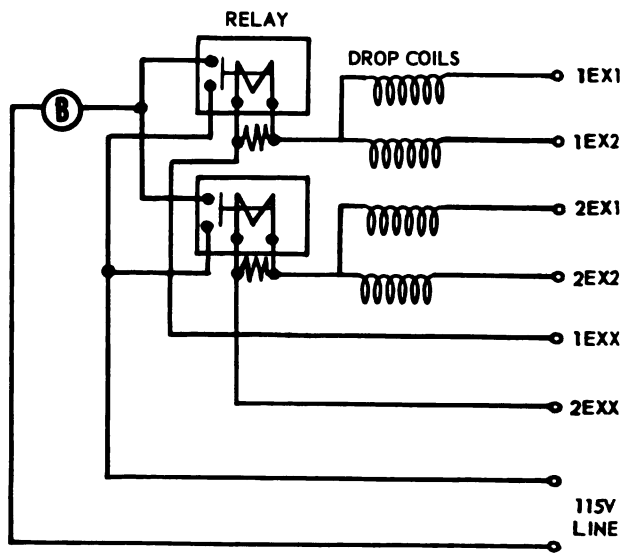
27.292
Figure 6-11.—Simple call-bell system.

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.

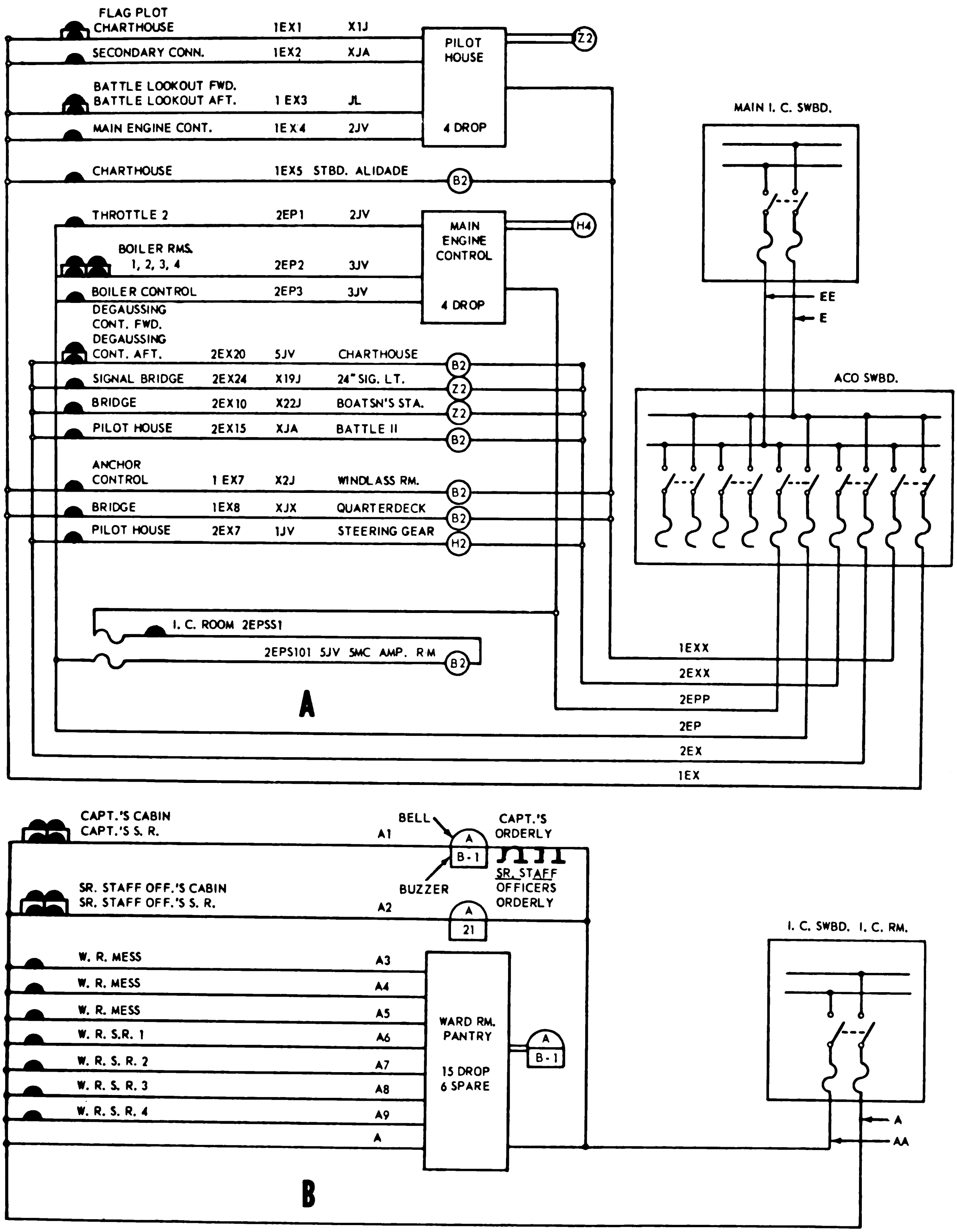
A simple diagram for a 2-circuit, 4-drop annunciator is shown in figure 6-12. When a pushbutton is operated, the proper annunciator drops and the bell rings. The alarm bell rings only while the pushbutton is closed. One side of each drop and one side of an audible-signal relay are connected together 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 6-13A and B, respectively.



27.293
Figure 6-12.—Two-circuit, four-drop annunciator.

Digitized by Google



27.294

Figure 6-13.—E- and A-call-bell circuits.

Digitized by Google

CHAPTER 7

ALARM AND WARNING SYSTEMS

Alarm and warning systems are installed in Navy ships to provide audible and/or visual signals when abnormal or dangerous conditions occur. The systems, and their circuit designations and classifications are listed in table 7-1.

The principal components of alarm and warning systems are switches or contact makers, relays, thermostats, and audible and visual signals.

SWITCHES, RELAYS, AND THERMOSTATS

Switches used with alarm and warning systems include manual switches, pressure and thermostatic switches, mechanical switches, and water switches as discussed in chapter 2 of this training course. Relays are used to open and close circuits that may operate indicating lights, annunciator drops and/or audible signals. Thermostats (discussed later), are used principally in fire alarm systems.

AUDIBLE SIGNALS

There are many types of audible signals in use aboard Navy ships. The type of signal used depends upon the noise level of the location, and the kind of sound desired. The principle types of audible signals are bells, buzzers, horns, and sirens. Electronic signals are being used for some applications on new construction ships.

BELLS AND BUZZERS

Bells used with alarm and warning systems may be either a-c or d-c operated, watertight or watertight explosion-proof construction, with circular or cowbell shape gongs.

Alternating current bells have 4 types of gongs: Circular 3-inch diameter, type IC/B8S4; Circular 4-inch diameter, types IC/B5DSF4 and IC/B5S5; Circular 8-inch diameter, types IC/B2S4 (watertight), and IC/B2S4 (watertight explosion-proof); and cowbell type IC/B3S4 (fig. 7-1).

Direct current bells have 3 types of gongs: Circular 2 1/2-inch diameter, type IC/B1D4; Circular 8-inch diameter, type IC/B2D4 (fig. 7-2); and cowbell type IC/B3D4.

Buzzers are used only in relatively quiet spaces. Buzzer, type IC/Z1D4 (fig. 7-3), is d-c operated and has make and break contacts. Buzzer, type IC/Z1S4, is a-c operated and has no contacts.

HORNS AND SIRENS

Nonresonated horns (types IC/H1D4, IC/H4D2, and IC/H4D3) utilize a diaphragm actuated by a vibrating armature to produce sound of the required intensity.

Resonated horns (fig. 7-4A), types IC/H2S4 and IC/H2D4, also use diaphragms, 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 as to intensity, frequency, or power supply.

Motor operated horns (fig. 7-4B), types IC/H8D3, IC/H8D4, and IC/H8S3, utilize electric motors to actuate the sound producing diaphragms.

Sirens are used in very noisy spaces or to sound urgent alarms. The sound is produced by an electric motor driving a multiblade rotor past a series of ports or holes in the housing (fig. 7-5). The air being forced through the ports gives a siren sound, the frequency of which depends upon the number of ports, the number of rotor blades, and the motor speed.

ELECTRONIC SIGNALS

The type IC/E1D1 electronic signal unit (fig. 7-6) is designed as a bus failure alarm. The unit

Digitized by Google

Table 7-1. —Alarm and Warning Systems

Circuit	System	Importance	Readiness Class
BZ	Brig cell door alarm and lock operating	NV	4
DL	Secure communications space door position alarm	NV	1
DW	Wrong direction alarm	V	2
EA	Reactor compartment or fireroom emergency alarm	NV	1
1EC	Lubricating oil low pressure alarm-propulsion machinery	SV	2
2EC	Lubricating oil low pressure alarm-auxiliary machinery	SV	1
1ED	Generator high temperature alarm	SV	1
2ED	Oxygen-nitrogen generator plant low temperature alarm	NV	1
BF	Generator bearing high temperature alarm	SV	1
EG	Propeller pitch control, hydraulic oil system low pressure alarm	SV	2
EH	Gas turbine exhaust high temperature alarm	SV	1 (aux. machinery) 2 (prop. machinery)
EJ	Feed pressure alarm	SV	1
1EK	Pneumatic control air pressure alarm	NV	2
3EK	Catapult steam cutoff and alarm	NV	2
EL	Radar cooling lines temperature and flow alarm	NV	1
EP	Gas turbine lubricating oil high temperature alarm	SV	1 (aux. machinery) 2 (prop. machinery)
1EQ	Desuperheater high temperature alarm	SV	1
2EQ	Catapult steam trough high temperature alarm	SV	2
3ES	Reactor fill alarm	V	1
ET	Boiler temperature alarm	NV	1
EV	Toxic vapor detector alarm	SV	1

Digitized by Google

Table 7-1. —Alarm and Warning Systems—Continued.

Circuit	System	Importance	Readiness Class
1EW	Propulsion engines circulating water high temperature	SV	1
2EW	Auxiliary machinery circulating water high temperature	SV	1
EZ	Condenser vacuum alarm	SV	2
F	High temperature alarm	SV	1
4F	Combustion gas and smoke detector	SV	1
9F	High temperature alarm system-ASROC launcher	SV	1
11F	FBM storage area temperature and humidity alarm	SV	1
12F	Gyro ovens temperature and power failure alarm	SV	1
FD	Flooding alarm	NV	1
FH	Sprinkling alarm	SV	1
FR	Carbon dioxide release alarm	NV	1
FZ	Security alarm (CLASSIFIED)	V	1
LS	Submersible steering gear alarm	SV	2
MG	Gas turbine overspeed alarm	SV	1 (aux. machinery) 2 (prop. machinery)
NE	Nuclear facilities air particle detector alarm	NV	1
QA	Air lock warning	NV	1
QD	Air filter and flame arrester pressure differential alarm, or gasoline compartment exhaust blower alarm	V	1
QX	Oxygen-nitrogen plant ventilation exhaust alarm	SV	1
RA	Turret emergency alarm	NV	1
RD	Safety observer warning	NV	2
RW	Rocket and torpedo warning	SV	3

Digitized by Google

Table 7-1. —Alarm and Warning Systems—Continued.

Circuit	System	Importance	Readiness Class
4SN	Scavenging air blower high temperature alarm	V	2
SP	Shaft position alarm	NV	2
TD	Liquid level alarm	NV	1
1TD	Boiler water level alarm	NV	1
2TD	Deaerating feed tank water level alarm	NV	1
5TD	Reactor compartment bilge tank alarm	SV	1
6TD	Primary shield tank, expansion tank level alarm	NV	1
7TD	Reactor plant fresh water cooling expansion tank level alarm	NV	1
8TD	Reactor secondary shield tank level alarm	NV	1
9TD	Lubricating oil sump tank liquid level alarm	SV	1
11TD	Induction air sump alarm	SV	1
12TD	Diesel oil sea water compensating system tank liquid level alarm	SV	1
14TD	Auxiliary fresh water tank low level alarm	NV	1
16TD	Pure water storage tank low level alarm	SV	1
17TD	Reserve feed tank alarm	NV	1
18TD	Effluent tanks and contaminated laundry tank high level alarm	V	1
19TD	Sea water expansion tank low level alarm	SV	1
20TD	Gasoline drain tank high level alarm	SV	1
21TD	Moisture separater drain cooler high level alarm	NV	1
24TD	Reactor plant on board discharge tank level alarm	V	1
25TD	Crossover drains high level alarm	SV	1
29TD	Sonar dome fill tank low level alarm	SV	1

Digitized by Google

Table 7-1. —Alarm and Warning Systems—Continued.

Circuit	System	Importance	Readiness Class
30TD	JP-5 fuel drain tank high level alarm	SV	2
TW	Train Warning system	NV	1

Legend:

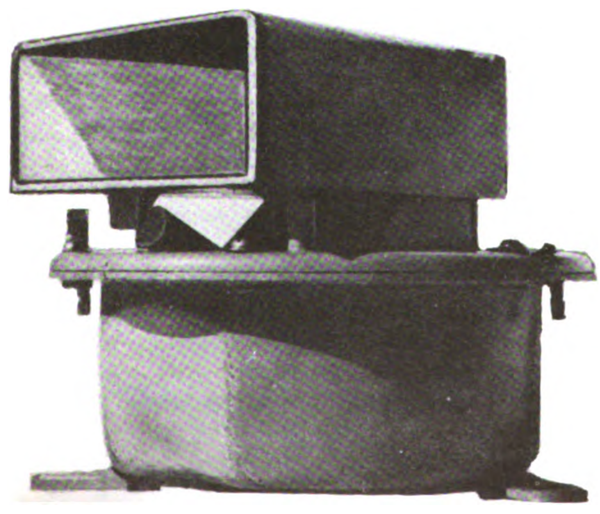
V—Vital SV—Semivital NV—Nonvital.
1—Continuously energized-supply switch color code yellow.
2—Energized when preparing to get underway, while underway, and until the ship is secured-supply switch color code black.
3—Energized during condition watches-supply switch color code red.
4—Energized only when required-supply switch color code white.
All electronic type alarm systems formerly designated as circuits CA, FC, FW, G, GD, GJ, GN, and FP are now classified as a portion of the respective announcing system with which they are associated.

contains an electronic solid state oscillator which drives a 2 inch howler unit to provide an audible signal upon loss of power on the supervised bus. The unit also provides a visual signal upon loss of power.

The power for the oscillator is provided by a small nickel-cadmium battery which is maintained on a low charge when the supervised bus is energized. The unit will operate on 115 VDC, 60 cycle, or 400 cycle a-c without modification.

The IC/E2 electronic signal unit is designed as a navigation signal. A solid state oscillator generates a horn tone which is fed to a speaker to produce a navigation horn signal. An electronic timing device automatically controls the length and frequency of the horn blasts. The unit is also capable of generating a suitable tone for an emergency signal.

The IC/E3 electronic signal unit is designed for use with Navy standard alarm systems. The unit contains a solid state oscillator which generates three distinct tones; a steady siren; a siren wail; and a siren yelp tone.



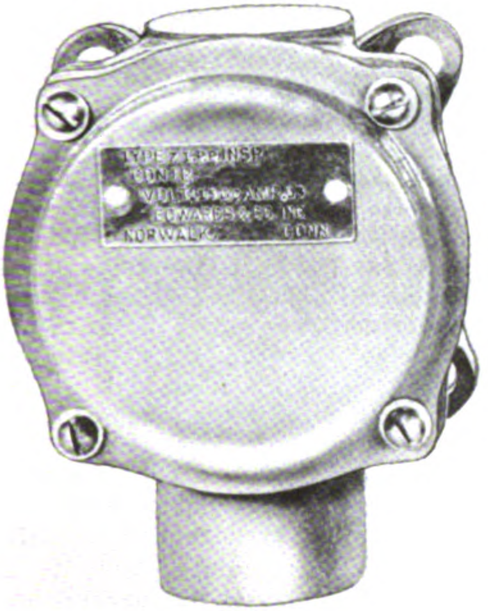
27.297

Figure 7-1.—IC/B3S4 bell (cowbell).

27.298

Figure 7-2.—IC/B2D4 bell.

Digitized by Google



27.299
Figure 7-3.—IC/Z1D4 buzzer.

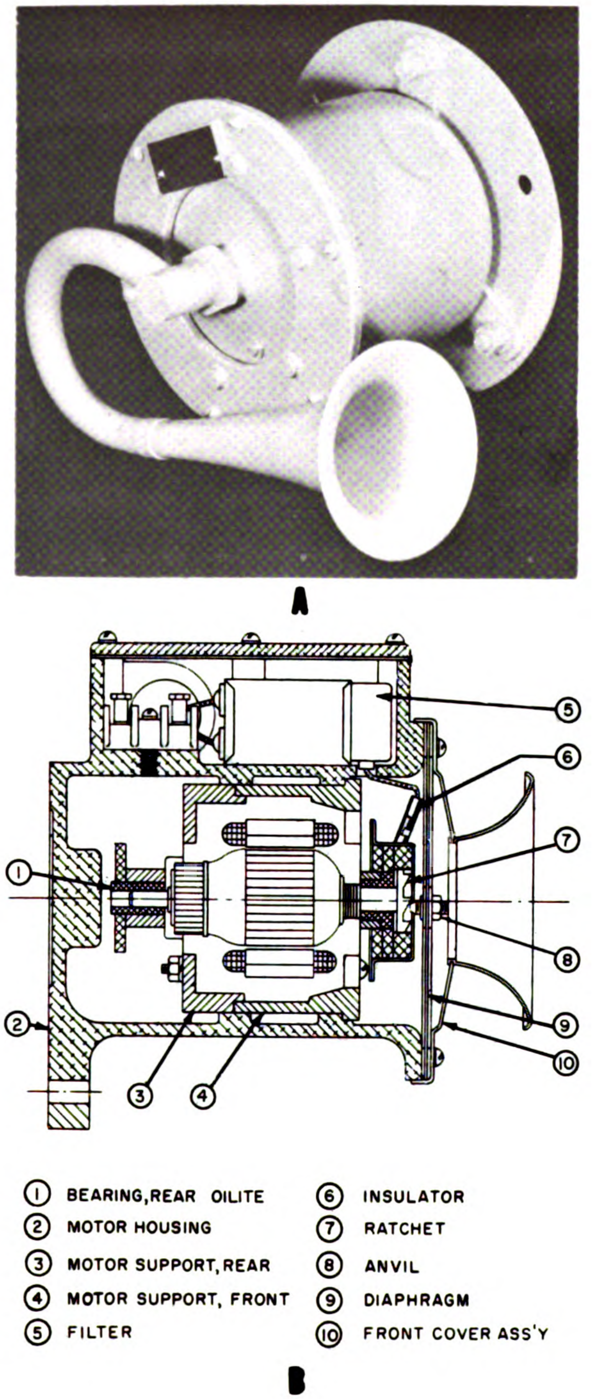
The type IC/E4 electronic signal unit (common electronic signal) contains oscillators for generating various audible tones such as bells, buzzers, horns, and sirens in various arrangements. Each solid state oscillator for genera - ing the tones is a modular type which is easily replaceable or interchangable.

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 brightly lighted spaces visual signals are supplemented by audible signals. In many instruments the same audible device is used in combination with several visual indicators. The principal types of visual signals are lamp type indicators and target drum type alarm indicators.

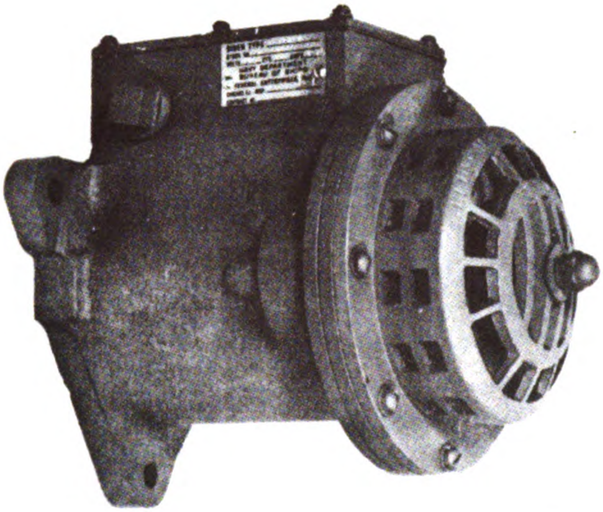
LAMP-TYPE INDICATORS

Standard watertight, lamp type indicators are designed as single-dial, 2-dial, 3-dial, 4-dial, and 6-dial units (fig. 7-7). The indicator contains two 115-volt lamps connected in parallel and mounted behind each dial. The use of two



27.300
Figure 7-4.—Motor operated and resonated horns.

Digitized by Google



27.301

Figure 7-5.—Siren.

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 is used with various alarm systems.

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 dial. A colored jewel disk and sheet-brass target are illuminated from the rear by the two lamps.

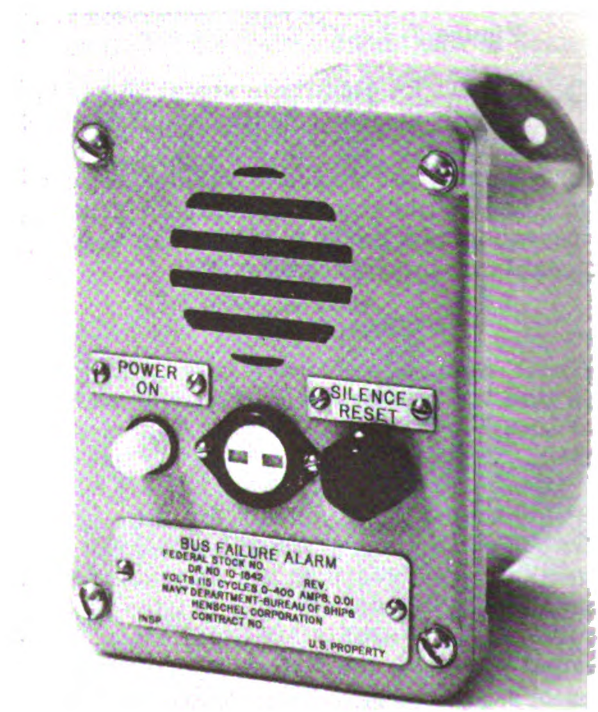
Special lamp type indicator panels are designed to give good visibility at all viewing angles. These panels contain rows of prism-shaped red and green jewels. Each indicator has two 6-volt lamps in parallel. This type of indicator is used in the main ballast tank and hull opening indicator system.

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 type of indicator is used in the traffic control ready light system on aircraft carriers.

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. 7-8), 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 mounted above the alarm relays. The two supervisory relays, with their indicator drums, are mounted above the test and cutout switches.

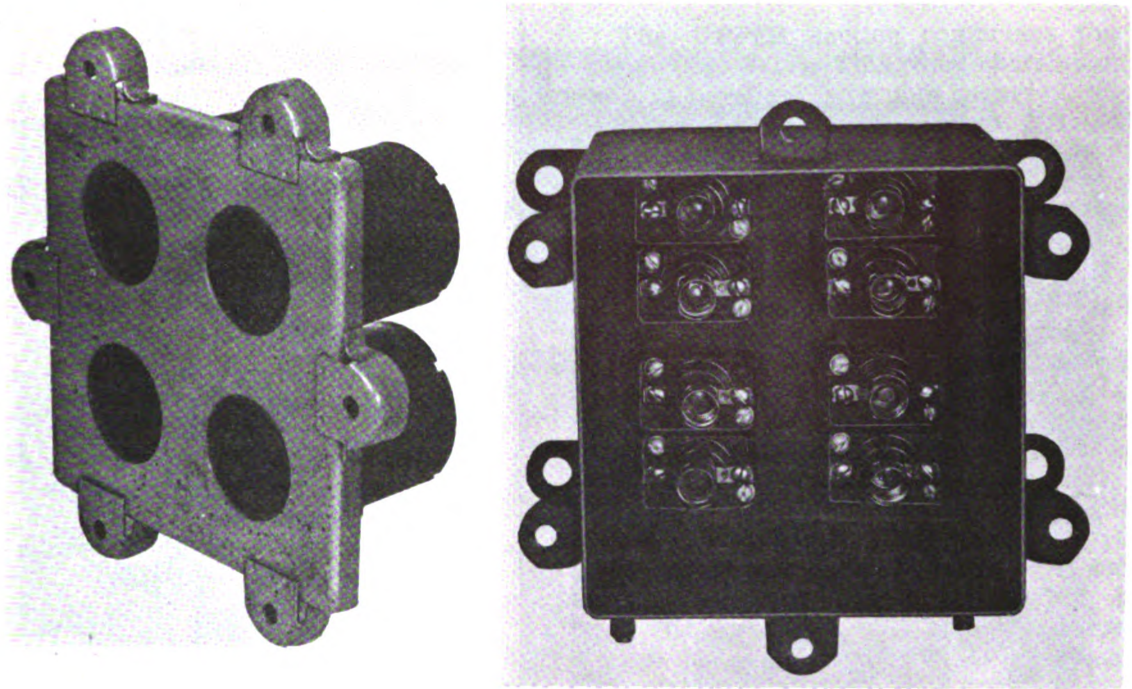
The relays (fig. 7-9) are of similar construction. However, the number of turns on the coils and the contact arrangement are different. Note that when the armature (1) of the alarm relay operates, it rotates the target drum (2B) through an eccentric, and closes the contacts



27.302

Figure 7-6.—Electronic signal unit type IC/E1D1.

Digitized by Google



27.303

Figure 7-7. —Lamp type indicator.

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.

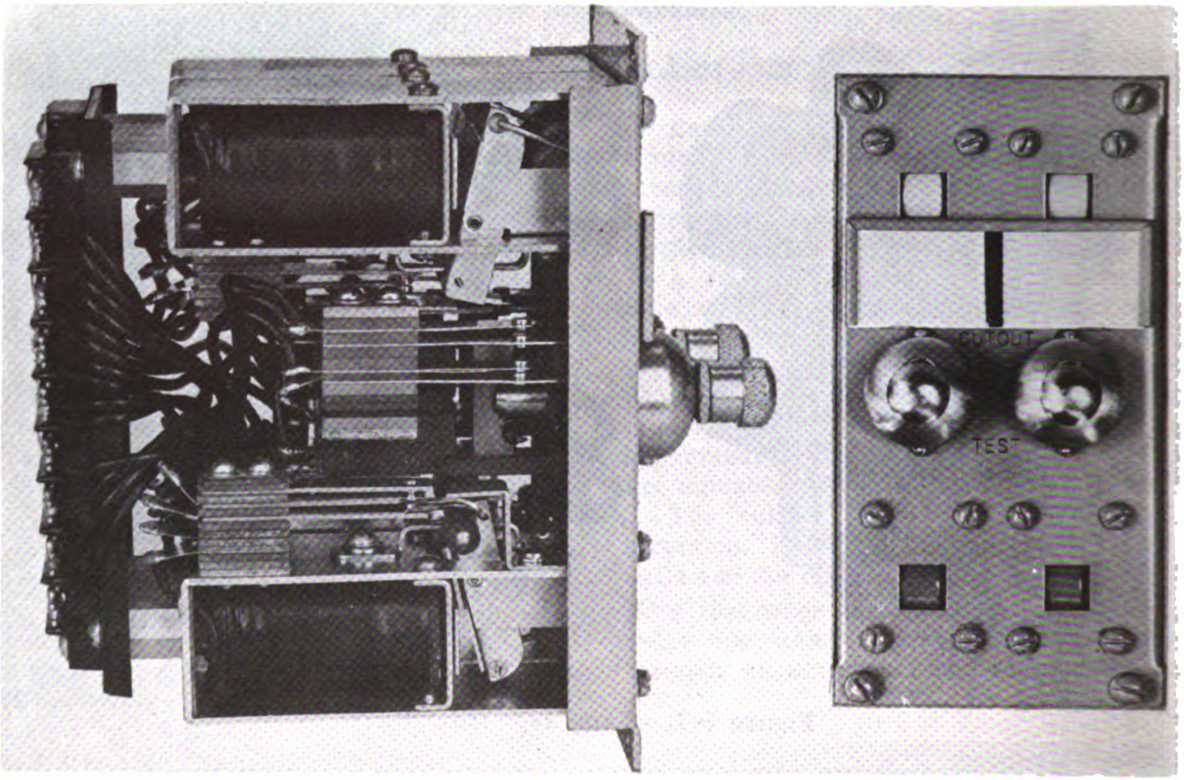
The two relays are in series with the alarm device, which is a mercury thermostat in the high-temperature alarm (fig. 7-10).

As 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. 7-10) is in series with both relays under normal conditions and acts as a current-limiting device.

Under normal conditions the current that flows in the supervisory circuit (fig. 7-10), 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 mercury 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. When the temperature rises at the alarm device, and the mercury reaches the upper contact, the 7000-ohm supervisory resistor is shunted out of the circuit. This reduces to 2675 ohms the total resistance of the circuit supplied by the rectifier. This increase in current is enough to operate the alarm target relay. The alarm-target relay in operating rotates its red target into position and closes the contact that completes the circuit to the extension relay, which is supplied power from the primary side of the transformer. When the extension relay operates, it closes the contacts to complete the circuit to the bell. The bell 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.

Digitized by Google



27.303

Figure 7-8.—Two-line alarm unit.

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.

FIRE ALARM SYSTEMS

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 mercury thermostat, is found on the older naval ships. On new construction, conversions, and ammunition ships, in addition to the temperature-rise system, there is a combustion gas and smoke detector system (circuit 4F).

HIGH-TEMPERATURE ALARM SYSTEM

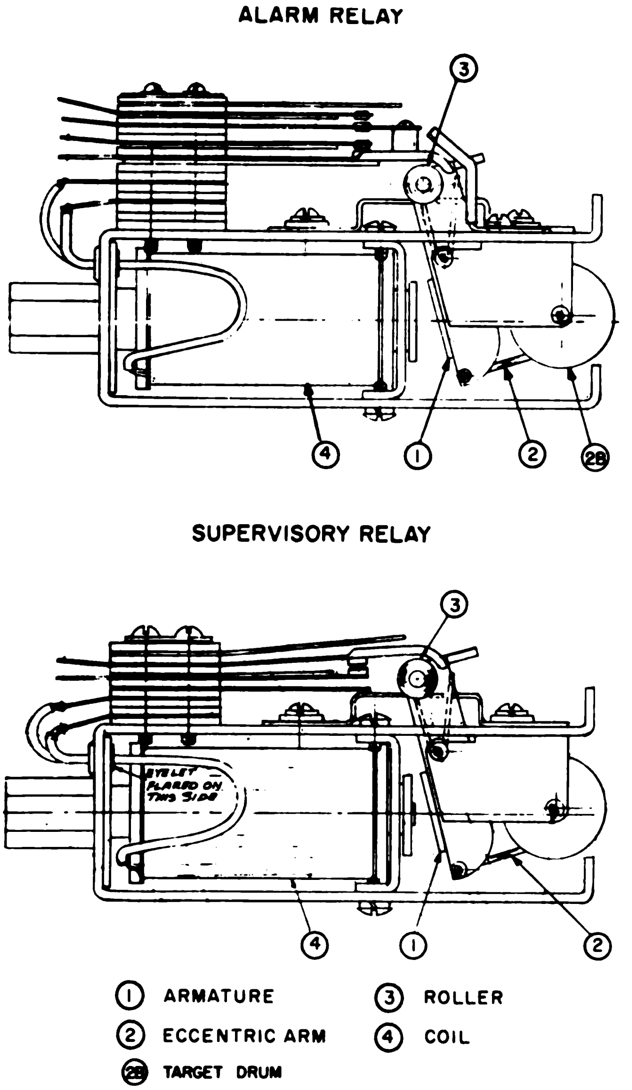
The high-temperature alarm system (circuit F) is an electrical system installed aboard ship to detect and warn of fires or overheated conditions in important compartments and spaces.

All alarm systems used in Navy Ships 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 Switchboard

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 IC switchboard. The alarm switchboard consists of an upper section and a lower section.

Digitized by Google



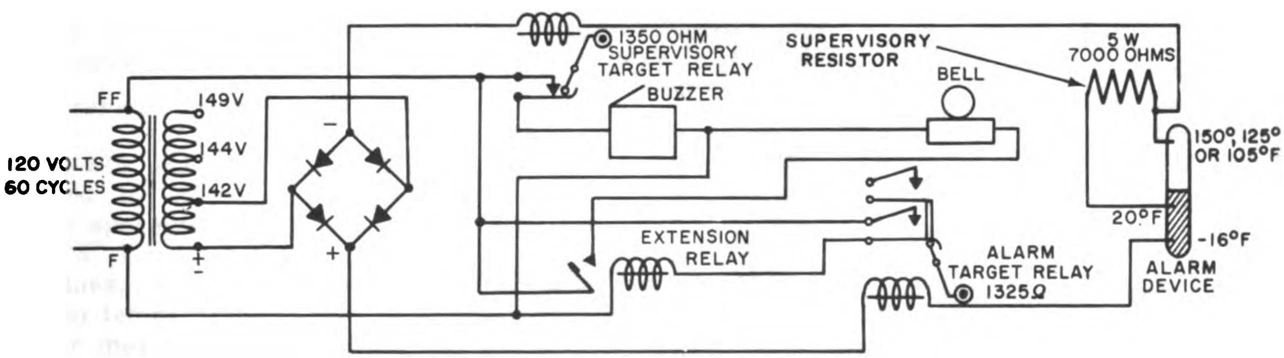
27.305
Figure 7-9.—Alarm and supervisory relays.

The UPPER section comprises the alarm panel (fig. 7-11). 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 accommodate the total number of high-temperature, circuit F, or water-sprinkling circuit FH stations aboard the ship. Six 10-line panels capable of accommodating 60 lines are shown in figure 7-11. 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

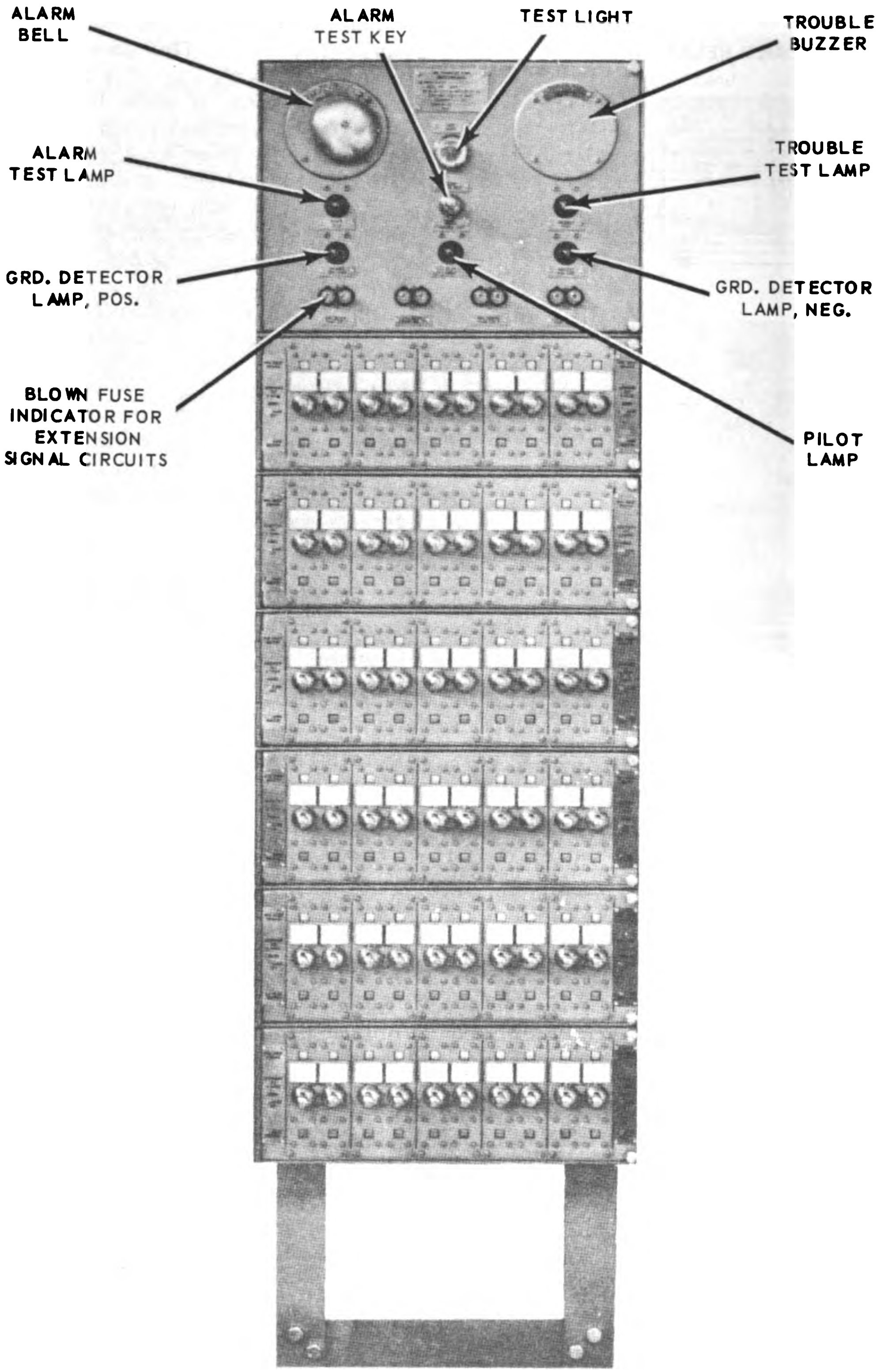
As previously mentioned, the detection of fires or overheated conditions is accomplished by means of mercury theremostats. These thermostats are installed at selected locations throughout the ship. Thermostats are installed on the overhead and require a free circulation of air for efficient operation. Barriers that would obstruct the free circulation of air should never be placed around thermostats in any compart-



27.306

Figure 7-10. —High-temperature alarm circuit.

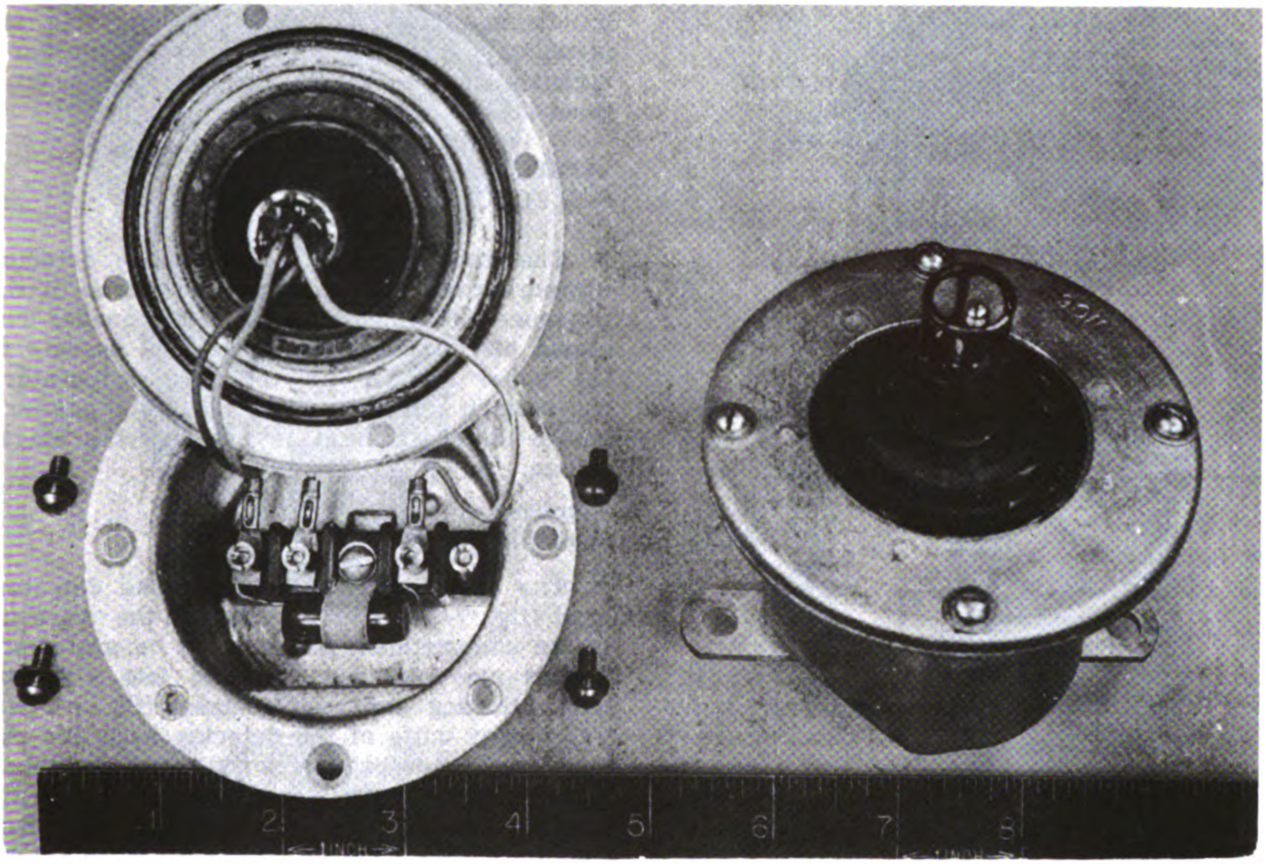
Digitized by Google



27.307

Figure 7-11. —Alarm switchboard.

Digitized by Google



27.308

Figure 7-12. —Mercury thermostat type IC/J125, internal and external views.

ment. 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.

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.

Temperature Ratings

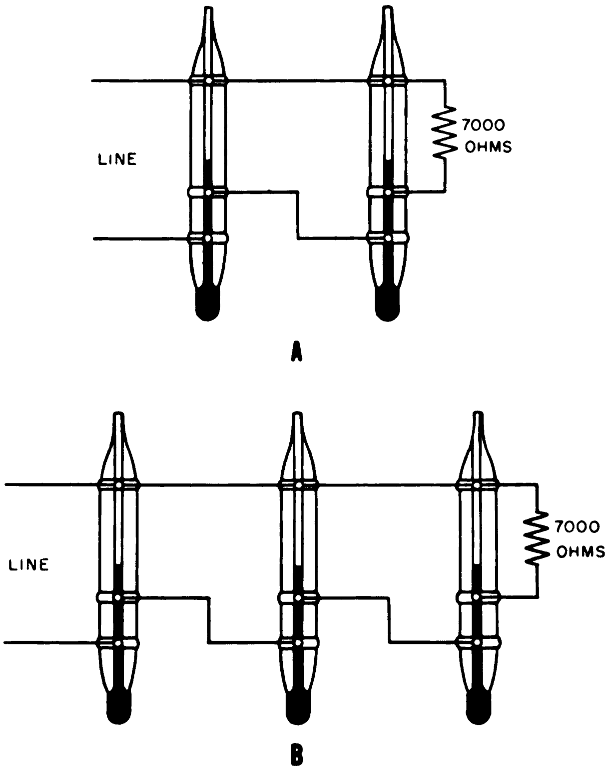
The 125° and 150° F thermostats are normally installed in storerooms, paint lockers, and similar spaces used to house combustible stores. The 105° F thermostat is normally installed in magazines. Because its function is to detect rises in temperature above the limits that are safe for magazine spaces, 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 prompt detection of a fire can be connected to any one line. If more than one thermostat is used in a compartment, only one supervisory resistor is required, as shown in figure 7-13A and B. With such a connection, when any one of the thermostats in the group is overheated, the alarm operates. These thermostats or groups of thermostats are connected to the alarm switchboard by multiconductor cable. Each circuit on the alarm switchboard is marked to designate one compartment, and the thermostat or group of thermostats, installed in each compartment is connected to the circuit marked for that compartment.

Operation

When conditions are normal, direct current flows from the full-wave rectifier (fig. 7-10), through the supervisory target relay, the supervisory resistor, to the intermediate contact of the thermostat, through its mercury column

Digitized by Google



27.310
Figure 7-13.—Thermostat connections.

to the lower contact, and through the alarm target relay to the rectifier. The current is limited by the 7000 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 technical manual provided for the alarm equipment installed in your ship.

COMBUSTION GAS AND SMOKE DETECTOR SYSTEM

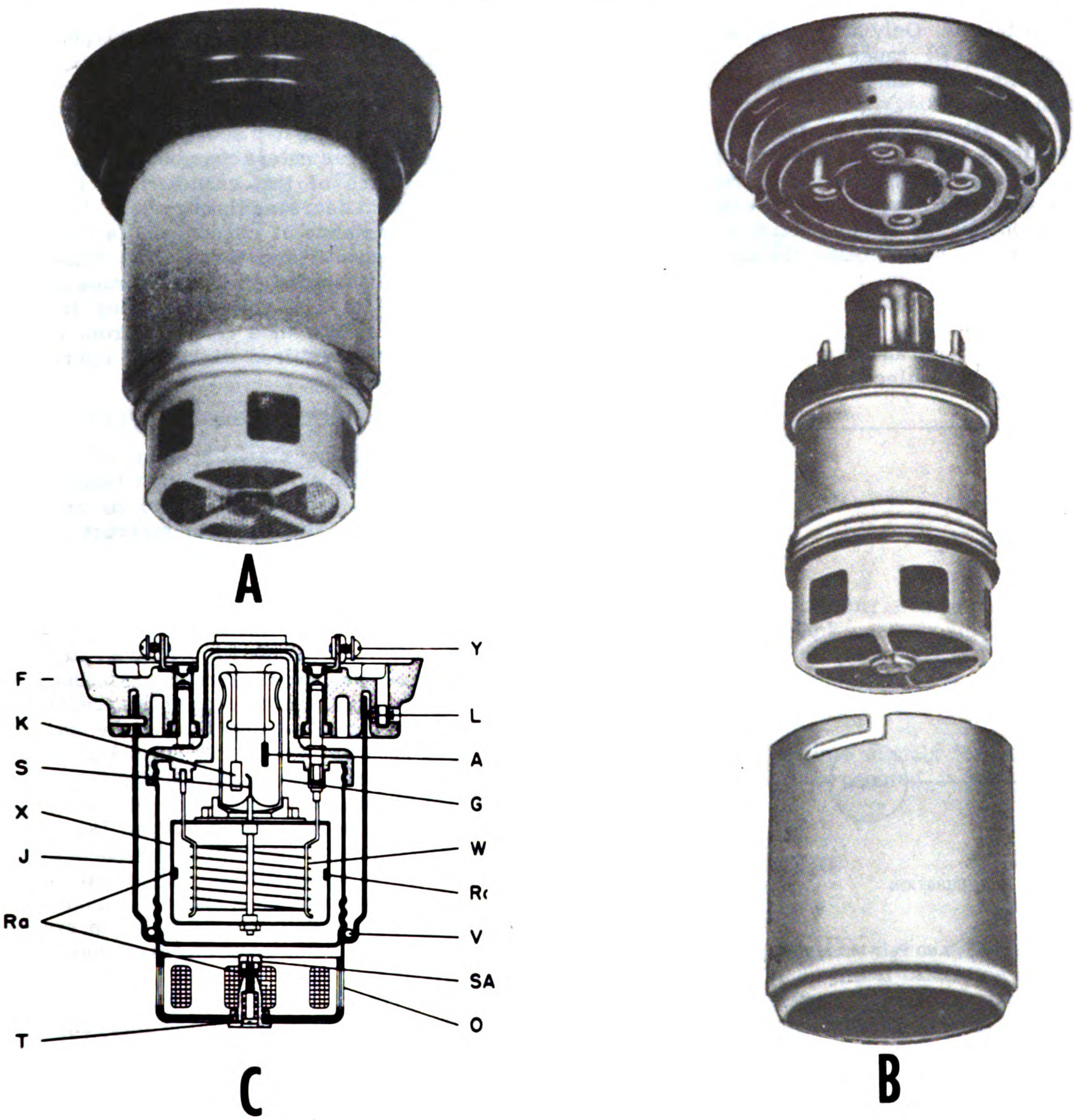
The combustion gas and smoke detector system (circuit 4F),detects and warns of the presence of combustion gases or smoke. The alarm circuits are similar to, and operate in the same manner as the high-temperature fire alarm circuits. A combustion gas and smoke detector head is used as the alarm device.

Combustion Gas and Smoke Detector Head

The combustion gas and smoke detector head (fig. 7-14A), is installed on the overhead in the compartment or space to be protected. A four-pin polarized plug fits into a socket base allowing easy replacement (fig. 7-14B). The major units of the detector head are the inner and outer chambers and the cold cathode tube (fig. 7-14C). The detector compares the air in the inner chamber with the air in the outer chamber. When combustion gases and/or smoke are present in the air of the outer chamber, the cold cathode tube fires and supplies the current to operate the alarm relay as discussed below.

OPERATING PRINCIPLES.—The air in the inner and outer chambers is made conductive by a small quantity of radium, Ra, (fig. 7-14C). Alpha particles given off by the radium have the ability to ionize air into positive ions and negative electrons. If this ionized air is introduced into an electric field, a current will flow. This principle is shown in figure 7-15. A potential from 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 the radium source, and within limits, the voltage of the battery. With low potentials, part of the ions and electrons collide and neutralize each other. It is only when the potential reaches a certain limit that all of the ions formed reach the plates. This is known as the saturation point. Beyond this point, the current remains virtually constant regardless of the increase

Digitized by Google



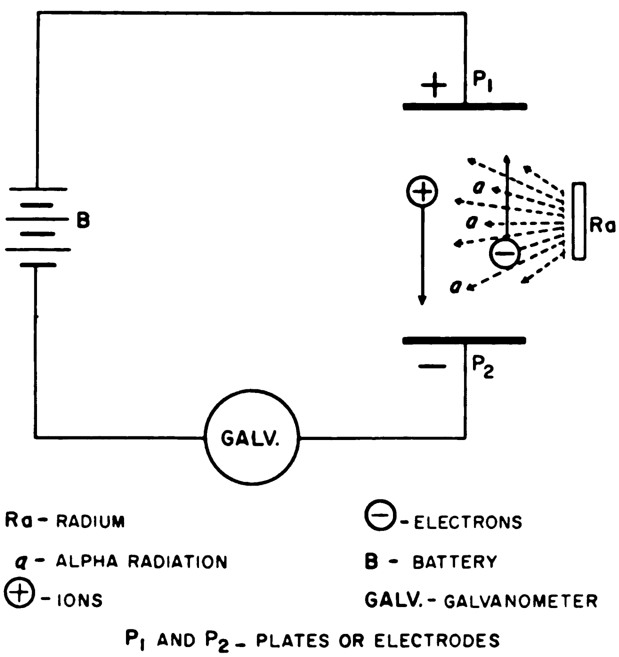
X-INNER OR REFERENCE CHAMBER; O-OUTER OR DETECTING CHAMBER;
Ra-RADIUM SOURSES; SA-SENSITIVITY ADJUSTMENT CAP; T-SENSITIVITY ADJUSTMENT SCREW; G-GAS DISCHARGE (COLD CATHODE) TUBE; A-ANODE;
K-CATHODE; S-STARTER ELECTRODE; W-INNER WIRE GRID ELECTRODE;
J-LOCKING SHELL; V-O RING; F-SOCKET BASE; L-LOCKING SET SCREW;
Y-TERMINAL SCREWS.

Figure 7-14.—Combustion gas and smoke detector head. (A) Assembled; (B) Principle parts; (C) Cross sectional view. 27.310

Digitized by Google

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 the saturation point.

The presence of combustion gas or smoke particles between the plates (fig. 7-15), would cause a sharp decrease in current flow through the galvanometer. This is true because the combustion gas and smoke particles are many times larger and heavier than the air molecules, and require a stronger radioactive source to become ionized. Also, the ionized combustion gas and smoke particles move much slower in the electric field, and are practically all neutralized by free electrons before reaching one of the plates.



27.311

Figure 7-15.—Ionization principle.

Basic Circuit

In the basic circuit of the detector system (fig. 7-16), the normal voltage across chamber X is 130 VDC, and 90 VDC across chamber O and tube elements S and K. The breakdown voltage between the plate, A, and cathode, K, of the cold cathode tube is greater than 270 volts. Therefore with 220 volts applied to A and K, the tube will not fire until triggered by the starter, S. The tube is triggered when the voltage between S and K reaches 110 volts.

With no smoke or combustion gas present in the outer chamber, only enough current flows to energize the supervisory target relay. The current flow is from the d-c source (a full-wave silicon diode rectifier) through the outer and inner chambers, the supervisory resistor, R, and back to the d-c source. When smoke or a combustion gas enters chamber O, it increases the resistance of that chamber which causes the current to decrease through both chambers. As the resistance of chamber X is fixed, the voltage across it decreases. This causes the voltage across chamber O and across S and K to increase to 110 volts triggering the cold cathode tube. The tube conducts from K to A furnishing the required current to operate the alarm target relay.

SPRINKLING ALARM SYSTEM

The sprinkling alarm system, circuit FH, is basically the same as the high-temperature alarm system except that water or pressure switches are used instead of mercury thermostats.

LUBRICATING-OIL, LOW-PRESSURE ALARM SYSTEM

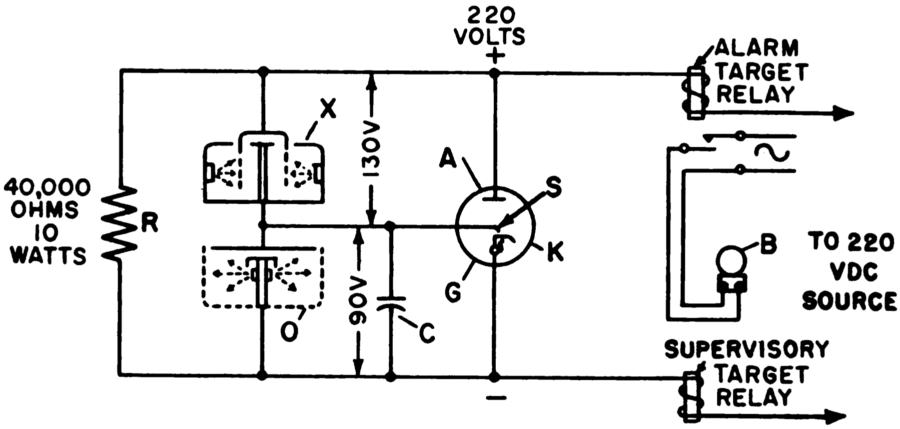
The purpose of the lubricating-oil, low-pressure alarm system, circuits 1EC and 2 EC, is to sound an alarm whenever the pressure in the lubricating-oil supply line to the main engine and reduction gear, or to the turbine-driven or diesel-driven generators, and other auxiliary machinery falls below a 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 IC 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

Digitized by Google



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.

27.312

Figure 7-16.—Basic circuit of detector system

temperature of 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 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. 7-17), 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.

GENERATOR AND GENERATOR BEARING HIGH-TEMPERATURE ALARM SYSTEMS

The generator high-temperature alarm system, circuit 1ED, provides a means of indicating high temperature of the cooling air exhaust of generator sets rated at 500 kw and above. The system consists of thermostatic switches located in the generator exhaust to the cooler, which energize visual and audible signals when the temperature of the circulating air rises above a predetermined limit.

The generator bearing high-temperature alarm system, circuit EF, provides a means of indicating high temperatures in the bearings of generator sets of 200 kw and above. Thermostatic switches energize visual and audible signals when a bearing temperature rises above a predetermined limit.

The visual and audible signals for circuits 1ED, and EF are incorporated in the alarm panel of circuit 2EC.

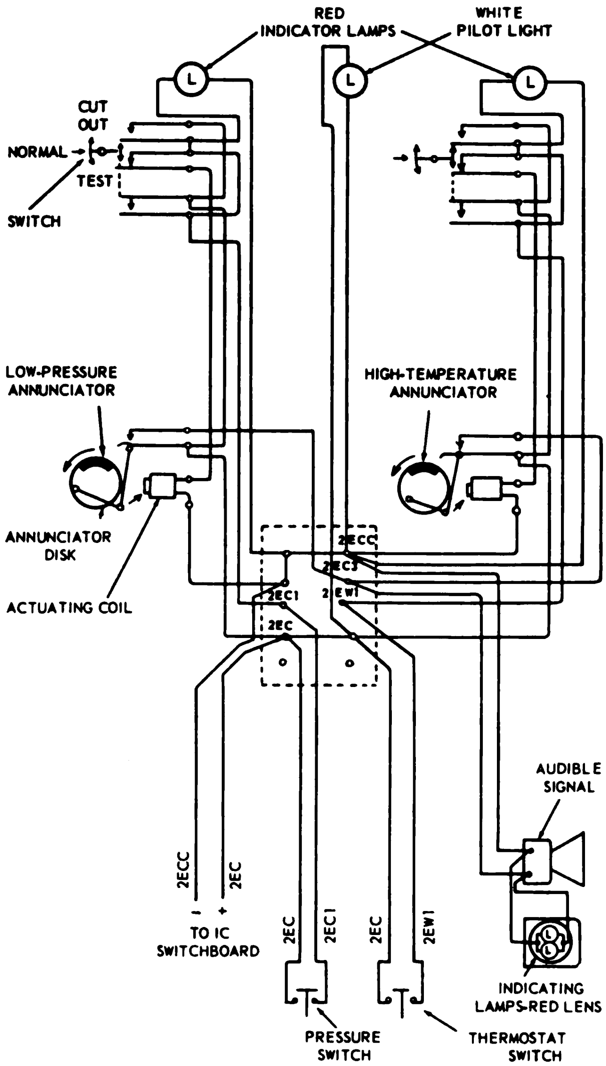
BOILER TEMPERATURE ALARM SYSTEM

The boiler temperature alarm system, circuit ET, provides a means of indicating boiler steam high temperature in ships having separately fired superheat control boilers. A thermostatic switch located in the main steam line from each boiler energizes a 2-dial lamp type indicator and a horn, when the total steam temperature at the superheater outlet rises above a predetermined limit.

MAINTENANCE

Alarm and warning systems require very little maintenance. Almost any trouble that may affect the system will give an audible and/or visual indication. Periodic tests may be made easily and quickly from the alarm panel.

Digitized by Google



27.313
Figure 7-17.—Schematic of 2EC and 2EW circuits.

No maintenance of the alarm indicator units is required other than adjustments shown to be necessary as a result of tests described by the manufacturer's technical manual. Do not use oil anywhere in the alarm units as it may cause flashovers and short circuits.

The electrodes of all water switches should be cleaned after the system has operated. Clean the electrodes with alcohol and rinse them with distilled water.

Remove all combustion gas and smoke detector heads periodically. Clean the heads and conduct a sensitivity check as described in the manufacturer's technical manual.

Check all indicator lamps frequently, and replace any burned-out lamps.

Digitized by Google

CHAPTER 8

ANNOUNCING AND INTERCOMMUNICATING SYSTEMS

Shipboard announcing and intercommunicating systems, circuits 1MC through 54MC, serve the general purpose of transmitting orders and information between stations within the ship by amplified voice communication. This function is accomplished by either (1) a central amplifier system, or (2) an intercommunicating system. A central amplifier system is employed when it is desired to broadcast orders or information simultaneously to a number of stations. An intercommunicating system is employed when it is desired to provide two-way transmission of orders or information.

Each announcing and intercommunicating system installed aboard ship is assigned an IC circuit designation in the MC series. The Chief of Naval Operations authorizes these MC circuits for each class of vessel, based on size, complement, function, and operational employment. Authorized IC announcing circuits are listed in Table 8-1, according to importance and readiness. These systems, however, are not all installed in any one ship.

For general announcing, circuit 1MC is installed in all surface ships above 180 feet in length, except aircraft carriers, amphibious ships fitted with flight decks, and large combatant ships. Aircraft carriers, amphibious ships fitted with flight decks, and large combatant ships are provided with circuits 1MC and 3MC.

An integrated intercommunication system (circuit MC), is installed in submarines. This system consists of circuits 1MC, 2MC, 4MC, 7MC, 21MC, 27MC, 31MC, 32MC, 35MC, and 47MC.

This chapter discusses representative central amplifier and intercommunicating systems, sound-powered telephone amplifiers, and portable announcing equipment.

CENTRAL AMPLIFIER ANNOUNCING SYSTEM

The central amplifier announcing system is designed to furnish amplified voice communications and alarm signals to the various loudspeaker groups aboard ship. The system provides for transmitting the spoken word or signal at any one of several stations, amplifying this signal at a central amplifier, and radiating the signal from a number of loudspeakers.

The components employed in a representative system installed in a cruiser are illustrated in figure 8-1. The system consists of audio amplifier equipment to provide circuit 1MC functions for general announcing, and circuit 6MC functions for intership announcing. Power for operating the equipment is obtained from the ship's single-phase 115-volt power supply.

ALARM CONTACT MAKERS

Alarm contact makers are located at various points in the ship. The closure of an alarm contact maker will sound any one of four alarm signals over all circuit 1MC loudspeakers. Alarm signals are not transmitted over circuit 6MC. The alarm signals in the order of their priority are: (1) collision, (2) chemical attack, (3) general, and (4) sonar. The order of priority is controlled automatically by relays in the audio amplifier cabinet. Any alarm takes priority over voice announcements.

If an alarm is being sounded and a higher priority alarm contact maker is closed, relays in the audio amplifier cabinet operate to cut off the alarm signal being sounded and cause the higher priority alarm to be sounded instead. Conversely, the closure of a low priority alarm contact maker has no effect on a high priority alarm that is being sounded.

Digitized by Google

Table 8-1. —Shipboard Announcing Systems

Circuit	System	Importance	Readiness Class
*IMC	General	V	1
*2MC	Propulsion plant	V	1
*3MC	Aviators'	V	1
4MC	Damage Control	V	1
*5MC	Flight Deck	SV	2
*6MC	Intership	SV	1
7MC	Submarine Control	V	1
8MC	Troop administration and control	SV	2
*9MC	Underwater troop communication	SV	2
*10MC	Dock Control (obsolete)	SV	1
*11-16MC	Turret (obsolescent)	SV	3
*17MC	Double Purpose Battery (obsolescent)	SV	3
18MC	Bridge	NV	2
19MC	Aviation Control	SV	2
*20MC	Combat Information (obsolescent)	SV	1
21MC	Captain's Command	SV	1
22MC	Electronic Control	NV	1
23MC	Electrical control	SV	1
24MC	Flag Command	SV	1
25MC	Ward Room (obsolescent)	NV	4
26MC	Machinery Control	SV	1
27MC	Sonar and Radar Control	SV	1
*28MC	Squadron (obsolescent)	NV	4
*29MC	Sonar Control and Information	SV	2
30MC	Special Weapons	SV	2
31MC	Escape trunk	SV	2
32MC	Weapons control	SV	3
33MC	Gunnery Control (obsolescent)	SV	3
34MC	Lifeboat (obsolescent)	SV	1
35MC	Launcher Captains'	SV	1
36MC	Cable Control (obsolete)	NV	4
37MC	Special Navigation (osbolete)	SV	2
38MC	Electrical (obsolete)	NV	1
39MC	Cargo Handling	NV	4
40MC	Flag Administrative	NV	1
41MC	Missile Control and Announce (obsolete)	SV	3
42MC	CIC Coordinating	SV	2
43MC	Unassigned		
44MC	Instrumentation Space	NV	1
45MC	Research operations	NV	1
*46MC	Aviation Ordnance and Missile Handling	SV	2
47MC	Torpedo Control	SV	2
48MC	Stores conveyor (obsolescent)	NV	1
49MC	Unassigned		
50MC	Integrated operational intelligence center	SV	2

Digitized by Google

Table 8-1. —Shipboard Announcing Systems—Continued

Circuit	System	Importance	Readiness Class
51MC	Aircraft Maintenance and handling control	SV	2
52MC	Unassigned		
53MC	Ship Administrative	NV	4
54MC	Repair officer's control	NV	4

*Central amplifier systems.

The oscillator operates to generate the alarm signals as long as the alarm contact maker is held closed (except for general alarm which is sounded for a predetermined 15-second interval after momentary closure of the general alarm contact maker). Release of the alarm contact maker causes the equipment to be returned to STANDBY after sounding the alarm. The visual alarm circuit is closed continuously during a chemical attack alarm, and intermittently during a general alarm.

MICROPHONE CONTROL STATIONS

Four microphone control stations are located at various points throughout the ship. The circuit 1MC-6MC microphone control station can select any one or more of the four 1MC loudspeaker groups or the circuit 6MC loudspeakers. The other microphone control stations are wired to permit the selection of circuit 1MC loudspeaker groups only. The operation of circuit 1MC from any microphone control station has priority over circuit 6MC operation. Microphone control stations on circuit 1MC do not have priority over each other, however, the bridge station does have priority over all others.

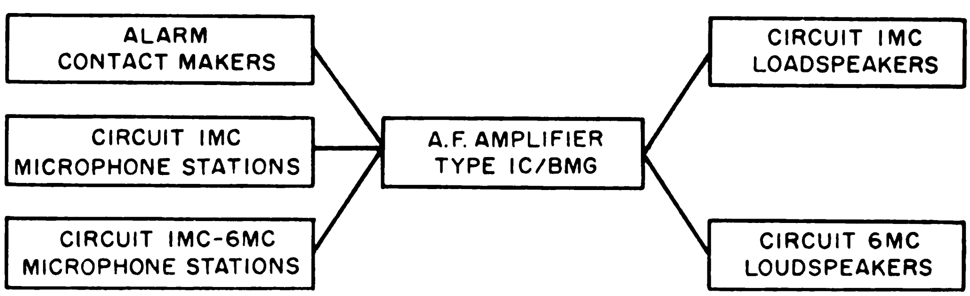
When the press-to-talk switch on the microphone of any microphone control station is operated for general voice announcements (fig. 8-2), all loudspeakers selected at this control station (except the loudspeaker in the immediate area of the control station in use) are connected to the equipment and reproduce the message spoken into the microphone. It is possible for the 1MC-6MC microphone control station to transmit over circuit 6MC loudspeakers at the same time that a circuit 1MC microphone control station is transmitting over a circuit 1MC loudspeaker group.

LOUDSPEAKER GROUPS

The loudspeakers associated with circuit 1MC operation are divided into four groups designated (1) officers, (2) topside, (3) crew, and (4) engineers. There is only one circuit 6MC loudspeaker group.

AUDIO AMPLIFIER CABINET

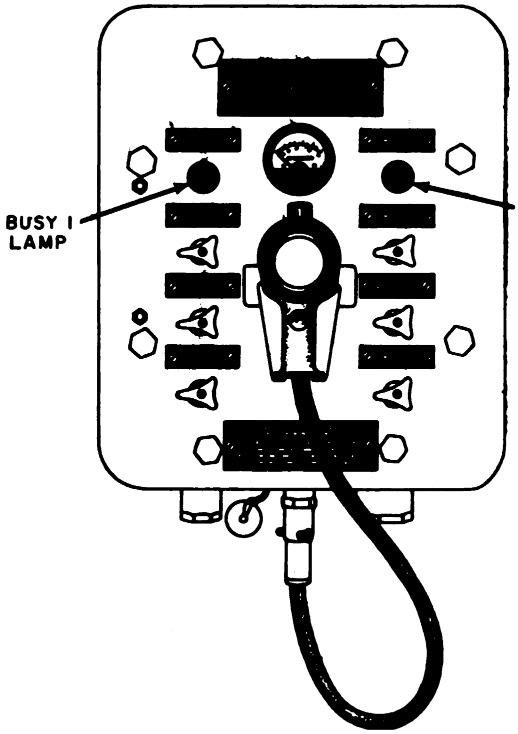
The control circuits for circuit 1MC and circuit 6MC are contained in the audio amplifier cabinet (fig. 8-3). In addition to the various relays, indicator lamps, fuses, transfer switches,



27.124

Figure 8-1.—Circuit 1MC-6MC equipment.

Digitized by Google



7.19
Figure 8-2.—Microphone control station.

and test switches, the cabinet contains two oscillator assemblies, two preamplifier assemblies, and two power amplifier assemblies.

The oscillators, one of which is a spare, are used to generate the alarm signals. The preamplifiers are used to increase the microphone output on voice signals to a level sufficiently high to drive the power amplifiers. The power amplifiers are used to increase the level of the alarm signals from one of the oscillators and the voice signals from one of the preamplifiers for reproduction by the loudspeakers.

Two identical amplifier channels are provided to permit the operation of the 1MC and 6MC circuits independently on the two channels (fig. 8-4). Each channel includes a preamplifier and a power amplifier. Channel selection is accomplished by means of the amplifier channel selector switch on the audio amplifier cabinet.

Normal operation of the system is obtained with the amplifier channel selector switch set at 1MC on A and 6MC on B. When the switch is set at 1MC-6MC on A, channel B is isolated for trouble shooting and repair, and the announcements and alarm signals are transmitted on channel A. Conversely, when the switch is set at 1MC-6MC on B, channel A is isolated and all transmission is over channel B.

Preamplifiers

The preamplifiers consist of a power supply, three parallel-connected voltage amplifier stages, a push-pull-parallel connected power amplifier stage, a limiter circuit, and a compressor circuit.

The COMPRESSOR circuit provides greater amplifier gain with low-level signals than with high-level signals, thus compensating for the differences in voice inputs at the microphone control stations. When the compressor switch, S1 (fig. 8-3) is in the ON position, the bias of the first stage voltage amplifier is reduced, resulting in a 14 db maximum increase in amplifier gain for low-level input signals. The LIMITER circuit provides for a rapid reduction in amplifier gain when the amplitude of the input signal would overload the amplifier and cause distortion.

The compressor-limiter circuit consists of twin triodes, operating as a phase-inverter and limiter.

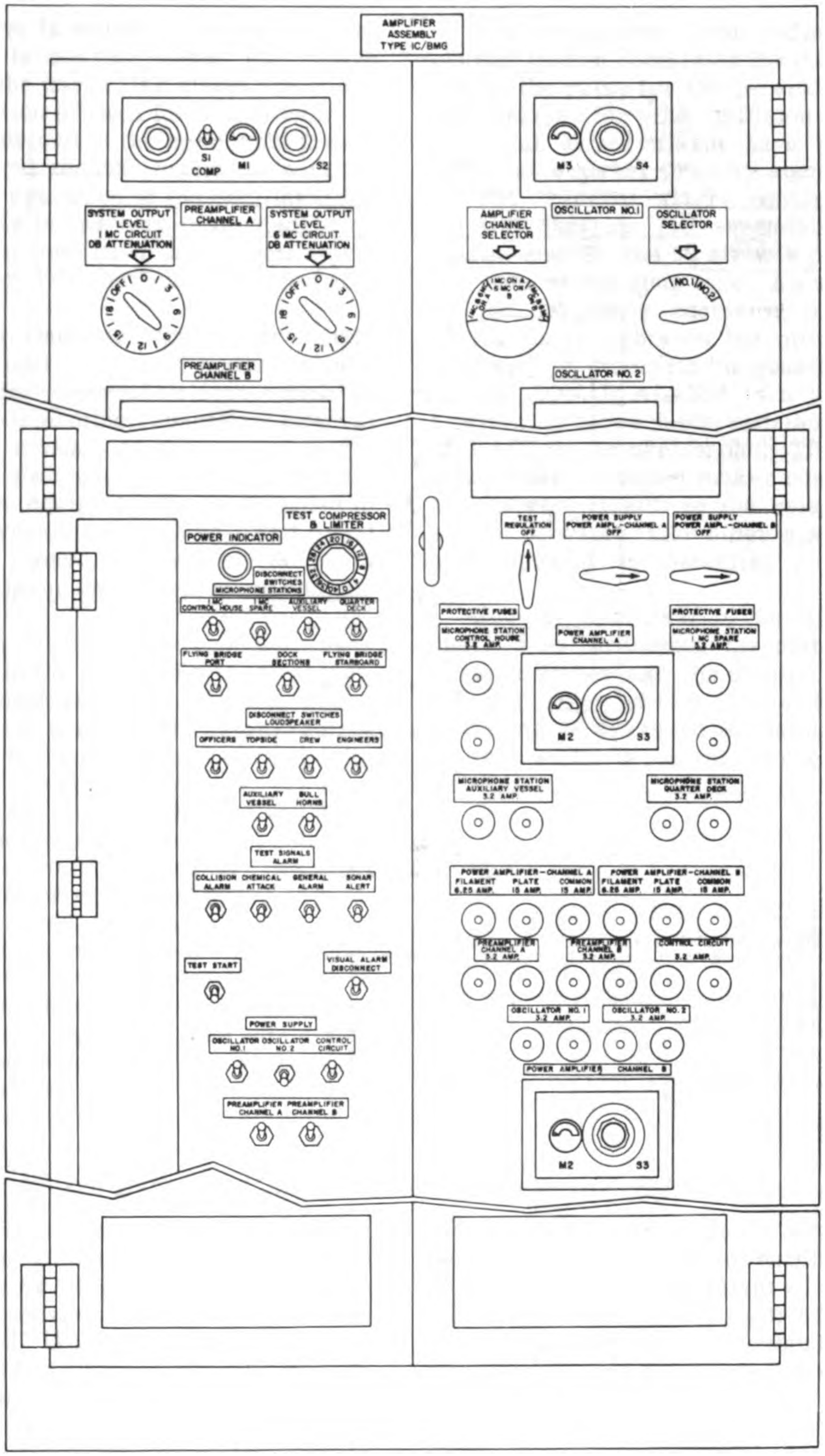
Normal operation of the preamplifier can be checked by measuring the overall output and plate current of each stage by the meter, M1, and meter switch S2. The meter switching is arranged so that normal operation of each stage is indicated by a midscale meter reading of 0 db ± 2 db.

Power Amplifiers

The power amplifiers consist of a voltage amplifier stage, a phase inverter stage, two driver stages, and a final power amplifier stage. Two tubes (not sections) operate in parallel for every stage except the final stage which has two groups of three triodes in parallel and the two groups in push-pull. The parallel connection of the triodes permits circuit operation in the event of failure or removal of one tube per stage (two tubes in the final stage).

The power to operate the power amplifier is supplied through a 3-conductor polarized plug, directly to the filament transformer, and through switch S3 (fig. 8-3) to the plate power transformer. A time-delay relay (not shown) external to the amplifier chassis, prevents the application of power to the plate power transformer until approximately 30 seconds after filament power has been applied.

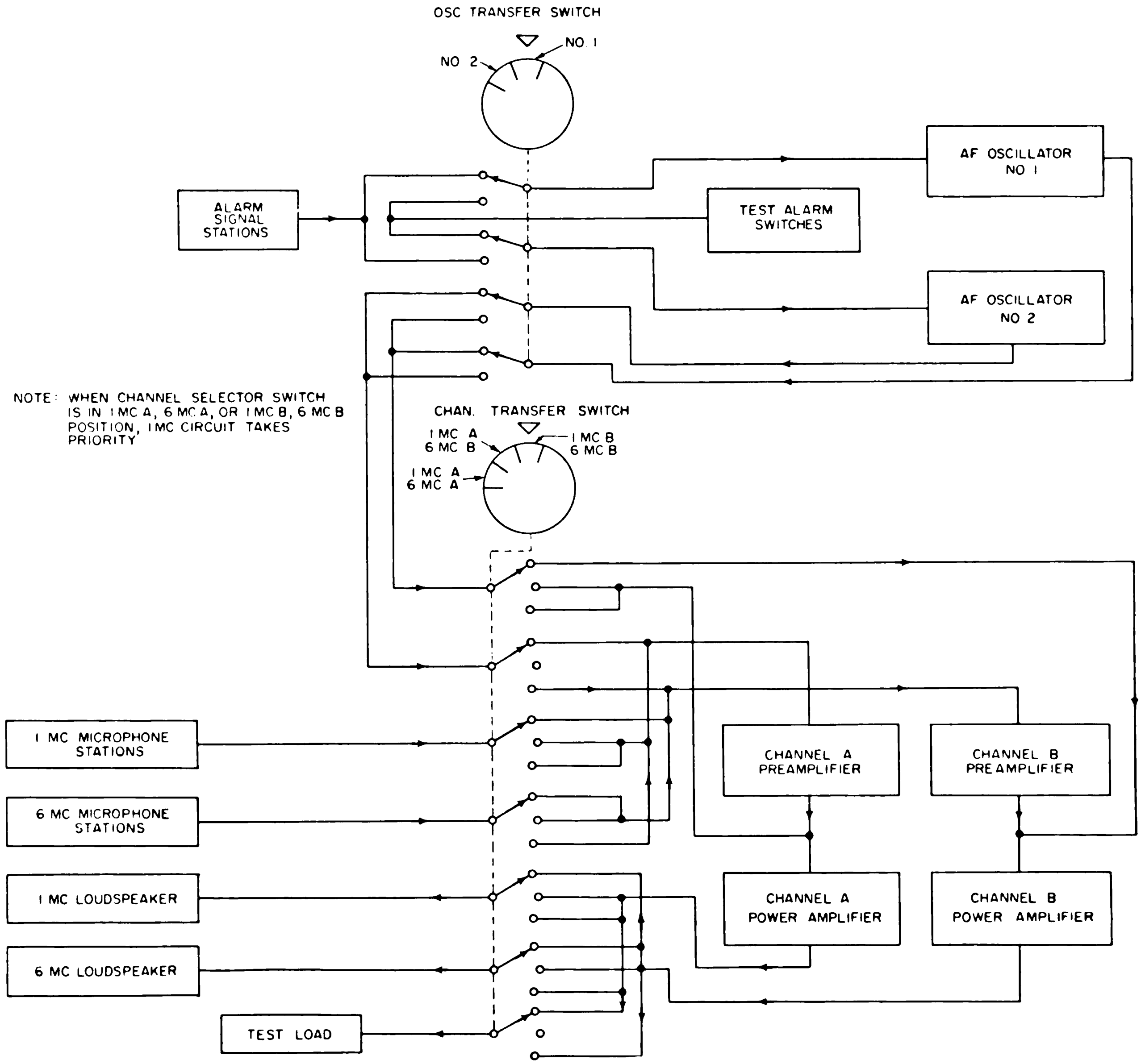
Digitized by Google



7.20

Figure 8-3.—Audio amplifier cabinet.

Digitized by Google



7.21

Figure 8-4.—Block diagram of 1MC-6MC announcing system.

The operation of each stage of the power amplifier in addition to the overall audio output can be checked by meter M2 and the 7-position meter switch, S3 (fig. 8-3). Normal operation of each stage is indicated by a midscale reading on the meter with rated input signal and output load.

Oscillators

Each oscillator is capable of generating a variety of alarm signals although only four are used in this application: (1) collision, (2) chemical attack, (3) general, and (4) sonar. Each oscillator is also capable of generating four additional alarm signals which can be used in the event of future expansion of the system. The additional alarms are: (1) simulated motor-operated horn-type signal; (2) jump-tone signal which alternates between 600 and 1,000 cps at the rate of 1 1/2 cps; (3) jump-tone signal which alternates between 600 and 1,500 cps at the rate of 6 cps; and (4) simulated siren-type signal. However, these alarms are not discussed in this chapter.

Digitized by Google

When any alarm is sounded, the frequency of relay operations is similar except that relays associated with the particular alarm are energized. The function of each individual relay in the system is explained in the applicable manufacturer's technical manual furnished with the equipment. The operation of the oscillator for the various alarms is based on the system being set up for normal operation using oscillator 1 and channel A for 1MC and channel B for circuit 6MC.

The oscillator generates the alarm signals as long as the alarm contact maker is held closed (except for general alarm which is sounded for a predetermined 15-second interval after momentary closure of the general alarm contact maker). Release of the alarm contact maker causes the equipment to be returned to STANDBY after sounding the alarm. The visual alarm circuit is closed continuously during a chemical attack alarm, and intermittently during a general alarm.

Closure of any collision alarm contact maker energizes relays in the audio amplifier cabinet, which in turn energizes the collision alarm contactor associated with the oscillator in active service to pulse the signal output of the oscillator and produce the collision alarm.

The COLLISION ALARM is a pulsed 1000 cps signal. Each cycle of the signal consists of three pulses of 0.06 second and the third pulse is followed by an off period of 0.3 second. This cycle is repeated continuously as long as the collision alarm contact maker is actuated.

The CHEMICAL ATTACK ALARM is a steady-tone signal of 1000 cps. The closure of any chemical attack contact maker effectively completes the control power circuit to the relay associated with the chemical attack alarm, provided the relay associated with the collision alarm has not operated to establish a higher priority signal. The chemical attack signal is generated and amplified in the same manner as the collision alarm signal; however, the signal is not pulsed.

The GENERAL ALARM is a simulated single-stroke gong-tone striking at the rate of 90 strokes per minute. The tone is caused to delay between strokes in a natural manner and the signal strokes are repeated automatically for 15 seconds after the alarm has been started. The signal-duration and stroke-repetition rate are determined by timing relays and contactors (not shown) in the audio amplifier cabinet but external to the oscillator assembly.

The momentary closure of any general alarm contact maker completes the control power circuit to the relay for the general alarm provided the relays for the collision alarm and the chemical attack alarm have not operated to establish a higher priority signal.

The general alarm contactor determines (1) the duration (15 seconds) of the general alarm, and (2) the 90 strokes per minute striking rate of the gong tone. An additional switch on the oscillator contactor pulses the visual alarm (busy lights on the microphone control stations) in step with the general alarm signal.

The SONAR ALARM is a jump-tone signal alternating between 600 and 1500 cps at the rate of 1 1/2 cycles per second. The closure of any sonar alarm contact maker completes the control power circuit to the relay for the sonar alarm provided that other alarm relays have not operated to establish a higher priority signal.

Normal operation of an oscillator can be checked by measuring the plate current of the various stages and the overall output by meter M3 and meter switch S4 (fig. 8-3). The meter switching is arranged so that normal operation of each stage is indicated by a midscale meter reading.

OPERATION

The path of circuits 1MC and 6MC from the inputs to the loudspeakers is shown by the block diagram in figure 8-4. The selector switch for the oscillators and amplifiers is set for normal operation with oscillator 1 and both amplifiers in active use. Channel A is normally used for circuit 1MC and channel B for circuit 6MC. In case of failure of a preamplifier or power amplifier, both circuit 1MC and circuit 6MC can be switched for operation on either channel A or channel B. When both circuits, 1MC and 6MC, are switched to the same channel, circuit 1MC has priority over circuit 6MC operation.

Circuit 1MC Microphone Control Station

To make voice announcements from a circuit 1MC microphone control station, operate one or more of the loudspeaker group selector switches (fig. 8-2) to select the area or areas to receive the announcement. Observe the busy indicators.

Digitized by Google

When BUSY 1 lamp is lighted, circuit 1MC amplifier is in use. Except in an emergency, do not attempt to use circuit 1MC when BUSY 1 lamp is lighted. If another microphone control station selects a circuit 1MC loudspeaker group and operates the press-to-talk switch, the transmission from both microphone control stations will go out to all loudspeaker groups selected by both microphone stations.

When BUSY 2 lamp is lighted, circuit 6MC amplifier is in use and will have no effect on circuit 1MC operation.

When both BUSY 1 and BUSY 2 lamps are lighted, (1) an alarm signal is being transmitted irrespective of the amplifier in use; (2) both circuit 1MC and circuit 6MC are in use, and if another microphone control station attempts to use circuit 1MC the transmission from both microphone stations will go out to all loudspeaker groups selected by both microphone stations; or (3) both circuit 1MC and circuit 6MC are on one amplifier (during test or in the event of failure of an amplifier channel) and one or the other circuit is in use.

Circuit 1MC takes priority over circuit 6MC, therefore, if circuit 6MC is in use and a circuit 1MC loudspeaker group is selected from another microphone control station, circuit 6MC will be cut off when the microphone press-to-talk switch is operated and the announcement will go out to the circuit 1MC loudspeakers only. If circuit 1MC is in use and a circuit 1MC loudspeaker group is selected, the transmission from both microphone stations will go out to all loudspeaker groups selected by both microphone stations.

Circuit 1MC-6MC Microphone Control Station

To make voice announcements from the 1MC-6MC microphone control station, operate the intership selector switch (fig. 8-2). Observe the busy indicators as previously described.

When the BUSY 1 lamp is lighted, circuit 1MC is in use, but circuit 6MC can be selected and used at the same time without interference to the transmission on circuit 1MC. Except in an emergency, do not attempt to use circuit 1MC when the BUSY 1 lamp is lighted. If a microphone control station selects a circuit 1MC loudspeaker group and operates the press-to-talk (microphone) switch when the BUSY 1 lamp is lighted, the transmission from both microphone stations will go out to all circuit 1MC loudspeaker groups selected by both microphone stations.

When both BUSY 1 and BUSY 2 lamps are lighted, (1) an alarm signal is being transmitted; or (2) both circuit 1MC and circuit 6MC are on one amplifier (during test or in the event of failure of an amplifier channel) and circuit 1MC is in use from another microphone control station. Because circuit 1MC has priority over circuit 6MC, it is not possible to use circuit 6MC when both the BUSY 1 and BUSY 2 lamps are lighted. If a circuit 1MC loudspeaker group is selected and the press-to-talk switch is operated, the transmission from both microphone control stations will go out to all circuit 1MC loudspeakers selected by both microphone stations.

Alarm Contact Maker

The operation of an alarm contact maker will take precedence over any microphone control station. When an alarm is sounded, the BUSY 1 and BUSY 2 indicators are lighted at all microphone control stations and the alarm signal is transmitted to all circuit 1MC loudspeakers. With the exception of the general alarm, the alarm signals will be sounded only as long as the contact maker is held in the operated position. The general alarm signal, once started by momentary operation of the general alarm contact maker, will continue for 15 seconds. This alarm can be repeated by again momentarily closing the general alarm contact maker.

Audio Amplifier Cabinet

Normal operation does not involve the operation or switching of controls at the audio amplifier cabinet, provided the switches and controls are set for normal operation. The meters on each oscillator and amplifier assembly can be observed for normal operation by placing the meter switch in position 1.

During the transmission from a microphone control station, normal operation of the preamplifier and power amplifier in active use is shown by a meter reading which swings to 0 db on voice peaks. During the transmission of alarm signals, normal operation of an oscillator in active service depends on the nature of the alarm signal. Normal operation of an oscillator on general alarm is indicated by a reading which swings from no reading to midscale (0 db). During alarm signals the preamplifier is bypassed. Normal operation of a power amplifier in active

Digitized by Google

service is indicated by a reading within ± 2 db of the meter reading for the oscillator.

MAINTENANCE

If the entire announcing system is inoperative, the trouble is probably in the ship's power supply or wiring from the ship's power supply. Check the power available indicator on the audio amplifier cabinet (fig. 8-3). This indicator, unless it is defective, will be lighted when power is available at the cabinet.

Check the fuses in the early stages of trouble shooting. All fuses are located on the control panel of the audio amplifier cabinet in combination fuse holders and blown-fuse indicators, and are accessible from the front of the cabinet. Failure of a fuse is indicated when the neon-glow lamp in the fuse-holder cap is lighted. The switch controlling power to the circuit (which a fuse protects), must be in the ON position for the glow lamp to give an indication of fuse failure. Also, in the case of fuses protecting microphone control stations, the microphone talk switch at the microphone control station must be operated to give an indication of fuse failure.

Performance failure of the shipboard announcing equipment can be corrected most readily by first isolating the assembly at fault, then isolating the circuit of that assembly, and finally by isolating the particular part causing the trouble. Localization of trouble in the system will be comparatively simple because of the test facilities included in the equipment. Also, the use of duplicate oscillator, preamplifier, and power amplifier assemblies permits the testing or repair of one assembly while the other assembly remains in active service, thereby avoiding the necessity for shutting down the system. Trouble in an assembly can be localized readily by using the meter and meter switch included in each assembly (fig. 8-3). In most cases a faulty assembly or even the faulty stage of an assembly can be localized by these meters without resorting to extensive troubleshooting procedures.

Microphone Control Station

A short circuit in the wiring to a microphone control station or a defect in a microphone control station can, under certain circumstances, prevent normal operation from other microphone control stations. In the event of such trouble, operate the microphone station disconnect switch to the OFF position. If the location of the defective microphone station is not known, operate all microphone station disconnect switches on the audio amplifier cabinet (fig. 8-3) to the OFF position, one at a time until the defective microphone control station is isolated. Leave this switch in the OFF position until the trouble has been corrected. Return all other microphone-station disconnect switches to the ON position.

Loudspeaker

A short circuit in a loudspeaker or in the loudspeaker wiring can cause a power amplifier, which tests normally, to act abnormally when switched into active service. It will result in a lower than normal meter reading of the power amplifier output. If the location of the defective wiring or loudspeaker is not known, operate the loudspeaker-group disconnect switches on the audio amplifier cabinet to the OFF position, one at a time until the defective loudspeaker group is isolated. This will be indicated by a return to normal meter reading (0 db ± 2 db) of the power amplifier.

If the trouble persists and is not in the microphone control stations or loudspeaker groups, it is probably in the preamplifier, power amplifier, or oscillator assembly.

Preamplifier

Normal output of a preamplifier is 10 volts which is indicated by a midscale reading of 0 db ± 2db on the output meter with the meter transfer switch in position 1. Normal output is obtained from a preamplifier when the voice signals from a microphone control station are applied to the input terminals, or when attenuated alarm signals from an oscillator being tested (or being used as a source of test signal) are applied to the same terminals. In normal system operation, the alarm signals generated by an oscillator in active service bypass the preamplifier in active service and are applied directly to the input of the power amplifier in active service.

To check a preamplifier for normal operation, apply an attenuated signal from the oscillator not in active service to the input transformer, of the preamplifier and observe the output meter readings from each meter switch position. Operate the test chemical attack alarm switch to the ON position (fig. 8-3) to cause the oscillator not in active service to generate a 1,000 cps signal. This signal is attenuated and fed

Digitized by Google

to the preamplifier on test through the test input control. The normal test signal input to the preamplifier will indicate a midscale reading of 0 db ±2 db for the normal outputs of the various stages.

When the meter switch, S2, (fig. 8-3) is rotated to positions 1 through 7 inclusive, the output meter, M1, is connected to terminals in the various output stages of the preamplifier. If other than a normal reading is obtained, check the voltage of the stage or stages at fault and compare the readings with those listed in the applicable manufacturer's technical manual. Localize the trouble and replace the defective part.

Power Amplifier

Normal audio output of a power amplifier is 70 volts which is indicated by a reading of 0 db on the output meter with the meter switch in position 1 (fig. 8-3). In normal operation, alarm signals from the oscillator in active service drive the power amplifier to normal output. Likewise, the amplified voice signals from the preamplifier will drive a power amplifier to normal output.

During test, the oscillator not in active service is used to drive the preamplifier not in active service. The preamplifier, in turn, drives the power amplifier not in active service. The audio output of the power amplifier is fed to a dummy-load resistor combination in the secondary of the output transformer of the power amplifier. Switching arrangements in the audio amplifier cabinet prevent the test signals from reaching the loudspeakers.

In the majority of cases, trouble in any stage of the power amplifier will also affect the meter reading when measuring the output signal. Therefore, when an abnormal signal output is indicated on the meter, localize the trouble by using the power amplifier meter and meter switch to check the operation of all the stages.

To check a power amplifier for normal operation, operate the TEST START switch to the ON position (fig. 8-3) and observe the output meter readings from each meter switch position. The normal test signal input to the power amplifier should indicate a midscale reading of 0 db for normal audio output, and a midscale meter reading of 0 db ±2 db will indicate normal output for the other stages of the power amplifier.

When the meter switch, S3, is rotated to positions 1 through 7, inclusive, the output meter, M2, is connected to terminals in the various stages of the power amplifier. If an abnormal meter reading is indicated, check the voltage of the stage or stages at fault with the normal readings listed in the manufacturer's technical manual. Isolate the trouble and repair or replace the defective component.

Oscillator

Normal output of an oscillator is 10 volts which is indicated by a midscale reading of 0 db with the meter switch in position 1 (fig. 8-3). On general alarm, collision alarm, and sonar alarm, this reading swings from no reading to 0 db. The 1,000 cps test checmical attack alarm signal is used for adjusting the amplifier. It is essential that an output of 0 db be obtained from the oscillator.

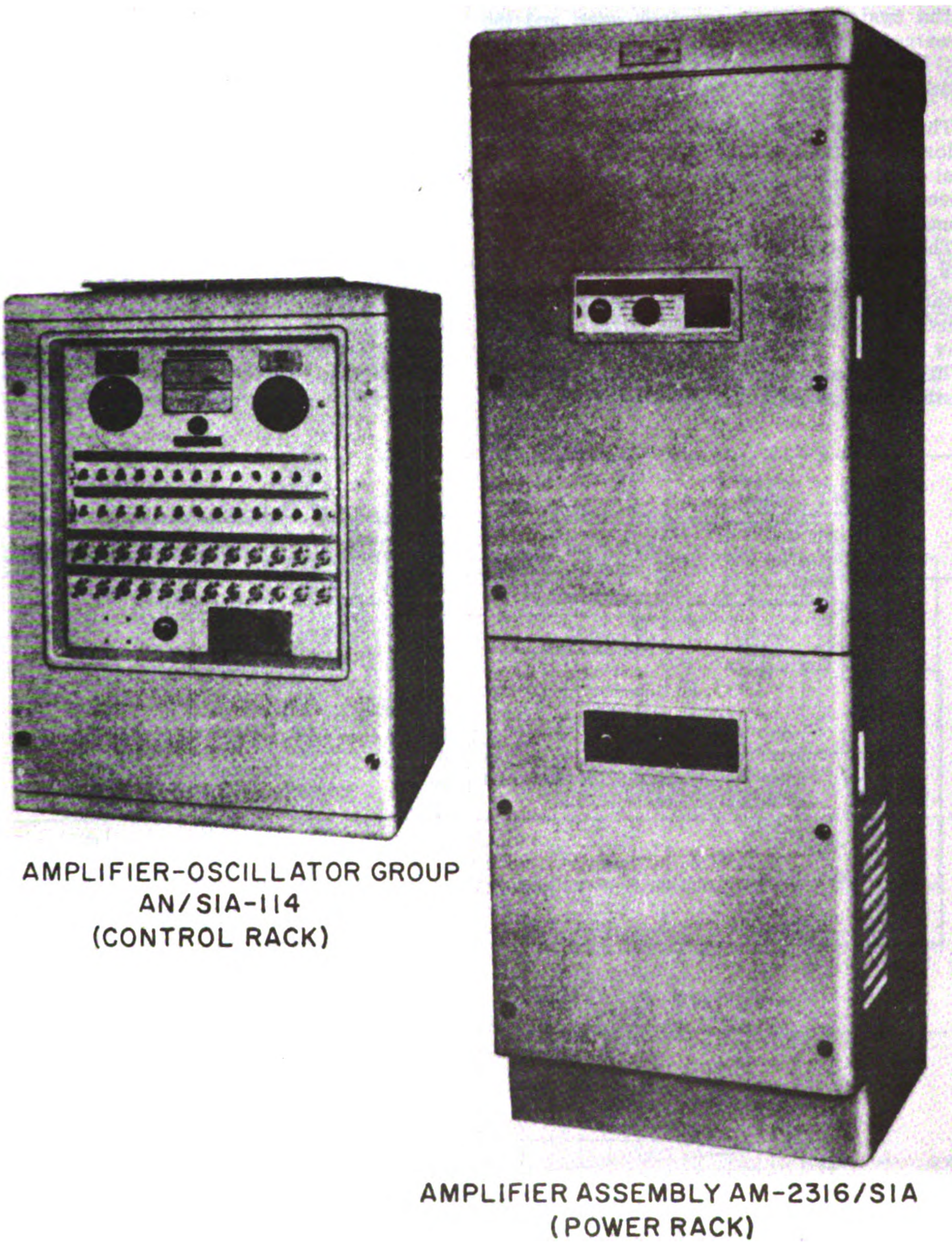
Normal operation of each stage of an oscillator is indicated by the correct meter reading, when the meter, M3, is switched into each stage by meter switch, S4, and the various test alarm switches are operated. It is important to note that no reading will be obtained from some positions of the meter switch when alarms (test or actual) are being sounded. When trouble shooting an oscillator, be certain that a normal meter reading is not obtained for the particular stage before attempting to localize trouble within the stage. In most cases, trouble in one stage will also affect the meter reading when measuring the oscillator output with the meter switch in position 1.

When an abnormal output is indicated, localize the faulty stage by checking the operation of each stage. Rotate the meter switch, S4, through its various positions and compare the readings of meter, M3, with the normal readings listed in the manufacturer's technical manual. If any of these readings are above or below normal (0 db) by more than 2 db or if no reading is obtained, make a voltage test of the faulty stage or stages and compare the readings with the normal readings listed in the technical manual. Localize the trouble and repair or replace the faulty component as necessary.

1MC-6MC ANNOUNCING SYSTEM, AN/SIA-114

The 1MC-6MC announcing system, AN/SIA-114 is a later type of shipboard announcing system designed to perform the same functions as the system just discussed. The major units

Digitized by Google



140.36

Figure 8-5.—1MC-6MC announcing system AN/SIA-114.

Digitized by Google

of the system are the control rack and the power rack, (fig. 8-5).

CONTROL RACK

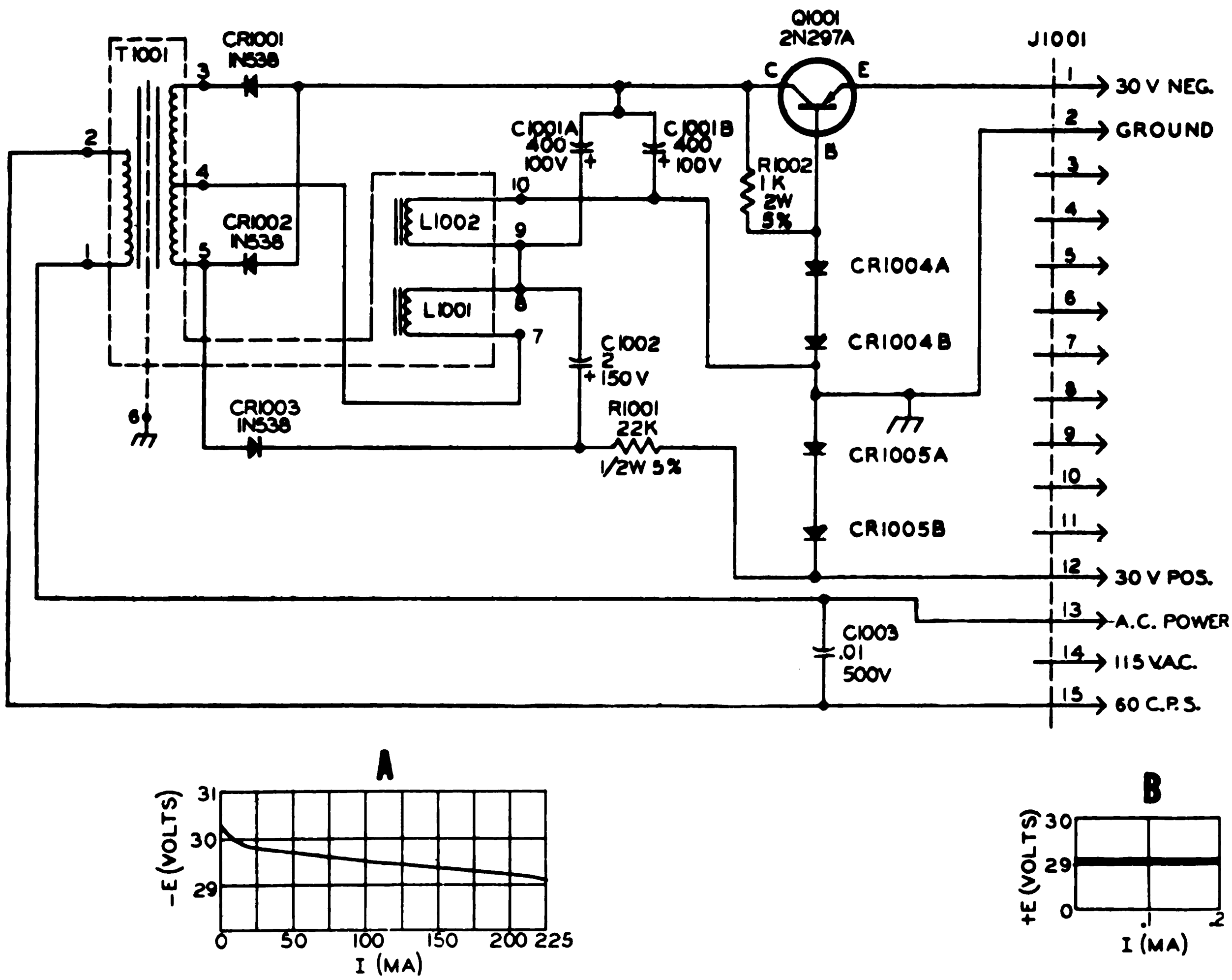
The control rack is a bulkhead mounted enclosure containing a control panel, two relay panel assemblies, a relay power supply, and sixteen plug-in assemblies, (eight for each channel).

The control panel mounts the various controls, switches, and indicators for system operation and testing. At the bottom of the control rack behind the front cover, are two relay panels. The outer relay panel consists of 70 relays mounted in rectangular sockets, and the inner relay panel consists of 14 relays mounted in octal sockets. A relay power supply is mounted near the top of the inner relay panel.

The 8 plug-in assemblies for each channel consists of power supply, PP-2563/SIA; a-f amplifiers, AM-2127/SIA, and AM-2506/SIA, and a-f oscillators, 0-718/SIA, 0-721/SIA, 0-722/SIA, 0-724/SIA, and 0-725/SIA. A handle is provided on each plug-in assembly to facilitate removal and installation of the assembly.

Power Supply PP-2563/SIA

Transistorized power supply PP-2563/SIA, (fig. 8-6), furnishes -30 ± 2VDC at 100 to 110 ma, and +30 ± 2VDC at .2 ma. The negative



140.37

Figure 8-6.—Power supply PP-2563/SIA, schematic diagram.

Digitized by Google

oltage is full-wave rectified, and the positive oltage is half-wave rectified.

Transistor Q1001 and Zener diodes CR1004A nd CR1004B regulate the -30 volt output as hown by curve A. Zener diodes CR1005A and R1005B regulate the +30 volt output as shown y curve B.

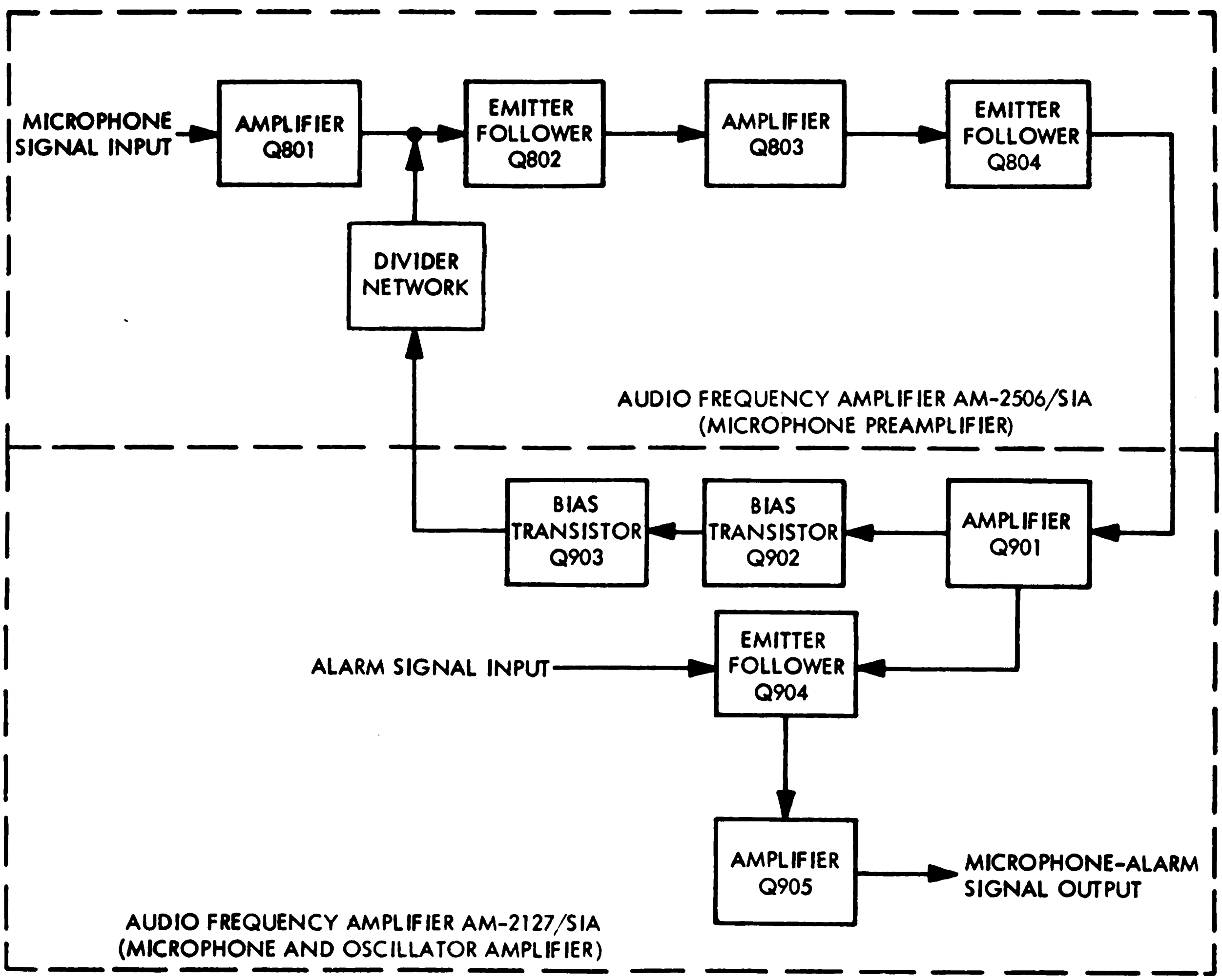
-F Amplifier AM-2506/SIA

Audio-frequency amplifier AM-2506/SIA is a transistor microphone preamplifier (fig. 8-7), ie output of which drives a 5 transistor microphone and oscillator amplifier, AM-2127/SIA. The microphone preamplifier (fig. 8-8), is common emitter 4 stage amplifier with a divider network between the first and second stages, and a feedback circuit (which acts as a limiter circuit), via transistors Q902 and Q903 in the microphone and oscillator preamplifier, (fig. 8-9).

A-F Amplifier AM-2127/SIA

Audio-frequency amplifier AM-2127/SIA contains 2 transistor amplifier stages, Q901 and Q905, an emitter follower stage, Q904, and 2 bias transistors, Q902 and Q903, employed in a limiter circuit.

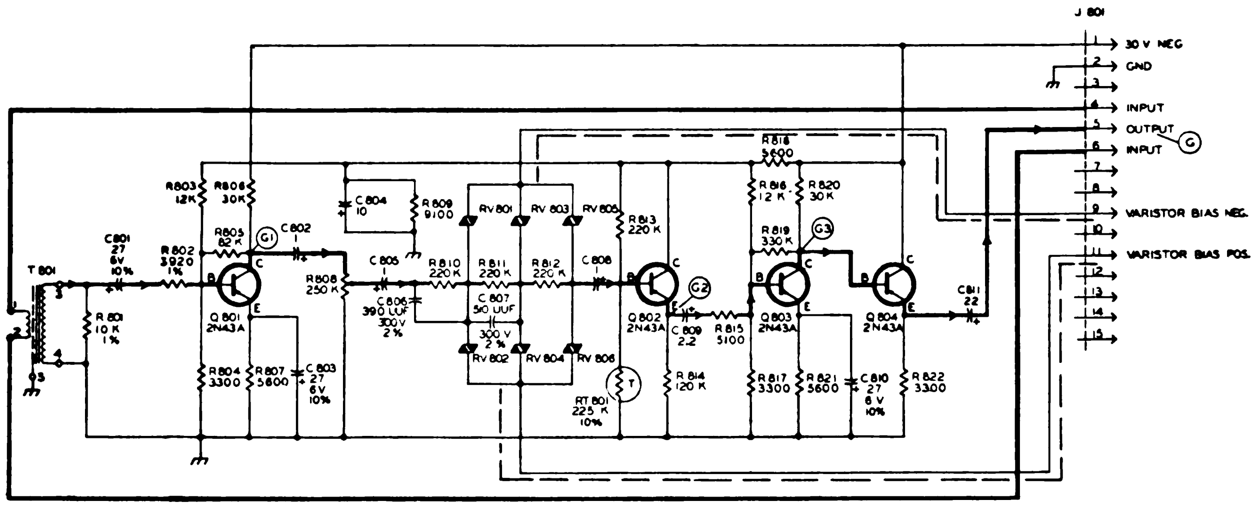
The limiter circuit consisting of Q902 and Q903, in conjunction with varistors V801 through



140.38

Figure 8-7.—A-f amplifiers AM-2506/SIA, and AM-2127/SIA, block diagram.

Digitized by Google



140.39

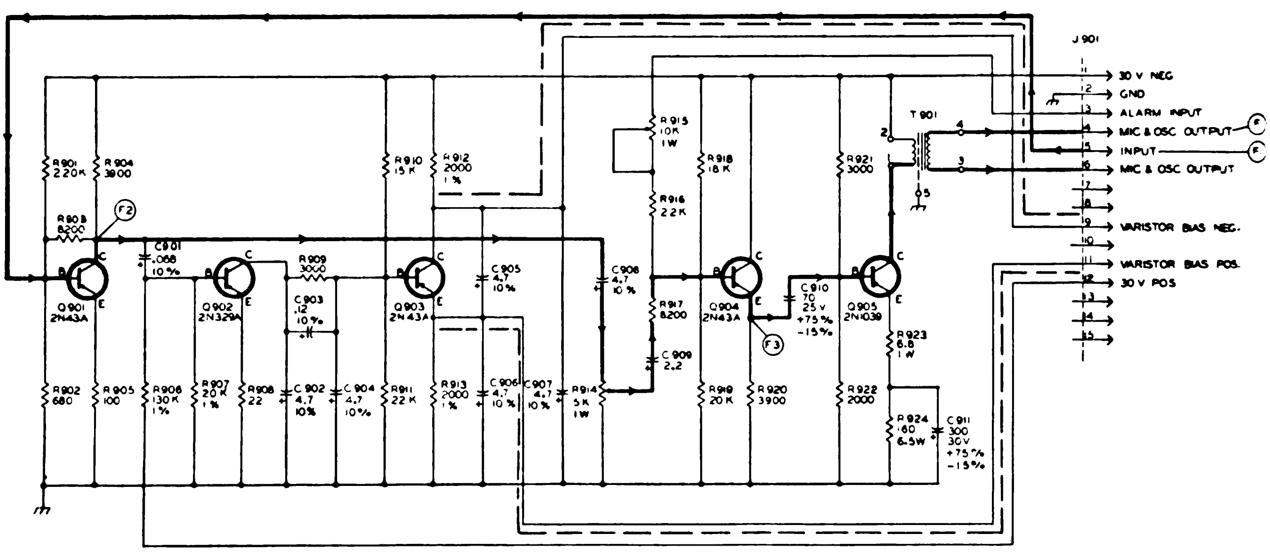
Figure 8-8.—A-f amplifier AM-2506/SIA, schematic diagram.

V806 (fig. 8-8), provides signal amplitude control. Transistor Q902 is biased to conduct only on microphone input signals greater than the maximum amplitude limit. Conduction of Q902 results in conduction of Q903. Conduction of Q903 lowers the impedance of the network (dashed lines figs. 8-8 and 8-9), resulting in a decrease in voltage across varistors V801 through V806. The voltage decrease on the varistors causes their resistance to increase, which reduces the Q802 base emitter bias current, and thus the gain of Q802.

Alarm signals require less amplification than microphone signals and are therefore applied directly to the base of Q904.

A-F Oscillator 0-718/SIA

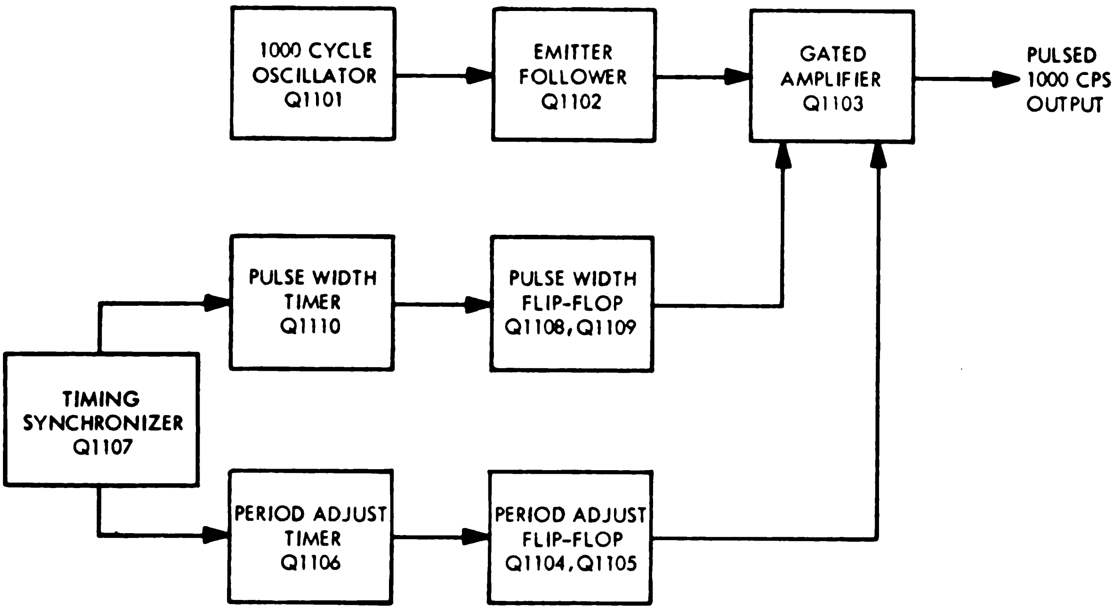
Collision alarm oscillator 0-718/SIA, (fig. 8-10, contains a transistorized oscillator



140.40

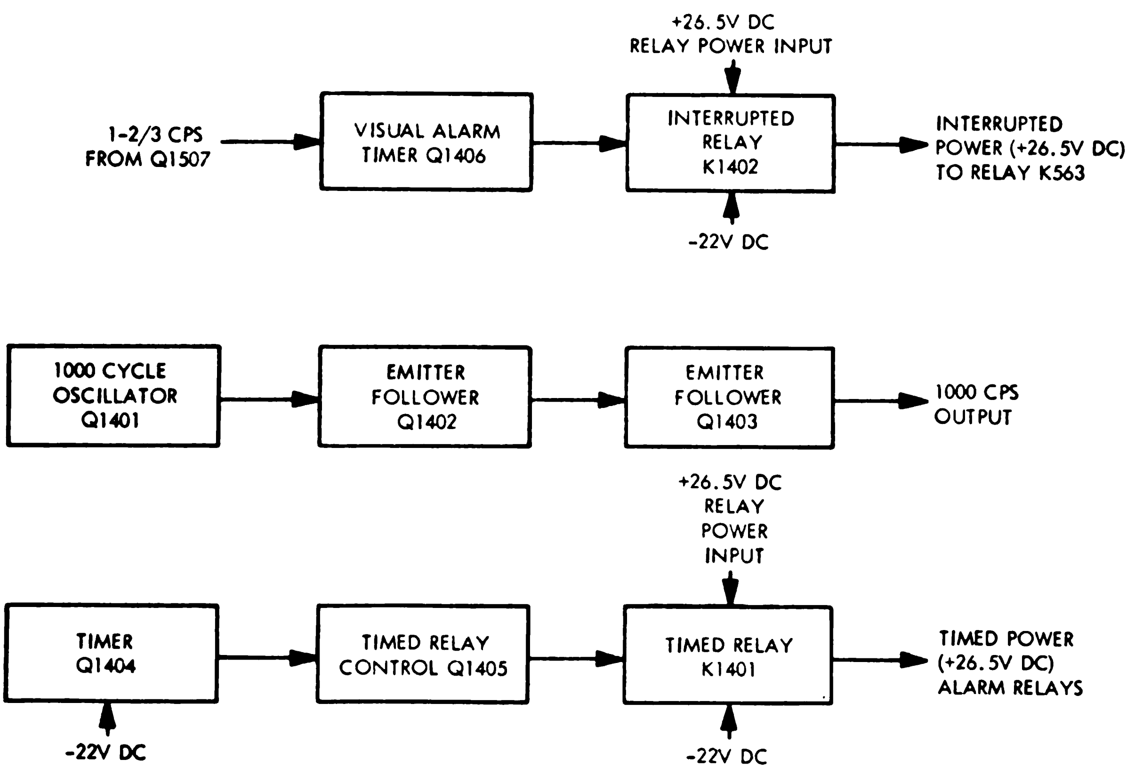
Figure 8-9.—A-f amplifier AM-2127/SIA, schematic diagram.

Digitized by Google



140.41

Figure 8-10.—A-f oscillator 0-718/SIA (collision alarm), block diagram.



140.42

Figure 8-11.—A-f oscillator 0-721/SIA (chemical alarm), block diagram.

Digitized by Google

circuit which generates a pulsed 1000 cps signal. Each period consists of three pulses 50 milliseconds in duration. Each group of three pulses is followed by an off time of 0.35 second. This cycle is repeated continuously as long as power is applied to the circuit.

A-F Oscillator 0-721/SIA

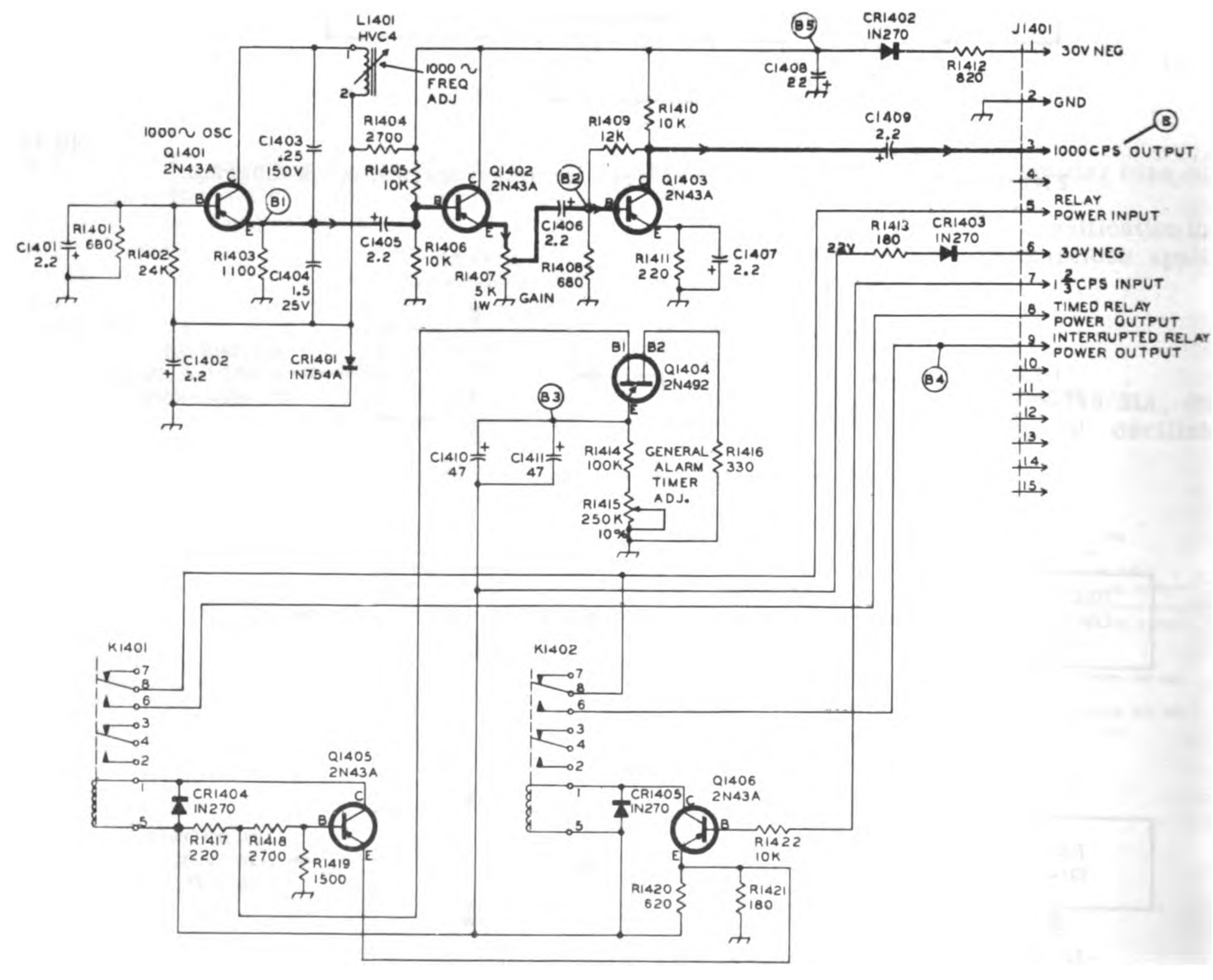
Chemical alarm oscillator 0-721/SIA (fig. 8-11), contains a transistorized oscillator circuit which generates a continuous 1000 cycle signal as long as power is applied to the circuit. The oscillator also contains two transistorized circuits which furnish a timed relay voltage and an interrupted relay voltage to the general alarm circuits.

Transistor Q1401 (fig. 8-12), is connected as a Collpitts oscillator, and generates a 1000 cycle sine wave signal. This signal is coupled to the base of emitter follower Q1402. From the emitter of Q1402 the signal is coupled through GAIN control potentiometer R1407 to the base of amplifier Q1403. The signal output is at pin 3 of connector J1401.

The circuits associated with the general alarm are discussed along with the general alarm oscillator discussion.

A-F Oscillator 0-722/SIA

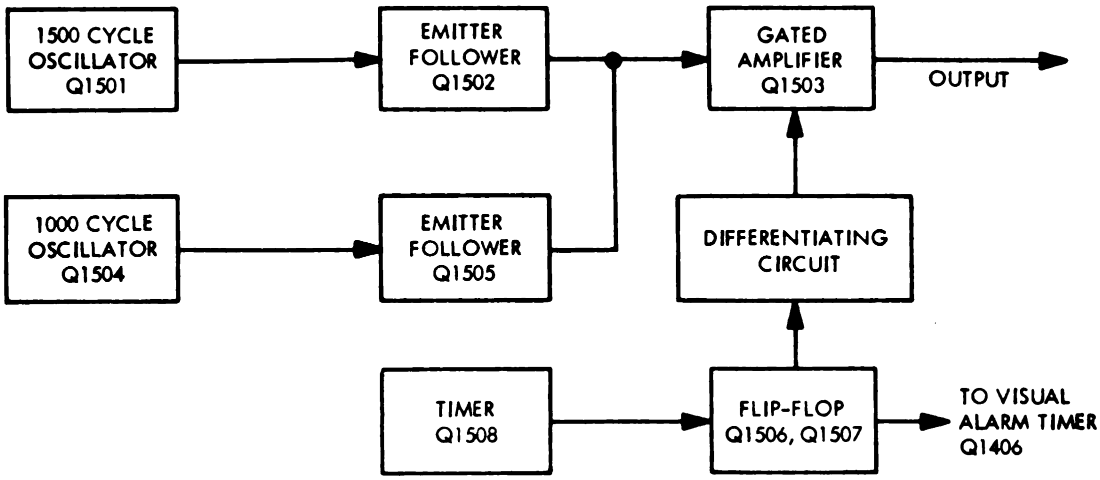
General alarm oscillator 0-722/SIA (fig. 8-13), contains oscillator and timer circuits, which in conjunction with circuits in the chemical



140.43

Figure 8-12.—A-f oscillator 0-721/SIA, schematic diagram.

Digitized by Google



140.44

Figure 8-13.—A-f oscillator O-722/SIA (general alarm), block diagram.

alarm oscillator, produce a simulated single-stroke, gong tone striking at the rate of 90 strokes per minute. The signal continues automatically for 15 seconds after power is applied to the circuit.

Transistors Q1501 and Q1504 (fig. 8-14), are connected as Collpitts oscillators, and generate sine wave signals at 1500 and 1000 cps. The 1500 cycle signal from Q1501 is coupled to emitter follower Q1502, and the 1000 cycle signal from Q1504 is coupled to emitter follower Q1505. The outputs of Q1502 and Q1505 are mixed at the base of amplifier Q1503, whose emitter is gaited by the timing circuit.

Unijunction transistor Q1508 is used as a timer to control flip-flop transistors Q1506 and Q1507. Potentiometer R1534 controls the timing of Q1508. The output of the flip-flop is a 1 2/3 cps square wave having a peak-to-peak amplitude of approximately 14 volts. This square wave is differentiated by R1516 and C1510, and gates the emitter of Q1503. The output, regulated by R1512, is at pin 3 of connector J1501.

When the general alarm is actuated, -30 VDC is applied to pin 6 of J1401 (fig. 8-12), capacitors C1410 and C1411 begin to charge. Potentiometer R1415, resistor R1414, and capacitors C1410 and C1411 are used as an RC time constant network. Potentiometer R1415 is set so that 15 seconds after the general alarm is actuated, timer Q1404 sends out a positive pulse that cuts off Q1405. When Q1405 is cut off, relay K1401 is deenergized which disconnects the relay power input circuit from the timed relay power output, deenergizing the general alarm relays.

The 1 2/3 cps signal output of Q1507 (fig. 8-14) is applied through pin 7 of J1401, (fig. 8-12), to the base of Q1406. This pulse turns Q1406 on and off, energizing and deenergizing relay K1402. Thus interrupted relay power is supplied through pins 9 of J1401 and J1501 to operate control relay K563, and visual alarm relay K580 (not shown).

A-F Oscillators 0-724/SIA and 0-725/SIA

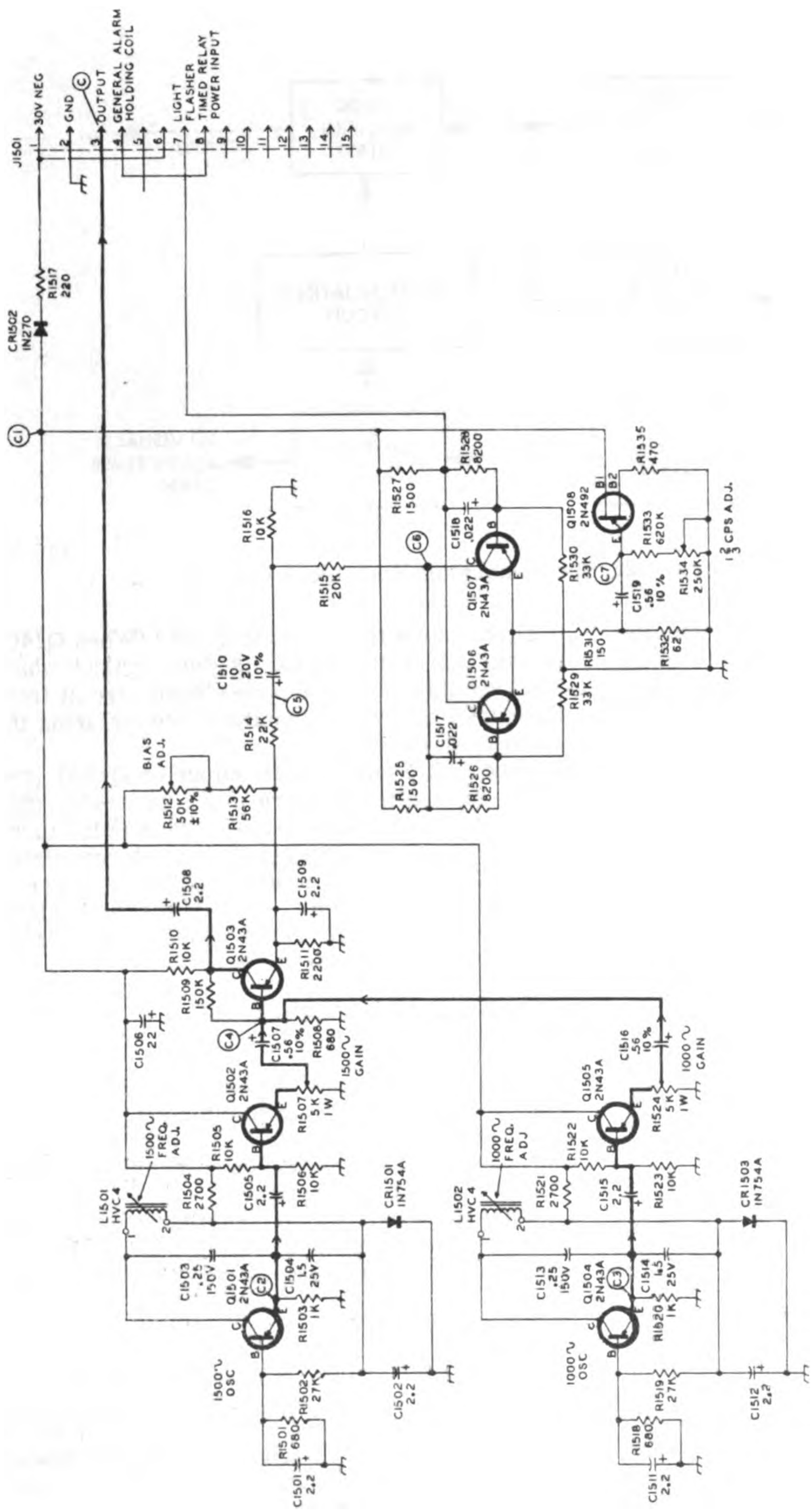
Unassigned alarm "A" oscillator 0-724/SIA, (fig. 8-15), contains transistorized oscillator and timer circuits which generate 500 cycle and 1500 cycle sine waves alternating at the rate of 1 1/2 cps (jump tone).

Unassigned alarm "B" oscillator 0-725/SIA generates a jump tone of 600 and 1500 cps sine waves alternating at the rate of 6 cps.

POWER RACK

The power rack is a deck mounted enclosure containing 2 identical 500 watt power amplifiers (a-f amplifier AM-2128/SIA), and a ventilation blower. Each amplifier consists of two units, the power amplifier, chassis 1, and the power supply, chassis 2, (fig. 8-16).

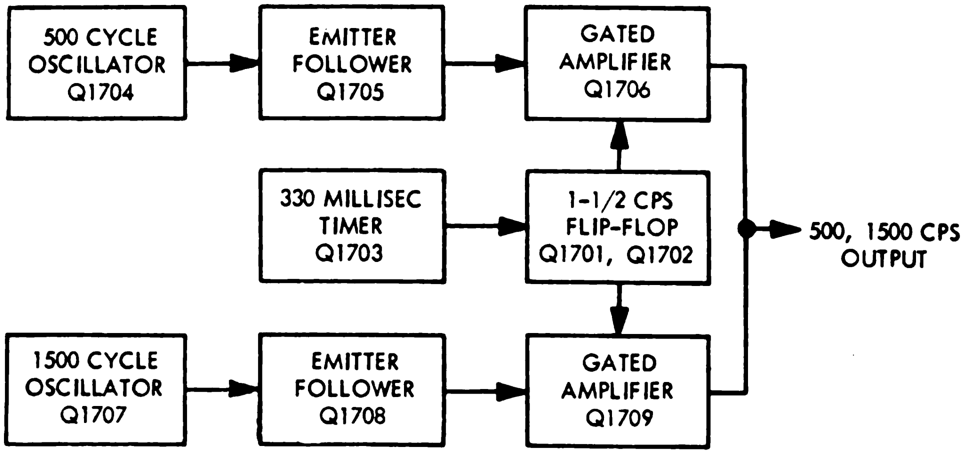
Digitized by Google



140.45

Figure 8-14.—A-f oscillator 0-722/SIA, schematic diagram.

Digitized by Google



140.46

Figure 8-15.—A-f oscillator 0-724/SIA (unassigned alarm "A"), block diagram.

The power amplifiers, similar to the power amplifiers in the 1MC-6MC system discussed previously, consist of a voltage amplifier stage, a phase inverter stage, 2 driver stages, and a final amplifier stage.

INTERCOMMUNICATING SYSTEMS

Intercommunicating (intercom) systems provide for two-way transmission of orders and information between stations. Each intercom unit contains its own amplifier.

INTERCOMMUNICATING UNIT

Intercommunicating units installed in naval vessels are of standard design (fig. 8-17). This standardization permits the units, irrespective of their mechanical construction, to be connected together electrically in a system. The electrical characteristics that must be identical to permit interconnection in a system are the (1) audio amplifier input and output power requirements; (2) amplifier output impedance to the loudspeaker line transformer; (3) supply voltages and currents; (4) call and busy signal voltages; and (5) interconnection circuits.

Standard intercommunicating equipment consists of the wired audio reproducing type of unit. The intercom units consist of two types. One type can originate calls up to a maximum of 10 other stations, and the other type can originate calls up to a maximum of 20 other stations. There is no operational difference between the two types of units. The schematic diagram of a standard intercommunicating unit is illustrated in figure 8-18.

The ship's power for the intercommunicating system is controlled by a master switch on the IC switchboard and is supplied through a TSGA cable. The TSGA cable interconnects the units in parallel for the single-phase 115-volt power supply and the signal circuit common line. The 115-volt power is fused at each unit. The audio and signal lines (excluding the signal circuit common) of the units in the system are interconnected with a TTHFWA cable.

The intercommunicating unit (fig. 8-20) is housed in a steel cabinet designed for bulkhead mounting. It will withstand shock vibration, and salt spray, and will perform under extremes of temperature and high humidity. The components consist essentially of a reproducer, controls, and amplifier.

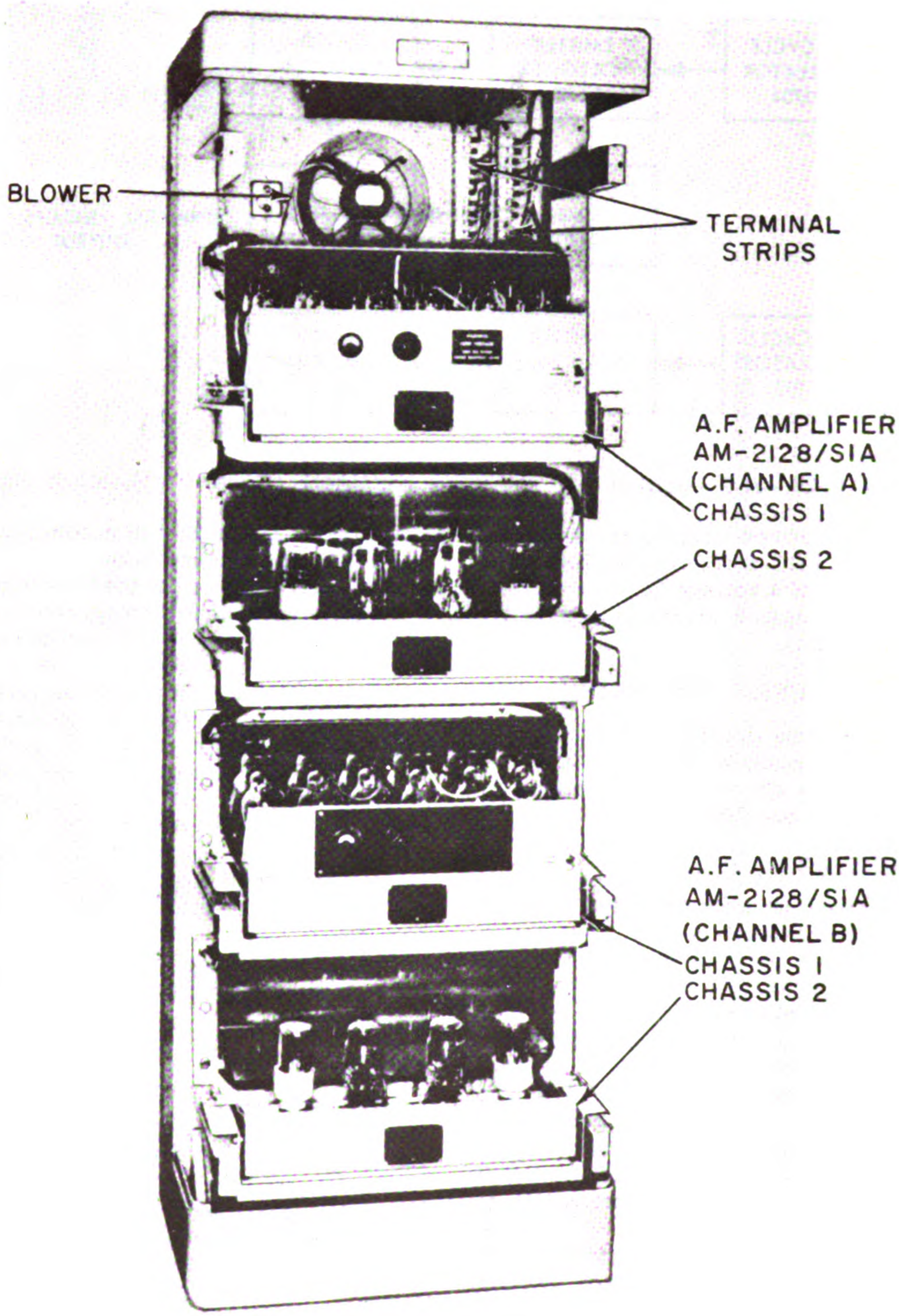
Reproducer

The reproducer serves as a microphone to transmit sound from the unit to other units in the system and as a loudspeaker to reproduce sound transmitted to the unit by any other unit. An incoming call can be heard through the loudspeaker because amplification is accomplished by the amplifier of the calling unit.

Controls

The controls consist of the talk switch, handset and microphone talk, pushbutton assembly, busy light, call light, volume control, and dimmer control.

Digitized by Google



140.47

Figure 8-16.—Amplifier assembly AM-2316/SIA (power rack), covers removed.

Digitized by Google

7.25

Figure 8-17.—Intercommunicating unit.

The TALK SWITCH, S26, (fig. 8-18), serves to select the function of the reproducer. When the switch is depressed, the reproducer functions as a microphone and the output of the amplifier of the calling station is electrically connected to the reproducer of the called station. When the switch is released the reproducer functions as a loudspeaker. The talk switch is spring loaded and returns to the listen or standby position when released.

A HANDSET can be used with the intercommunicating unit in place of the reproducer. The operation is the same as that of the reproducer except that the pushbutton in the handset is used as a talk switch in place of the regular talk switch on the front panel. Incoming calls will be heard simultaneously in the handset and in the reproducer. The volume control will control the level of the incoming call to the reproducer only.

A PORTABLE MICROPHONE can also be used with the equipment. The operation is the same as that of the reproducer, except that the pushbutton on the microphone is used as a talk switch instead of the regular talk switch on the equipment.

The PUSHBUTTON ASSEMBLY, or station selector buttons, are located at the top of the front panel. The locations or designations of the various units in the system are engraved in the station designation plate below the associated selector buttons. When the station selector buttons are depressed they will lock in the operated position until the release pushbutton is depressed to return them to the non-operated position.

The 10-station unit is provided with one bank of station selector switches, whereas the 20-station unit is provided with two banks of selector switches. In the 20-station unit,

Digitized by Google

however, the latchbar switches and release pushbuttons are electrically interconnected.

One bank of selector switches consists of the switch mechanism, 11 pairs of spring pile-up switches, and a latch-bar switch. Each pair of pile-up switches (consisting of an upper pile-up designated S1U, S2U, and so forth, and a lower pile-up designated S1L, and so forth, is operated simultaneously by a separate release pushbutton.

During standby periods the release pushbutton is kept in the depressed, or operated position. When any station selector button is depressed, the release pushbutton will automatically return to the nonoperated position and the release lamp under the pushbutton will be lighted. At the conclusion of a conversation the release pushbutton must be depressed to extinguish the release lamp and return any station selector buttons which were operated, to the nonoperated position.

The BUSY lamp is lighted when a station button is depressed to call another station and the station being called is busy. Do not leave a station selector button depressed when the busy lamp is lighted. Depress the release pushbutton and call later.

The DIMMER CONTROL, S27, (fig. 8-18) controls all illumination of the unit. The signal lights are off when the control knob is in the extreme counterclockwise position and are fully lighted for all other positions as the knob is turned clockwise. The station designation lights are lighted for all positions of the control knob and the illumination increases as the knob is turned clockwise.

The VOLUME CONTROL, S25, is associated with a variable impedance output transformer, T2, inside the unit. As the knob is rotated, the electrical energy passing through the tapped coil to the loudspeaker is increased and the volume of sound output of the loudspeaker is correspondingly increased. This control has no effect on the volume of the outgoing sound from the unit. Thus, each unit in the system can control the incoming volume to the desired level.

Amplifier

The amplifier is a 3-stage push-pull amplifier consisting of the input transformer, T1, double triodes, V1 and V2, beampower tubes, V3 and V4, output transformer, T2, and the power supply rectifier twin diode, V5.

The primary of T1 is tapped to match it either to the internal loudspeaker, LS1, used as a microphone, or to an external microphone over a frequency compensating network consisting of R21, R22, R23, and C12. The secondary of T1 drives the grids of the first voltage amplifier stage, V1.

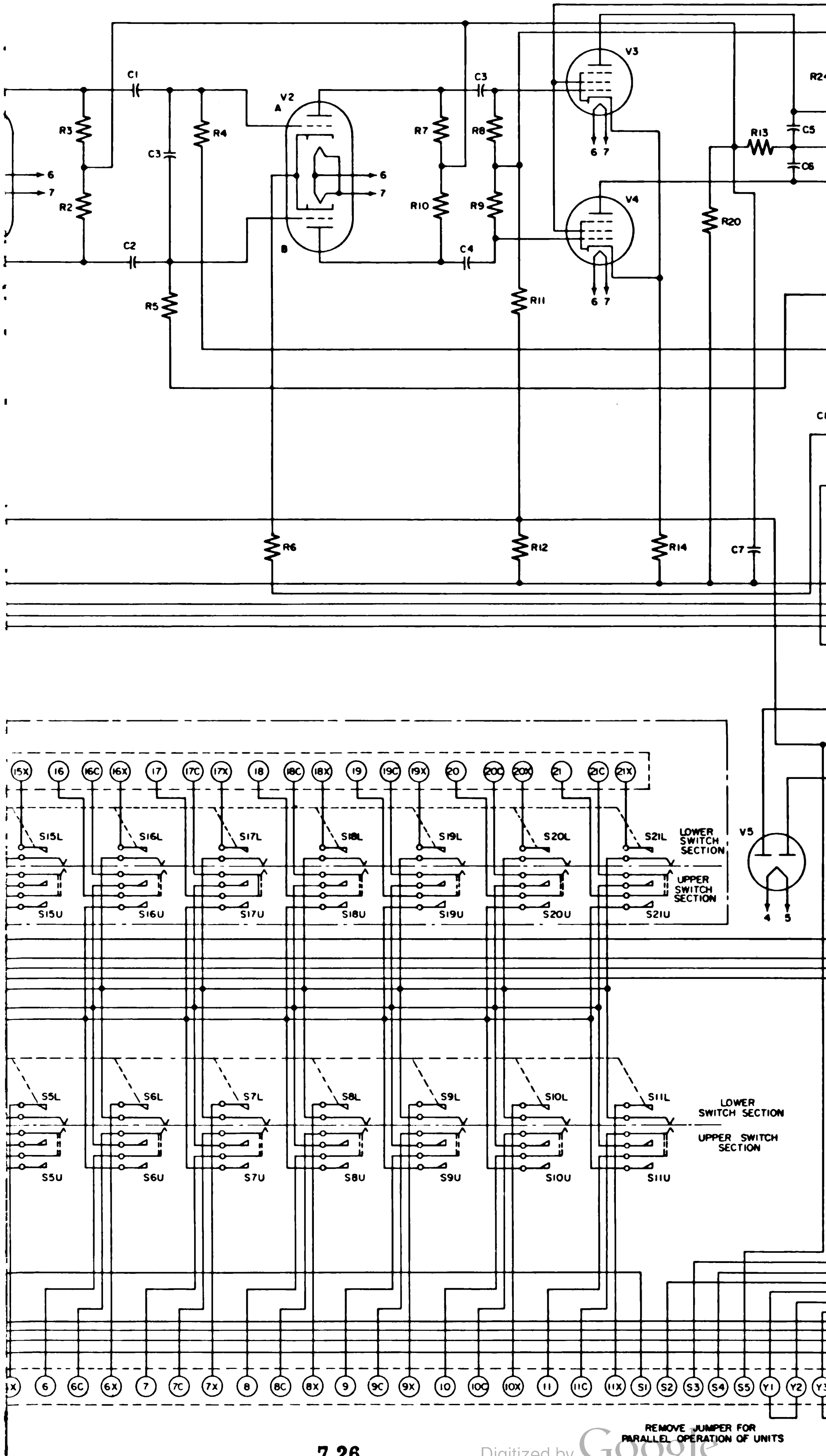
Resistance-capacitance coupling is used between the three stages of the amplifier. The output of the power stage, V3 and V4, is coupled through the output transformer, T2, to the voice transmission line. When the amplifier is not in use (when receiving calls) transformer, T2, acts as a line transformer. Calls are received over the voice transmission line and are coupled over a separate winding to the loudspeaker, LS1. This winding is provided with taps connected to the switch-type volume control, S25, to change the step-down voltage ratio of T2 and thus control the volume of the incoming signal.

During the standby periods the plate current of V2 is cut off completely and the plate current of the output tubes, V3 and V4, is reduced to a very low value. This reduction in plate current is accomplished by the voltage drop across R12 connected between the center tap of the high-voltage winding of T3 and ground. This voltage increases the bias on V3 and V4. The d-c voltage on the filter capacitors C7, C8, and C9 is substantially the same during standby periods (no load) and during periods of speech (load) because R12 changes the rectifier circuit from capacitor-input (with load) to resistor-input on no load. The reduced voltage with capacitor input on load is approximately the same as with resistor input on no load. Resistor, R12, is in series with C9 during standby periods.

This type of cut-off circuit eliminates voltage surges on the capacitors when switching from standby to ready conditions and also eliminates the delay caused by charging of the capacitors. To ready the amplifier for outgoing speech, R12 is shorted by operating the loudspeaker, LS1, talk switch, S26 (terminals 7 and 8); by pressing the pushbutton in the auxiliary handset or microphone (terminals C and D on J6); or by operating an external switch connected to terminals S5 and GND.

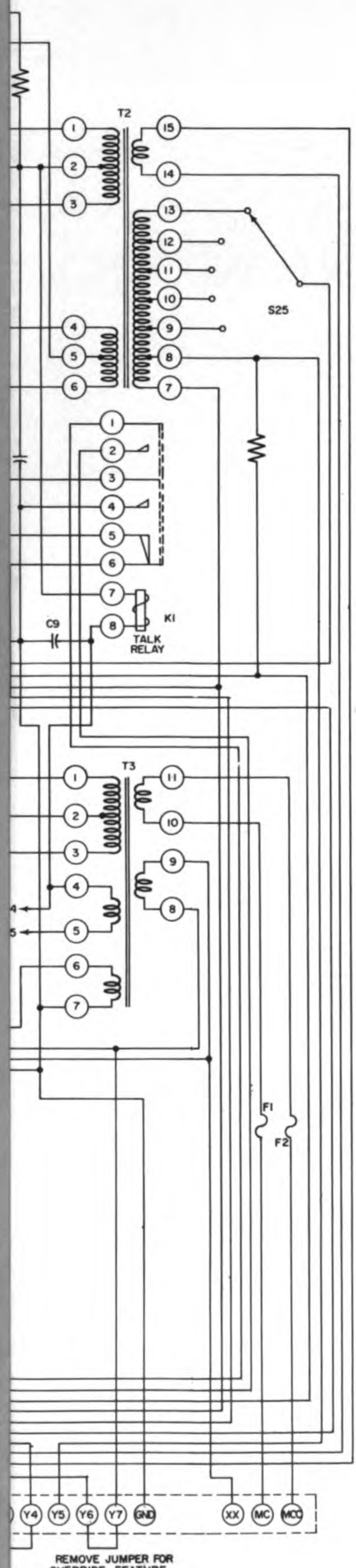
The upper end of resistor, R11, is connected from the junction of R8 and R9 to ground (R12 being shorted during ready periods). Any unbalance in the audio voltages reaching the grids

Digitized by Google



Digitized by Google

communicating unit.



Digitized by Google

of V3 and V4 will develop a voltage across R11. The upper end of resistor, R11, is also connected to terminal 5 of the feedback winding on T2. Terminal 6 of this winding is connected to the V2A grid via R4 and terminal 4 is connected to the V2B grid via R5. The unbalanced voltage developed across R11 will be fed back to the grids of V2A and V2B through R4 and R5 respectively in the proper phase to correct the unbalanced condition. The cathode circuit of V2A and V2B is returned to ground through contacts 3-4 of the talk relay, K1.

Negative feedback is incorporated in the design of the amplifier to lower the apparent output impedance and to develop a 70-volt output (within 3 db) when the amplifier is delivering 10 watts to any combination of from one to four other intercommunicating units. The feedback is developed by the separate winding on the combination output-line transformer, T2 (terminals 4, 5, and 6). The voltage is fed back symmetrically to the grids of V2 through R4 and R5.

OPERATION

To call a particular station, depress the station selector switch of the desired station (S2 through S11), depress the talk switch, S26, and speak directly into the grille. Release the talk switch, S26, to listen. When the conversation is completed, depress the release pushbutton, S1, to return the selector pushbutton to the nonoperated position.

To accept a call from another station, listen to the incoming call through the loudspeaker. Do not operate any of the station selector pushbutton switches. Depress the talk switch, S26, to reply to the incoming call. The call light is illuminated to indicate the station is being called by another station. If the call light remains illuminated after the conversation is completed, remind the calling station to depress his release pushbutton.

The audio circuit between two stations is illustrated by the simplified schematic diagram in figure 8-19. The talk switches at both stations are shown in the normal (listen) position.

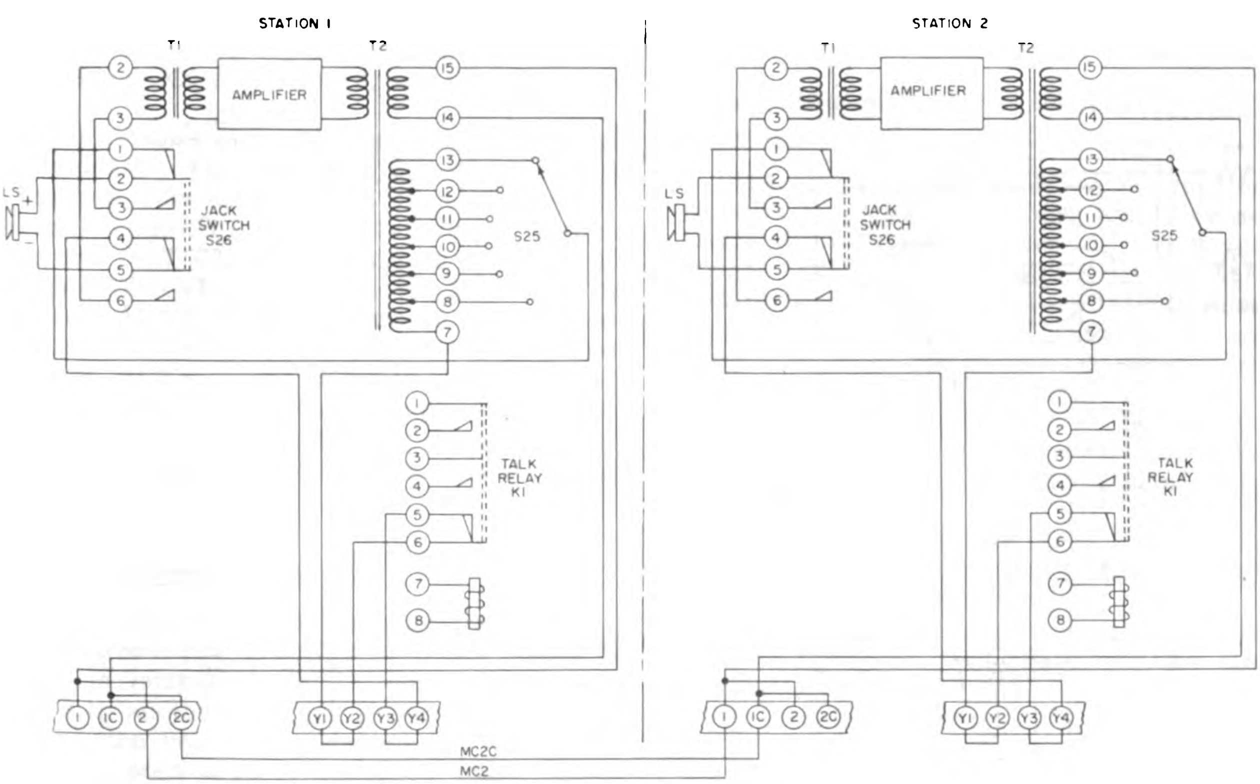


Figure 8-19.—Schematic diagram of audio lines between two stations.

7.27

Digitized by Google

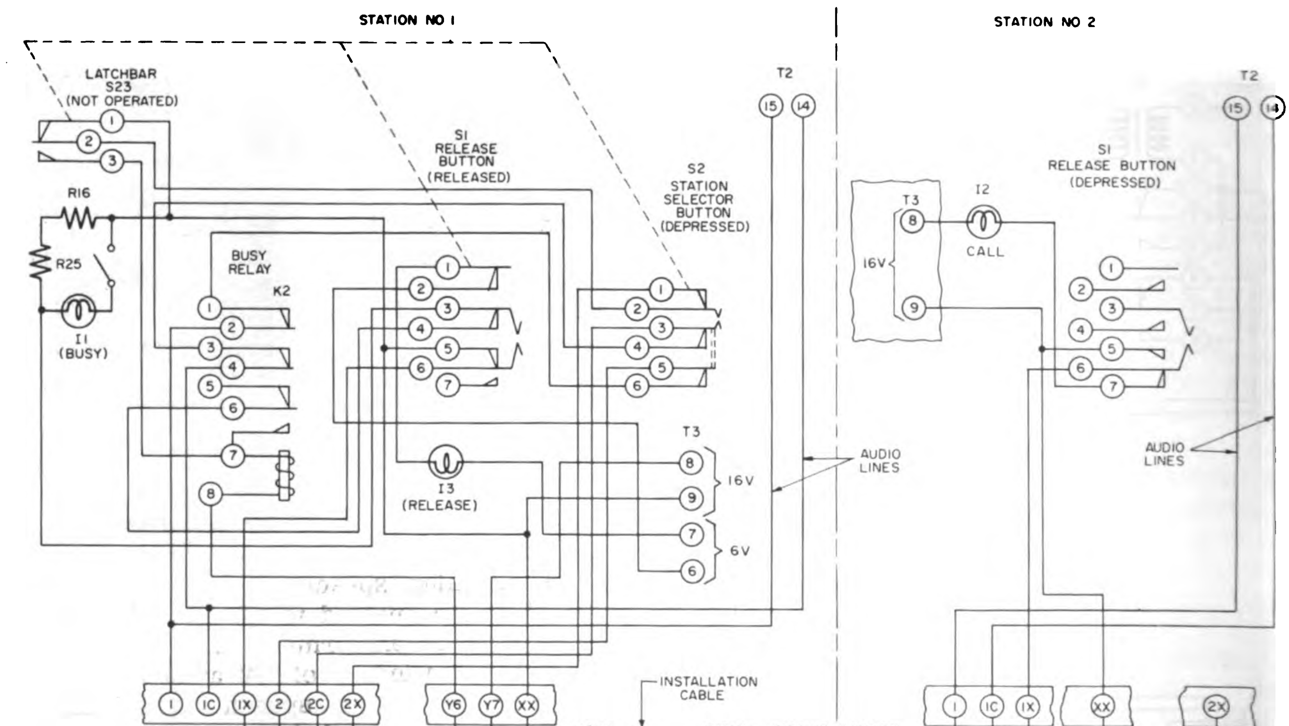
When the talk switch, S26, at either station is depressed, the voice coil leads of the loudspeaker are shifted from terminals 7 and 13 of the secondary of T2 to the input transformer, T1, of the associated amplifier. At the same time contacts 7-8 of S26 (fig. 8-18), are closed to short resistor, R12, to ground, thereby decreasing the bias on V3 and V4. This action increases the V3 and V4 plate current through the operating coil terminals 7-8 of relay, K1. The increase in plate current operates relay, K1, to close contacts 3-4 and complete the circuit from the V2 cathodes through R6 to ground. This action applies plate voltage to V2 and the amplifier at the talking station is placed in the ready condition.

The voice signals are amplified and applied to terminals 14 and 15 of T2 at the listening station and appear across terminal 7 of T2 and the moving contact of the volume control, S25, and then to the loudspeaker.

The amplifier of the listening station is in a standby condition. In the standby condition the plate current of V2 (fig. 8-18) is completely cut off, and that of V3 and V4 is reduced to a very low value by the voltage drop across R12, which is in the negative high-voltage center tap 2 of T3 to ground.

Station 1 Calling Idle Station 2

The signaling circuits between two stations are illustrated by the simplified schematic diagram in figure 8-20. Terminal 9 of the 16-volt winding of the power transformer, T3, in both stations is connected through terminal XX to the signal circuit common MCXX, which is connected in parallel with all XX terminals throughout the system. Terminal 8 of T3 at station 1 is connected to terminal 8 of the busy relay, K2. When the station selector pushbutton switch, S2, is depressed to call (idle) station 2, the release pushbutton, S1, will be released as soon



7.28

Figure 8-20.—Schematic diagram of signaling circuits between two stations.

Digitized by Google

as S2 is depressed. The latchbar switch, S23, will operate to momentarily connect terminal 7 of the busy relay, K2, to the signal line, MC2X. The circuit is from terminal 7 of busy relay K2, contacts 3-2 of S23, contacts 2-1 of S2, to terminal 2X, and to line MC2X. If station 2 is idle, line MC2X will be connected to terminal 8 of T3 at station 2. The circuit is from line MC2X to terminal 1X of station 2, contacts 6-7 of S1, through call lamp I2, and to terminal 8 of T3.

During the time that latchbar switch, S23, is momentarily operated, terminal 7 of busy relay, K2, at station 1, is connected to terminal 8 of T3 at station 2 through call lamp I2. Terminal 8 of K2 at station 1 is connected to terminal 8 of T3 at the same station. Terminal 8 of T3 at station 1 is at the same potential as terminal 8 of T3 at station 2 and K2 does not operate.

As soon as latchbar, S23, releases, terminal 7 of busy relay, K2, is open circuited and the connections of both the audio (heavy) lines and the signal (light) lines between the two stations are established. The call lamp, I2, is lighted at station 2. The signal circuit is from terminal 8 of T3 to I2, contacts 7-6 of S1, to terminal IX, over signal line MC2X to terminal 2X of station 1, contacts 1-2 of S2, contacts 2-1 of S23, to terminal XX, over signal common line MCXX, to terminal XX of station 2, and to terminal 9 of T3.

The release lamp, I3, at station 1 is lighted (S1 released when S2 was depressed). The circuit is from terminal 7 of T3 at station 1, to release lamp I3, contacts 1-2 of S1, and to terminal 6 of T3. Line MCIX is connected to line MCXX. The circuit is over line MC1X to terminal 1X of station 1, contacts 6-5 of S1, to terminal XX of station 1, and to signal line common MCXX. Line MC2X is also connected to line MCXX. The circuit is from terminal 2X of station 1, contacts 1-2 of S3, contacts 2-1 of S23, to terminal XX of station 1, and to line MCXX.

Station 1 Calling Busy Station 2

When the station selector pushbutton switch, S2, is depressed at station 1 to call station 2, which is busy (line MC2X connected to line MCXX by another parallel connected station not shown), the release pushbutton, S1, will be released as soon as S2 is depressed. The latchbar switch, S23, will momentarily operate to energize the busy relay, K2. The circuit is from terminal 8 of T3, terminals Y7-Y6 of station 1, terminals 8-7 of busy relay K2, contacts 3-2 of S23, contacts 2-1 of S2, to terminal 2X, over signal line MC2X to terminal 1X of station 2, contacts 6-5 of S1 (released), terminal XX of station 2, over signal common MCXX, terminal XX of station 1, and to terminal 9 of T3.

The busy relay, K2, will lock in the operated position after latchbar switch, S23, opens. The circuit is from terminal 8 of T3, terminals Y7-Y6, terminal 8 and contacts 7-6 of busy relay K2, contacts 4-3 of S1, to the busy lamp I1, and to terminal 9 of T3. The busy lamp, I1, is now in series with the coil of busy relay, K2, and will be lighted. The audio lines from terminals 14 and 15 of T2 to line MC2 and line MC2C will be open at contacts 3-4 and 1-2, respectively, of busy relay, K2, which is operated.

The normal connection of the audio line from terminal 14 of T2 (station 1) is through contacts 4-3 of busy relay, K2 (released), contacts 4-3 of S2 (depressed), to terminal 2C, and to line MC2C. The normal connection of the audio line from terminal 15 of T2 is through contacts 2-1 of busy relay, K2 (released), contacts 6-5 of S2 (depressed), to terminal 2, and to line MC2.

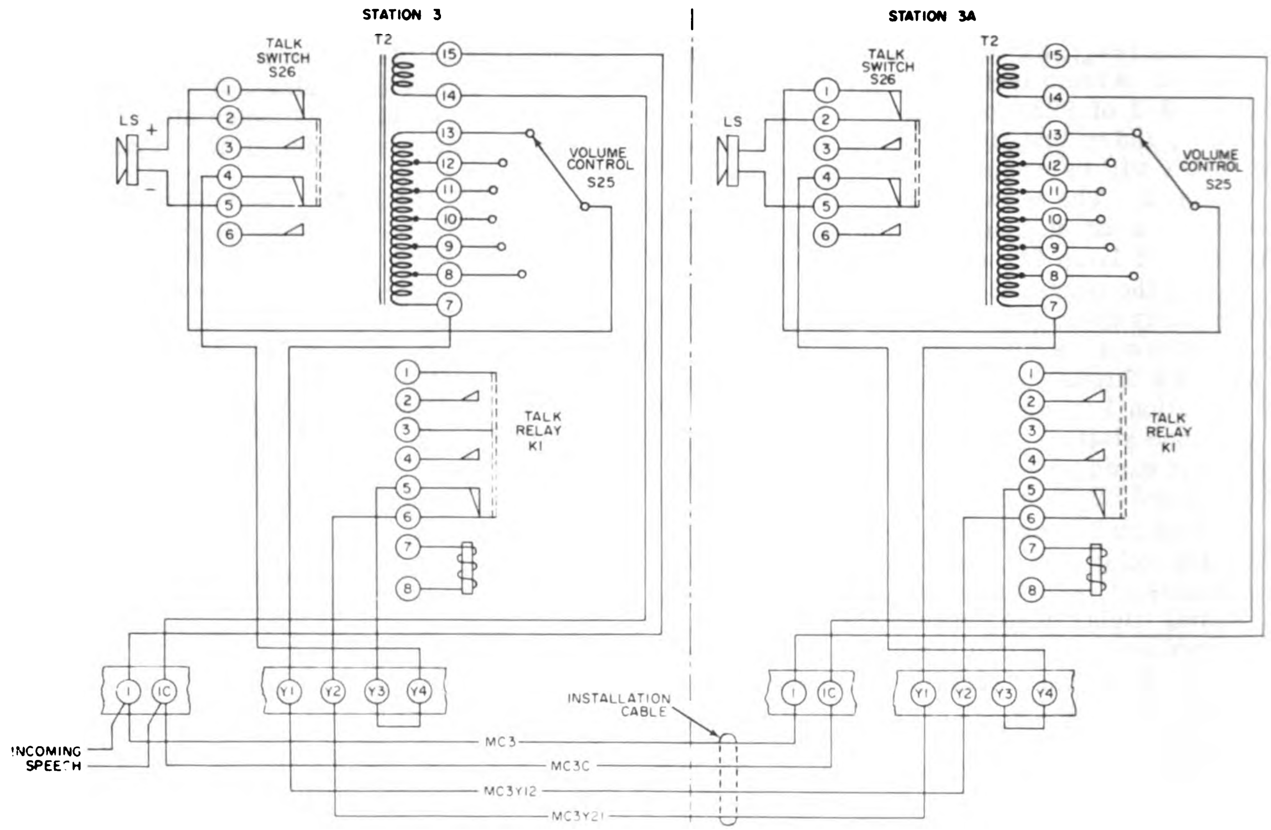
Parallel Operation of Two Adjacent Stations

The operation of two intercom stations in parallel is illustrated by the simplified schematic diagram in figure 8-21. The incoming speech from a remote station will be heard at both stations 3 and 3A, and replies can be made from either station. Either station can call a third station but both stations cannot call at the same time. When the talk switch, S26, at station 3 is depressed to transmit a message, the talk relay, K1, at station 3A, is operated to open the circuit to the loudspeaker and prevent acoustic feedback (not shown).

The incoming speech lines, 1 and 1C, of station 3 are connected to terminal 15 and 14 respectively on transformer, T2.

The 14-15 winding of T2 at both stations couples the incoming speech to the tapped windings of T2 which include the volume controls, S25. Thus the incoming signals appear across terminals 7 of T2 and the moving contact of the volume control, S25, at both stations. These signal sources are connected in series addition through a closed loop containing both loudspeakers.

Digitized by Google



7.29

Figure 8-21.—Schematic diagram of two stations in parallel.

The circuit is from the arm of S25 at station 3, contacts 1-2 of S26, the loudspeaker, contacts 4-5 of S26, terminals Y4 and Y3, contacts 5-6 of K1, terminal Y2 over line MC3Y21 to terminal Y1 of station 3A, terminal 7 of T2, the arm of S25, contacts 1-2 of S26, the loudspeaker, contacts 4-5 of S26, to terminals Y4-Y3, contacts 5-6 of K1, terminal Y2, over line MC3Y12, terminal Y1 in station 3, to complete the circuit at terminal 7 of T2.

The volume at both stations will be the same and can be controlled by either volume control, S25. Both volume controls, however, should be kept at the same setting.

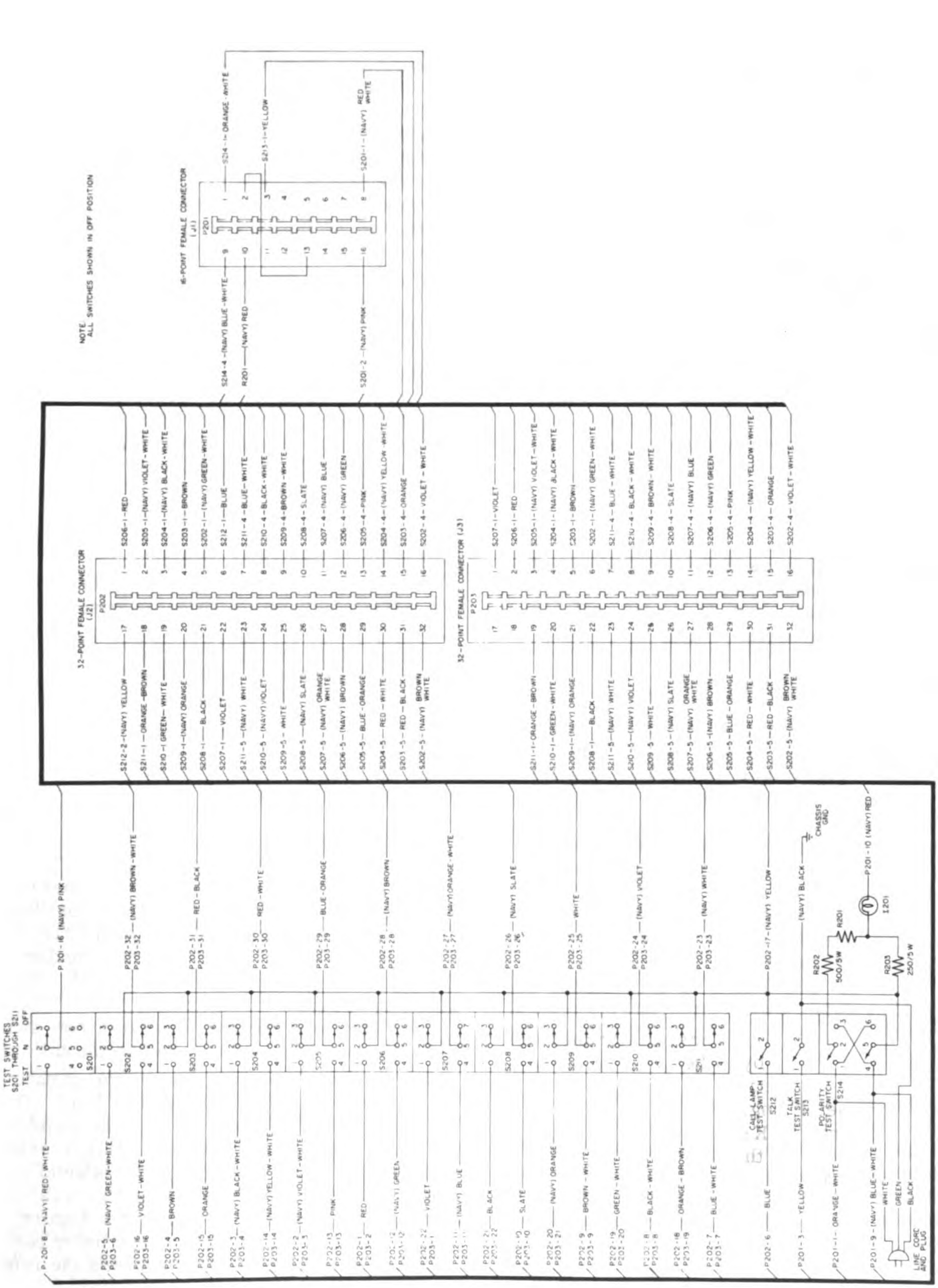
If the talk relay, K1, is operated at either station, the input to the audio circuit will be open for both stations.

MAINTENANCE

A test fixture is provided with the maintenance parts of the equipment to facilitate testing the intercom units. The test fixture is housed in a metal case and includes the necessary switches, resistors, and controls to perform all essential tests on a unit. It is provided with a line cord and plug for connection to the ship's 115-volt 60-cycle power supply, and suitable female connectors for attaching it to the rear of the unit under test. The front cover contains 11 DPDT test switches, S201 through S211, a SPST call lamp test switch, S212, a SPST talk test switch, S213, a DPDT polarity test switch, S214, and an indicator lamp, I201 (fig. 8-22).

To use the test fixture, remove the intercom unit to be tested from its case and attach the test fixture to the rear of the unit by plugging it into the unit and connecting the line cord and plug to the ship's 115-volt 60-cycle power. On the test fixture, operate the talk switch, S213, to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test, depress the release

Digitized by Google



7.30

Figure 8-22.—Wiring diagram of test fixture.

pushbutton, S1, turn the volume control, S25, and dimmer control, S27, to the extreme clockwise positions, and connect a microphone or handset into the microphone jack, J6 (fig. 8-18).

Polarity Test

To test the polarity of the unit, operate the polarity test switch, S214 (fig. 8-22), to the OK WHEN LIT position (not shown). The indicator lamp, I210, should light with full intensity if the polarity is correct. Now operate the polarity test switch, S214, to the REVERSED position (not shown). The indicator lamp should go out if the polarity is not correct. The lamp may glow faintly but it is not important. The polarity test checks the polarity of the line and signal voltage windings (terminals 10-11 and 8-9 respectively) of the power transformer, T3 (fig. 8-18).

Call Lamp Test

To test the call lamp of the unit, operate the call lamp test switch, S212, on the test fixture (fig. 8-22). The call lamp, I2, on the unit under test should be lighted (fig. 8-18).

Amplifier and Reproducer Test

To test the amplifier and reproducer, depress the (microphone) talk switch and talk into the microphone. The talker should hear his voice clearly through the reproducer. Rotate the volume control knob, S25, on the unit under test while talking into the microphone, and observe the effect on the output volume. Now place the microphone close to the reproducer. A microphonic feedback should be observed when the volume control is in the full-volume position as well as at one step below full volume. This test provides a rough indication of the amplifier gain, power output, and the general performance of the entire unit, except for the signaling circuits.

Station Selector Circuit Test

On the test fixture (fig. 8-22), operate the talk test switch, S213, to the TALK position with the microphone reasonably close to the reproducer to produce a microphonic howl. Reduce the volume control the the minimum position at which the howl can still be obtained by moving the microphone as close to the reproducer as required. This position will produce the minimum objectionable howl during the subsequent station selector circuit tests.

On the test fixture, operate the test switch, S210, to the TEST position which should stop the microphonic howl. Then restore S210 to the STANDBY position. This test checks the circuit from terminals 1 and 1C, through the busy relay, K2, (not operated) to the line winding terminals 14 and 15 of the output transformer, T2 (fig. 8-18.) When test switch, S201, is in the TEST position, it places a short circuit across terminals 1 and 1C to interrupt the microphonic howl.

On the unit under test, depress the station selector pushbutton, S2 (adjacent to release pushbutton S1). On the test fixture operate the test switch, S202, to the TEST position which should interrupt the microphonic howl. Then restore S202 to the STANDBY position and depress the release pushbutton, S1, on the unit under test. This test checks the continuity between terminals 2 and 2C (fig. 8-18), through switch S2U and busy relay K2 to the line winding terminals 14 and 15 of transformer T2.

Similarly, on the unit under test, depress the remaining station selector pushbuttons S3 through S11, using the corresponding test switches, S203 through S211, on the test fixture for each test. This test checks the continuity of the various audio circuits. If the unit under test is provided with facilities for originating calls to 20 stations, repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

Signal Circuit Test

On the test fixture (fig. 8-22), operate the talk test switch, S213, to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test, depress the release pushbutton, S1, for the subsequent signal circuit tests.

On the test fixture, operate test switch, S202, to the TEST position and on the unit under test, depress the station selector pushbutton, S2. The busy lamp, I1, should light. On the unit under test, depress the release pushbutton, S1, and again depress the station selector switch, S2. The busy lamp, I1, should go out and again light. Repeat this test several times in rapid succession. On the test fixture, restore test switch, S201, to the standby position and on the unit under test, depress the release pushbutton, S1.

Digitized by Google

When the test switch, S202, on the test fixture is operated to the TEST position, it makes station 2 busy by connecting terminal 2X to terminal XX (fig. 8-18). When the station selector pushbutton, S2, on the unit under test is depressed to select station 2, it checks the busy circuit through the lower switch assembly, S2L, busy relay, K2, latchbar switch, S23, and associated wiring. It also checks the operation of the upper switch assembly, S2U, and associated wiring.

On the test fixture, operate the test switch, S203, to the TEST position and on the unit under test, depress the station selector pushbutton, S3. The busy lamp I1 should light. Restore the test switch, S203, to the STANDBY position and depress the release pushbutton, S1. This test checks the operation of the busy relay, K2, the lower switch assembly, S3L, the latchbar switch, S23, and associated wiring. It also checks the operation of the upper switch section, S3U, and associated wiring.

Test the remaining pushbuttons by operating first the test switches, S204 through S211, to the TEST position on the test fixture and then depressing the corresponding station selector pushbuttons S4 through S11, on the unit under test. If the unit under test is a 20-station type repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

The manufacturer's technical manual furnished with the equipment installed in your ship contains more detailed information concerning the operation, repair, and maintenance of intercommunicating units.

SOUND-POWERED TELEPHONE AMPLIFIER SYSTEM

The sound-powered telephone amplifier provides a method of amplifying one-way communication (incoming speech) in a two-way sound-powered telephone communication system. The equipment is designed to amplify voice signals so that the reproduced message will be clear and understandable at locations aboard ship where the noise level is high (gun positions or machinery spaces). When the amplifier is turned off, the system functions normally for two-way communication at the sound-powered level.

A sound-powered telephone amplifier circuit consists of an amplifier, one to six sound-powered telephone headsets, and one or two loudspeakers. A sound-powered telephone amplifier system consists of one or more sound-powered telephone amplifier circuits connected to the ship's soundpowered telephone lines and to the ship's 115-volt 60-cycle power supply (fig. 8-23). For simplicity, only one headset and one loudspeaker are shown in each amplifier circuit. Each amplifier supplies voice signals to the local headsets and loudspeakers at the associated machinery spaces.

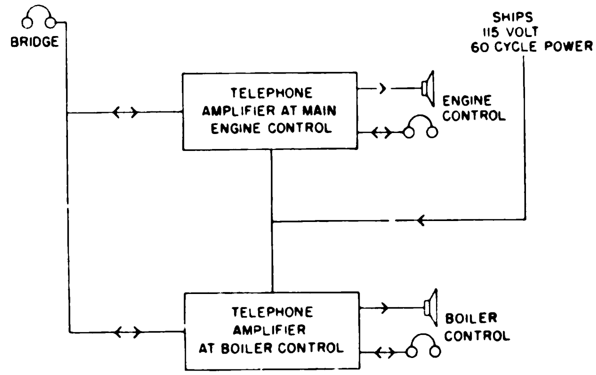


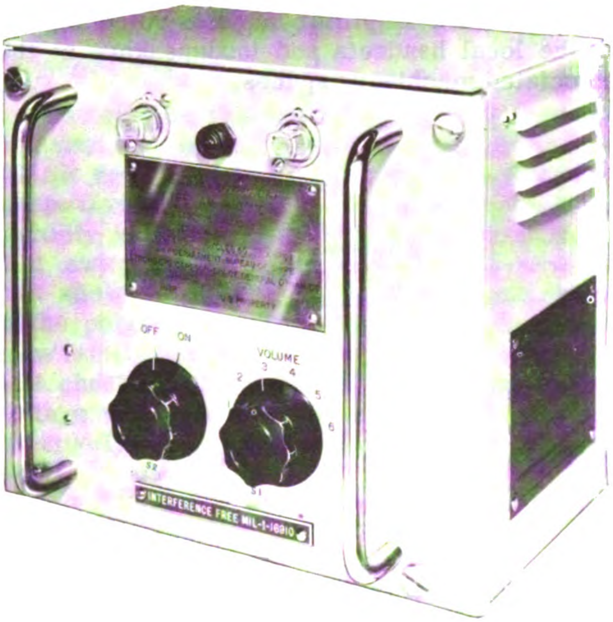
Figure 8-23.—Block diagram of sound-powered telephone amplifier system.

TELEPHONE AMPLIFIER

The telephone amplifier (fig. 8-24) consists of a metal enclosure designed for bulkhead mounting and a plug-in panel chassis assembly. The panel chassis assembly contains all the electrical components of the amplifier and is provided with a male receptacle. The case is provided with a female receptacle which is connected through two terminal boards to the ship's wiring. The plug-in feature completes all electrical connections between the panel chassis assembly and cabinet wiring. The front panel of the chassis assembly contains the on-off switch S2, the volume control S1, a pilot lamp, and two blown-fuse indicators.

A schematic diagram of the telephone amplifier is illustrated in figure 8-25. The amplifier is a three-stage resistance-capacitance coupled unit. The signal received from the sound-powered telephone line (terminals 1-2) is applied to the primary of the input transformer T1 via contacts 3 and 6 of S2 wafer 1. The secondary of T1 is connected via the volume control S1 to the grid of section V1A operating as a voltage amplifier. Section V1B is a phase inverter. The filter choke L1 in the cathode circuit of the voltage amplifier stage V1A compensates for

Digitized by Google



7.32

Figure 8-24.—Sound-powered telephone amplifier.

the sharp-peak response characteristics of sound-powered telephone transmitters.

The outputs of V1A and V1B drive V2 and V3 respectively, operating as a push-pull voltage amplifier. The outputs of V2 and V3 drive V4 and V5 respectively, as a push-pull power amplifier. The output of the power stage is applied to the primary of the output transformer T3, the secondary of which is connected to the local headsets and loudspeakers.

The parallel-connected full-wave rectifiers V6 and V7 supply d-c potentials for the plates and grids of all amplifier tubes. The pulsating d-c output of the rectifiers is filtered by the capacitor-resistor network consisting of C9B, R30, and C9A.

The sound output level of the amplifier to both the local headsets and loudspeakers is controlled by the volume control S1, comprising resistors R1 through R6 as a voltage divider between T1 and V1A. An additional gain control mounted on each loudspeaker may be used to control the loudspeaker volume. The volume of the headsets is determined by the connections to the output transformer T3.

OPERATION

The methods of operating the soundpowered telephone amplifier system depend on the position of the on-off power switch S2, and the availability of the ship's 115-volt 60-cycle power at the amplifier (fig. 8-25).

When the on-off power switch S2 is in the OFF position, (shown in figs. 8-25 and 8-26) soundpowered telephones are connected directly to the telephone line and the system functions as a two-way communication circuit between the local sound-powered telephone stations and the remote station at the sound-powered telephone level.

When it is desired to amplify the incoming speech at the local stations (fig. 8-27), operate the on-off power switch S2 to the ON position. A-c power is applied to the amplifier through wafer 2 of switch S2 (not shown); the telephone line input is connected to the 1-2 winding of transformer T1, through contacts 1-3 and 4-6 of switch S2 wafer 1; the local telephones are connected to the 1-2 winding of the isolation transformer T2, through contacts 7-9 and 10-12 of switch S2; and relay K1, which is energized when a-c power is applied to the amplifier, operates to connect the output transformer T3 to the 3-4 winding of the isolation transformer T2. Thus the incoming signals on the telephone line are amplified and reproduced by the headsets and loudspeakers connected to T3.

When it is desired to transmit speech over the local headset (fig. 8-28) operate the talk switch (not shown) on the transmitter. The local loudspeaker will be cut off, and speech goes out to the other local headsets and over the sound-powered telephone line at the sound-powered telephone level.

If the power switch S2 is in the ON position when the transmitter talk switch is operated at the local headset, a-c power is applied to the amplifier through wafer 2 of switch S2. Relay K2 is energized when the local telephone talk switch is operated to complete the circuit between terminal V and N, P, R, S, T, or U of plug P1 (fig. 8-25), depending on which telephone talk switch is operated. The talk switch completes a circuit between the low impedance transmitter (not shown) and the two telephone lines. This action effectively places K2 across R35 to operate the relay with a portion of the

Digitized by Google

7.33

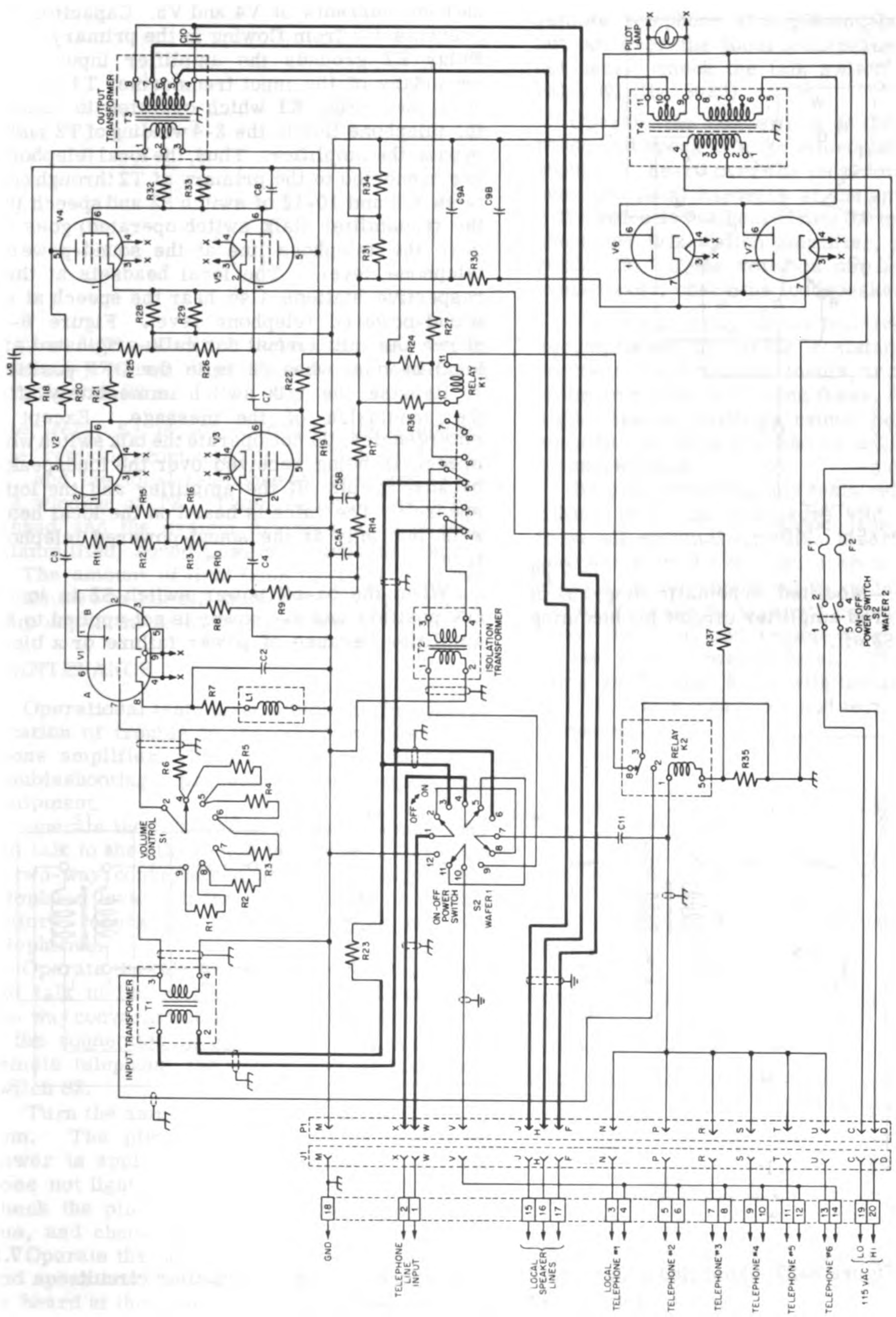
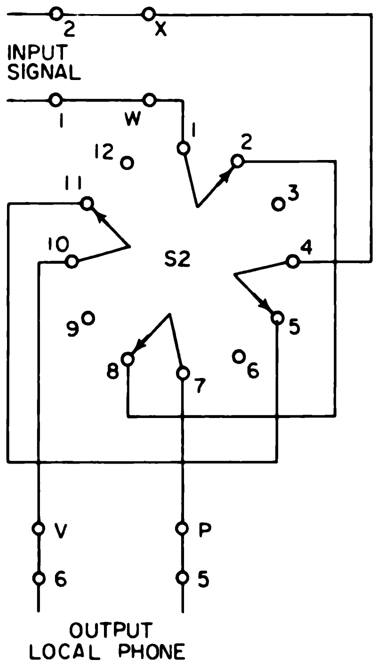


Figure 8-25.—Schematic diagram of sound-powered telephone amplifier.

Digitized by Google



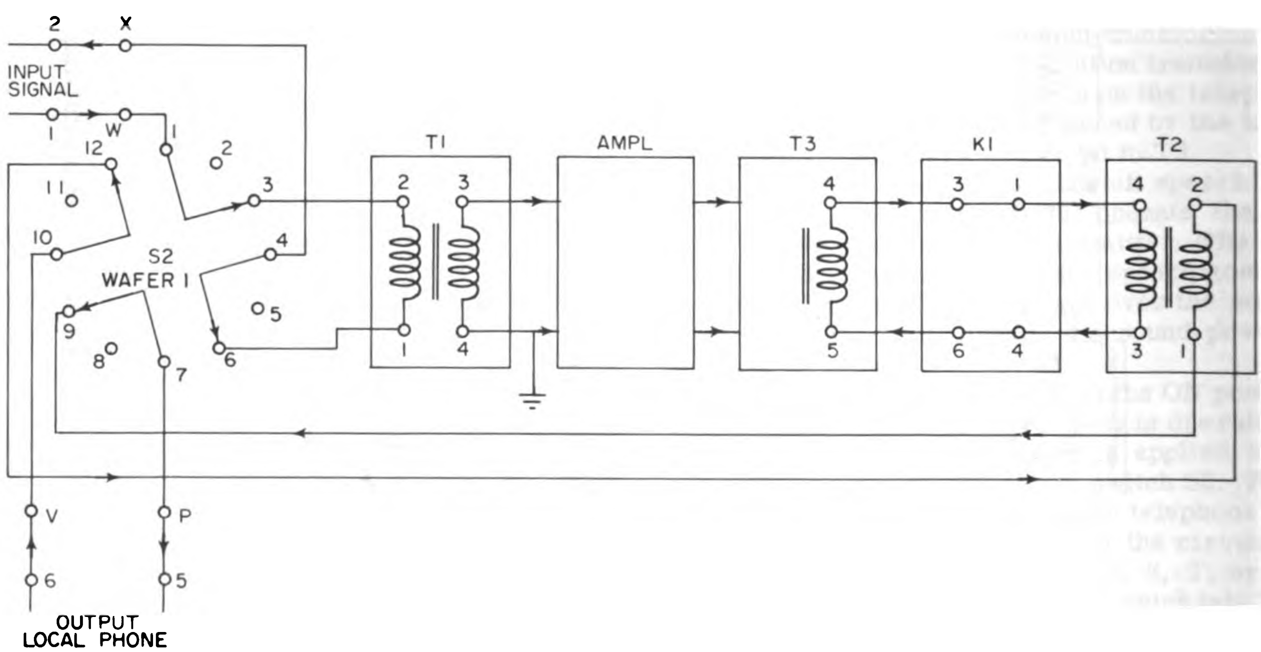
7.34

Figure 8-26.—Modified schematic diagram of sound-powered amplifier circuit for incoming calls with S2 off.

cathode currents of V4 and V5. Capacitor C11 prevents d-c from flowing in the primary of T2. Relay K2 grounds the amplifier input at the secondary of the input transformer T1 and de-energizes relay K1 which operates to connect the telephone line to the 3-4 winding of T2 and to bypass the amplifier. Thus, the local telephones are connected to the primary of T2 through contacts 7-9 and 10-12 of switch S2 and speech into the transmitter (talk switch operated) goes out over the telephone line at the sound-powered telephone level. The local headsets at their respective stations also hear the speech at the sound-powered telephone level. Figure 8-29 shows the talk circuit for calls originated at a local headset when S2 is in the OFF position.

Release the talk switch immediately after the conclusion of the message. Except in emergencies, do not operate the talk switch when speech is being received over the loudspeaker because it cuts off the amplifier and the loudspeaker. The voice is heard on the local headsets but only at the sound-powered telephone level.

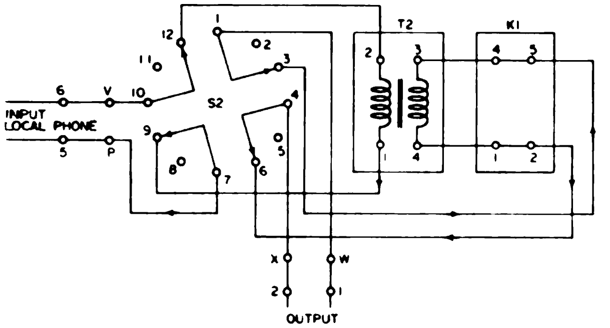
When the on-off power switch S2 is in the ON position and a-c power is not applied to the amplifier because of power failure or a blown



7.35

Figure 8-27.—Modified schematic diagram of sound-powered amplifier circuit for incoming calls with S2 on.

Digitized by Google



7.36

Figure 8-28.—Modified schematic diagram of sound-powered amplifier circuit for outgoing calls with S2 on.

fuse, relay K1 is not energized, the telephone line remains connected to the 3-4 winding of T2, and the local telephone is connected to the 1-2 winding of T2. Thus, the amplifier is bypassed and the system functions as a normal (unamplified) sound-powered telephone circuit.

The amount of light from the pilot lamp can be dimmed or cut off completeby by rotating the lamp cap in the lockwise direction.

MAINTENANCE

Operational tests usually indicate the general location of trouble in the sound-powered telephone amplifier. Before attempting amplifier troubleshooting procedures deenergize the equipment.

Operate the talk switch at the local telephone and talk to the other local telephones. Carry on a two-way conversation at the sound-powered telephone level. If the connection is not satisfactory, check the telephone wiring and the telephones.

Operate the talk switch at the local telephone and talk to the remote telephone. Carry on a two way conversation at the sound-powered level. If the connection is not satisfactory, check the remote telephone, the wiring, and the amplifier switch S2.

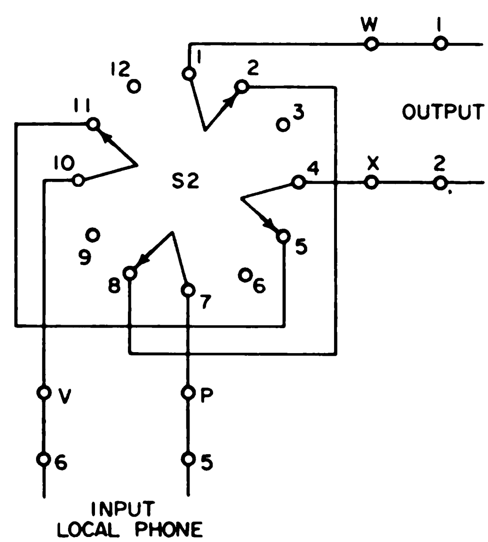
Turn the amplifier switch S2 to the ON position. The pilot lamp lights to indicate when power is applied to the amplifier. If the lamp does not light, check the blown-fuse indicators, check the pilot lamp by replacing it with a new one, and check the a-c power to the amplifier.

Operate the talk switch at the local telephone and speak into the microphone. The voice should be heard at the other local telephones and at the remote telephone at the sound-powered level, but not over the local loudspeaker. If voice is not heard, check the talk switch, relay K2 and relay K1 (fig. 8-25).

Operate the talk switch at the remote telephone and speak into the microphone. The voice should be heard over the local loudspeaker and over the local headsets at the amplifier level. If the voice is not heard from the local headsets, check the talk switch amplifier, relay K1, and relay K2. If the voice is not heard from the loudspeaker, check the loudspeaker.

Troubleshooting on an inactive amplifier is accomplished by taking resistance measurements, voltage measurements, or signal tracing. If the amplifier is blowing fuses, the voltage and signal tracing methods cannot be used and the amplifier must be checked by making resistance measurements.

Before conducting any tests remove the amplifier from the enclosure and disconnect it from all external circuits. Insert a plug in the receptacle in the enclosure while the amplifier chassis is not connected to, or inserted in, the enclosure case to maintain communication between the local and remote telephone stations at the sound-powered level. The plug is the same as P1 (fig. 8-25) with terminals N, P, R, S, T, U, and X connected and terminals W and V connected.



7.37

Figure 8-29.—Modified schematic diagram of sound-powered amplifier circuit for outgoing calls with S2 off.

Digitized by Google

Signal Tracing

Signal tracing helps to localize troubles to a particular stage of the amplifier. An externally generated signal from an audio oscillator is applied to the input of the amplifier and the signal voltage is measured at the grid and plate of each tube.

An audio oscillator capable of delivering a 1,000 cps signal at 12 millivolts and an a-c voltmeter section of a VTVM capable of reading 12 millivolts to 155 volts are required. Connect the 115-volt 60-cycle power to terminals C and D of the input connector J1 (fig. 8-25), with the amplifier removed from the enclosure. Apply the 1,000 cps signal at 12 millivolts to terminals X and W of the input connector. Operate the on-off power switch S2 to the ON position and turn the volume control S1, clockwise to position 6. Allow about one minute for the tubes to reach operating temperature. Using the a-c voltmeter with the low side of the meter connected to the amplifier chassis, compare the readings obtained at the grid and plate of each tube with those listed in the technical manual. Normal operation is indicated if the readings agree within 10 percent. Start with tube V1A and check each stage in order. If the measured voltage is low, use further isolating techniques to determine the defective part within the stage.

Component Tests

Check the tubes that are suspected of being weak or otherwise defective with a tube tester. A tube that is defective because of internally shorted electrodes may affect the operation to the extent that voltage and resistance readings will be abnormal. The absence of filament glow in a tube indicates an open filament.

RESISTORS that are defective can be detected in several ways. A resistor that has been overloaded with often become discolored and give off noticeable odors. Ohmmeter readings across a resistor (with the power off) will indicate a resistor that is open or if its value has changed. When checking the values of resistors with an ohmmeter, determine if other components directly associated in the circuit will affect the readings. In some cases it may be desirable to disconnect one end of the resistor when making resistance checks.

With the power on, voltage readings can be compared with those listed in the technical manual. Overloaded resistors are often caused by defective capacitors. Check the capacitors in the circuit before restoring power to the amplifier.

CAPACITORS that are short-circuited are indicated by a zero ohmmeter reading. An ohmmeter reading of infinity will be obtained on a paper capacitor if the capacitor is good, or if it has a broken internal lead. A lower value will be obtained on an electrolytic capacitor which leaks. Temporarily replace a paper capacitor that gives an ohmmeter reading of infinity and that is suspected of being defective with one that is known to be good and note the effects on the voltage checks and operation. If the trouble is corrected after the replacement, the capacitor is defective and should be permanently replaced.

When testing the electrolytic capacitor C9 (removed from its socket) set the ohmmeter to a medium range and connect it to the capacitor with the correct polarity (common to negative and positive to positive). A deflection will occur on the meter and the pointer will return slowly toward the infinite-ohms position as the capacitor takes a charge. Usually, some reading is obtained even when the electrolytic capacitor is fully charged. If C9 is good, the final ohmmeter reading will be over 500,000 ohms for each section (C9A and C9B).

PUBLIC ADDRESS SETS

Public address sets are used at Fleet Landings and in amphibious operations to direct the movement of personnel, vehicles, and small boats; to communicate between ships and small boats; and to address personnel aboard ship where high noise levels are present or where the installed announcing is inoperative. They are also used for entertainment, and such functions as church services, wardroom and ready room briefings, change-of-command and other ceremonies, and personnel training. The two types of public address sets are the electronic megaphone type, and the lectern type.

PUBLIC ADDRESS SET AN/PIC-2

The AN/PIC-2 is an electronic megaphone type public address set designed to perform

Digitized by Google

under extremes of temperature and high humidity. The driver unit, microphone, amplifier enclosure, and battery enclosure are watertight. The set consists of a loudspeaker horn, a microphone, a transistor amplifier assembly, a driver unit, 8 size "D" batteries, and a pistol-grip handle with a press-to-talk switch, battery selector switch, and external battery connector. All components are housed in one assembly, (fig. 8-30). A 15-foot external power cable is provided for connecting the set to an external 12 volt battery when desired.

To operate the set, put the battery selector switch to the INT. position (or to the EXT. position if operation is to be from external battery). Grasp the pistol-grip handle with one hand and raise the unit so that the rubber microphone is almost touching the mouth, and direct the horn in the direction it is desired to communicate. Press the press-to-talk switch and speak directly into the microphone in a strong voice. Release the press-to-talk switch when the message is completed. The set is specially designed to eliminate acoustic

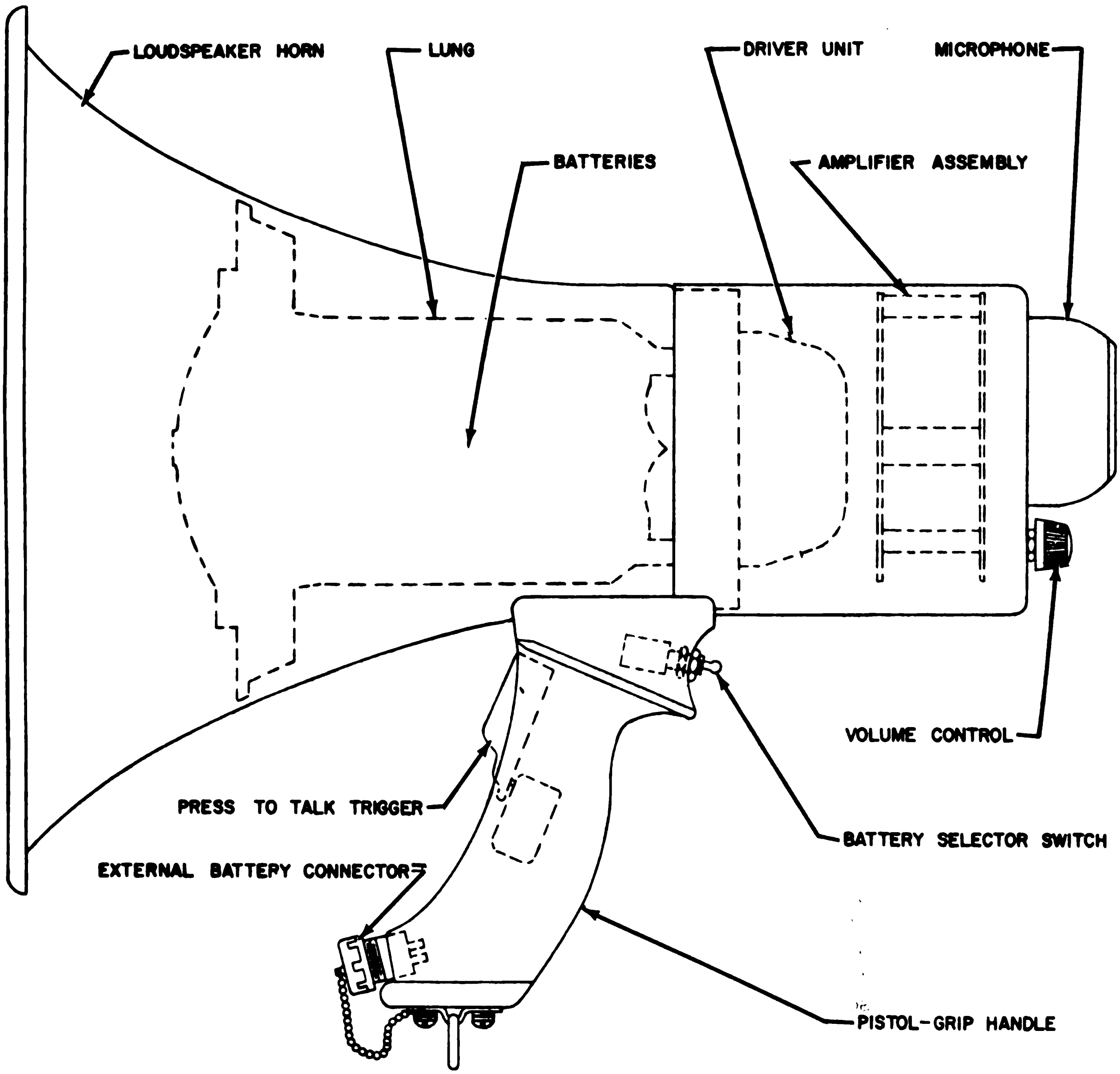


Figure 8-30.—Public address set AN/PIC-2. 27.295

Digitized by Google

feedback to the extent possible. Acoustic feedback may occur however, if the horn is directed toward a reflecting surface such as a deck or bulkhead. When using the set below decks, back the volume control knob off until feedback stops, then advance it gradually to a point where maximum volume without feedback is obtained.

Amplifier Circuits

The transistor amplifier is a three stage transformer coupled type, (fig. 8-31). It consists of a volume control, R1, input transistor, Q1, interstage transformer, T1, driver transistor, Q2, driver transformer, T2, push-pull power transistors Q3 and Q4, and an output inductor L1.

Transistors Q1 and Q2 are biased for class A operation, and Q3 and Q4 operate in class AB. The output stage bias network includes thermistor assembly RT1, to temperature stabilize transistors Q3 and Q4 at high operating temperatures. For further stabilization, each stage includes an emitter resistor. The driver and output stages each have reverse feedback from collectors to bases, the feedback resistor in each case being also part of the d-c bias network. In addition, reverse feedback over two stages is provided through C3 and R8, from the collector of Q3 to the base of Q2.

The base circuits of the output stage normally have a small negative d-c bias applied through the bias network resistors, adjusted so that the no-signal collector current of this stage is small. Temperature rise in the transistors tends to increase this current. To prevent this current increase, the thermistor resistance decreases with increasing temperature, thus reducing the negative bias and keeping the no-signal collector current small.

D-C Power Circuits

The 12 volt d-c supply is selected from either the internal or external batteries by the battery selector switch S2. The press-to-talk switch S1 supplies d-c power to the amplifier only while the switch is held closed.

The current drain is very small when S1 is closed and no signal is applied to the microphone. The current is maximum when the loudest signal is being amplified, as the collector current of the output stage varies with the strength of the amplified signal.

Microphone and Loudspeaker Assemblies

The MK1 magnetic microphone has an impedance of approximately 150 ohms. The microphone output is applied to transistor Q1 through the volume control R1, and capacitor C1. A selected portion of the sound radiated to the rear by the loudspeaker horn acts on the back of the microphone diaphragm. This sound is phased so as to reduce acoustic feedback.

Loudspeaker LS1 is a moving coil permanent magnet type. Amplifier output signals actuate the voice coil and diaphragm, and the resulting sound waves are amplified and directed by the loudspeaker horn.

Maintenance

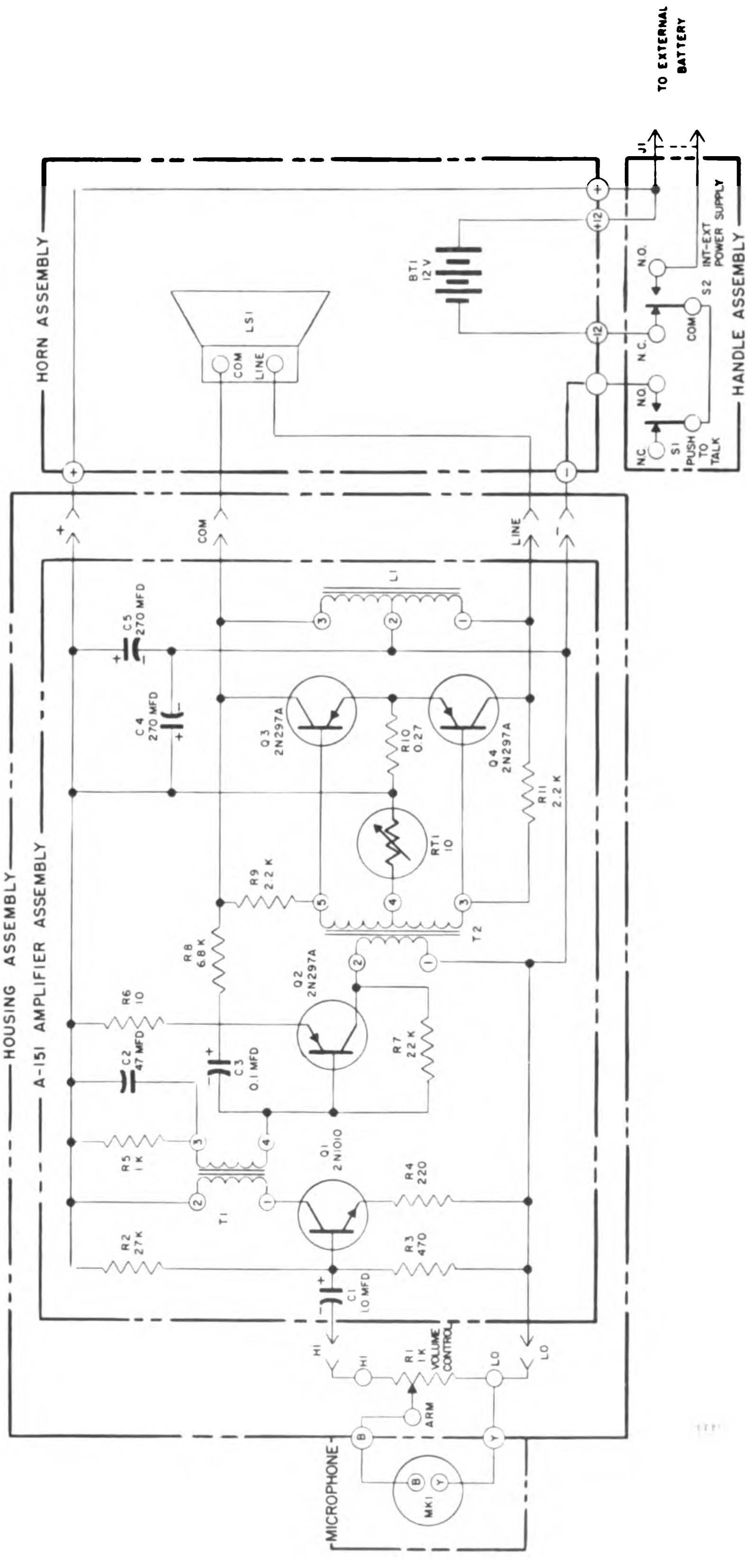
Preventive maintenance consists of replacing batteries, and routine cleaning and inspections. When the batteries are replaced, inspect the battery contact springs and clean if necessary. If the springs are badly corroded they should be replaced. Keep the external power cable free of dirt and corrosion. Clean the spring clips with sandpaper and apply a thin coat of petrolatum to reduce corrosion. Inspector the connector and clean if necessary.

Periodically check the microphone housing. Keep the opening to the microphone free of dust, dirt, oil, grease, salt crystals or other foreign matter. Salt crystals left by the evaporation of salt water and spray should be dissolved and rinsed away with fresh water, then the parts dried with a soft cloth.

Check the inside of the pistol-grip handle occasionally. Remove the handle cover and inspect the switch contacts. Clean if necessary.

The manufacturer's technical manual contains detailed instructions for troubleshooting and repair of the set. All components are designed for easy replacement.

Digitized by Google



140.48

Figure 8-31.—Public address set AN/PIC-2, schematic diagram.

Digitized by Google

27.296X
Figure 8-32.—Public address set, lectern type.

PUBLIC ADDRESS SET, LECTERN TYPE

Modern Navy ships are provided with the lectern type public address set. This set (fig. 8-32), is a portable self-contained unit capable of reproducing sound for entertainment or dissemination of information. The set consists of an illuminated reading counter with a removable unidirectional dynamic microphone, a transistorized amplifier and controls, an extended range loudspeaker, a battery meter, and jacks for microphones, record player, tape recorder, and two external speakers. Power to operate the set is provided either by the self-contained dry battery, or an external 115 VAC supply.

Some ships, not provided with the lectern type public address set, utilize an audio amplifier, and one or more speakers as separate units.

As an IC Electrician, you may be assigned the responsibility for setting up and checking out public address sets. To allow time for any minor adjustments or repairs that may be required, always check the set or system out well in advance of the time it is to be used.

Digitized by Google

CHAPTER 9

DIAL TELEPHONE SYSTEM

The dial telephone system, circuit J, is primarily an administrative circuit that provides complete selective telephone communication throughout the ship. This system is also used to supplement other communication facilities for ship control, fire control, and damage control. The capacity of the system varies with the size and needs of the particular ship.

A telephone system consists of a group of telephones with lines so arranged at a central point that any two telephones in the system can be interconnected. In an automatic telephone system, the connections between the telephones are completed by remotely controlled switching mechanisms. In a manual telephone system, the connections between the telephones are completed by a switchboard operator.

The switching mechanisms in an automatic system are controlled at the calling telephone by a device, or dial on the telephone instrument. The dial has 10 digits, any one of which can be dialed. When the dial is operated it causes a series of interruptions, or impulses, in a current flowing in the line circuit. The number of impulses sent out by the dial corresponds to the digit dialed. These impulses cause the automatic switches to operate and to select the called telephone.

The dial telephone system (fig. 9-1) consists of: (1) telephone station equipment, (2) automatic switchboard equipment, (3) power equipment, and (4) accessory equipment.

TELEPHONE STATION EQUIPMENT

The telephone station equipment consists of various types of telephones for mounting in both protected and exposed locations. Telephones installed in locations where the noise level is so high that the telephone ringer may not be heard are provided with extension signals. An extension signal is a motor-operated horn that is controlled by a power signal relay. The power signal relay operates on ringing current to close a 115-volt ship's power circuit to the extension signal.

AUTOMATIC SWITCHBOARD EQUIPMENT

The automatic switchboard is the switching center of the dial telephone system. It includes the switching mechanisms necessary for setting up automatically the connection between any two telephones and certain miscellaneous equipment used in common by all switches.

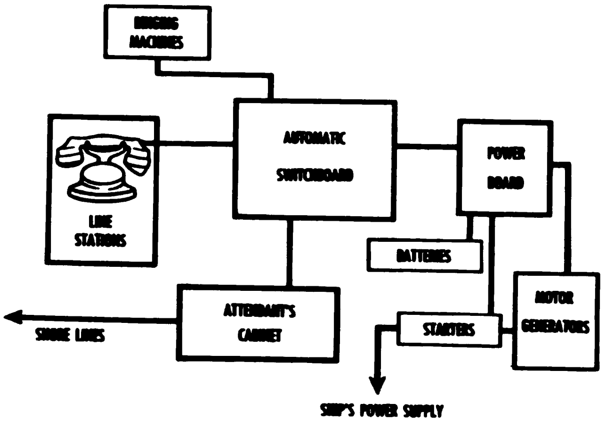
The miscellaneous equipment includes the ringing machines, or signals, testing equipment, and control circuits for the switching mechanisms, start and stop circuits for the ringing machines, line disconnect keys, fuses, and so forth.

The switchboard proper mounts all telephone switching mechanisms, control circuits, line disconnect keys, part of the testing equipment, and most of the supervisory alarm signals. The ringing machines and the common alarm signals are usually mounted externally. The switching mechanisms and miscellaneous equipment automatically locate a telephone station desiring to make a call, supply dial tone, extend the calling station to the called station in response to impulses from the dial, ring the called station, supply ringback tone or busy-tone as required, and disconnect the calling and called stations at the completion of the conversation.

POWER EQUIPMENT

The power equipment includes the power control panel, motor-generator set or rectifier, and storage battery. The motor-generator set, or rectifier, and the storage battery are connected in parallel and supply approximately

Digitized by Google



7.76

Figure 9-1.—Block diagram of dial telephone system.

51.6-volt d-c power to operate the automatic switchboard equipment, including the ringing machines. The power to operate the motor-generator set, or rectifier is obtained from the ship's 440-volt 60-cycle 3-phase power via the nearest IC switchboard. A reserve supply of energy is maintained in the storage battery so that the telephone system will continue in operation should the ship's power supply fail.

ACCESSORY EQUIPMENT

The accessory equipment (furnished in some ships) includes an attendant's cabinet which is a small manual switchboard. The attendant's cabinet is used to establish calls to and from shore exchanges when the ship is in port, and between ships when they are nested.

PRINCIPLES OF DIAL TELEPHONE SYSTEM

Numerous methods of switching have been devised, however, the most extensively used switching equipment for shipboard installations is the Strowger automatic type. It is the type that is described here.

SWITCHING MECHANISMS

The switch mechanisms and the associated circuits are the mechanical operators that perform all of the functions required of a telephone switchboard. The major types of switches used in the shipboard dial telephone system are the linefinder, selector, and connector; all of which are Strowger switches.

The Strowger switch is an electromechanical device that extends the connection from the calling to the called telephone. It consists of a bank of electrical contacts arranged in 10 levels with 10 sets of contacts to a level. The wipers, which make contact with the selected set of contacts are connected to the switch shaft. The switch mechanism elevates the shaft (and wipers) any number of steps from 1 to 10, and then rotates the shaft (and wipers) any number of steps from 1 to 10. When the shaft is released, it rotates backwards under the influence of a spring and then returns to normal under the pull of gravity. The Strowger switch, because of the up and around movement, is referred to as a two-motion or step-by-step switch. It is the basic switch of the step-by-step system, and with a few mechanical and electrical variations, is used as a linefinder, selector, and connector.

The LINEFINDER finds the line of the telephone station seeking to make a call and extends the line to the selector for all systems in excess of 100 lines. The line-finder mechanism is controlled by the finder control relays. The impulses to step the mechanism up and around are furnished by interrupter springs on the vertical and rotary magnets. The finder switch is referred to as a NONNUMERICAL type of Strowger switch, because its operation is automatic and not under the control of dial impulses. The linefinder switch is not entire within itself like the connector, but depends on its associated line-and-cutoff relays, group control relays, and distributor relays.

The LINE-AND-CUTOFF RELAY is a relay individual to the line with which it is associated (in contrast to the switch circuits which serve many lines and the control circuits which serve many switches). For example, when a call is initiated by a telephone, the line-and-cutoff relay functions to: (1) apply ground (positive side of the battery) to start the linefinder control relays to actuate a linefinder switch to hunt for the calling line; (2) mark a contact in the bank of a linefinder by placing battery (negative voltage) on the contact so that when the linefinder wiper encounters battery the linefinder will know it has located the line it is trying to find.

The SELECTOR extends the line of the calling telephone to the connector. The vertical

Digitized by Google

stepping of the selector is controlled by the first digit dialed at the calling telephone, and the rotary stepping is controlled by interrupter springs on the rotary magnet.

The CONNECTOR extends the line of the calling telephone to the line of the called telephone. The impulses transmitted from the dial of the calling telephone actuate the connector mechanism to step the wipers up and around to the set of contacts associated with the called telephone station. A connector switch is referred to as a NUMERICAL type of Strowger switch because it operates under the control of dial impulses.

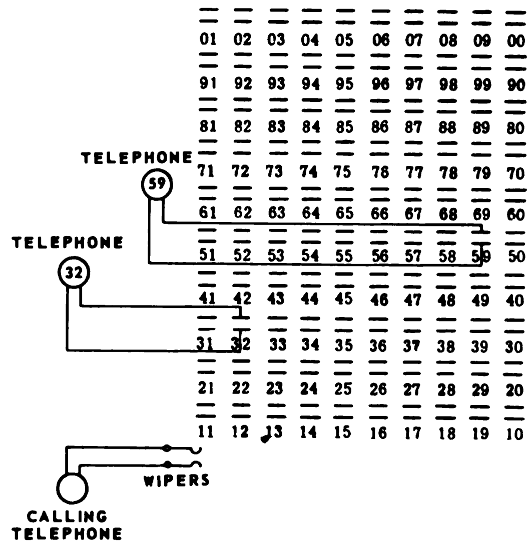
STATION NUMBERING

Each telephone in the 100-line system is assigned a 3-digit number. The first digit dialed causes a minor switch to rotate in steps. The number of rotary steps of the minor switch determines the side of the line on which ringing current will be impressed. The arrangement of the switching facilities is such that the first digit of the telephone number for the first party or a positive ring of a 2-party line may be any number expect 9. The first number of the negative ring party of this line will be 9.

The second and third digits of the telephone number always correspond to the line number. If the last two digits of the telephone number are 12, for example, the set of contacts in the connector bank associated with the telephone station is the second pair on the first level in the control and line banks. Thus, when the second and third digits of the telephone are dialed, the connector switch is actuated to step the wipers up and around to the set of contacts associated with the called telephone station.

The line bank as its name implies, furnishes facilities for the line-circuit connections. One line bank furnishes facilities for 100 line connections (+ and -) and is called a 100-point bank. The 100-point line bank contains 100 sets of contacts. The control bank, as its name implies, furnishes facilities for control circuit connections (C and EC). The control bank contains 200 contacts.

The arrangement of the 100 sets of contacts that comprise the standard Strowger bank is illustrated in figure 9-2. The contacts are arranged in 10 horizontal levels with 10 sets of contacts to a level. Each set of contacts is designated by a 2-digit number which represents the number of vertical and rotary steps necessary to reach the particular set of contacts. In



7.77

Figure 9-2.—Numbering plan of connector bank.

other words, the first digit represents the number of vertical steps and the second digit represents the number of rotary steps. Number 32, for example, is 3 steps up and 2 steps in. Note that the second digit of the called number represents the level, and the third digit represents a particular set of contacts on that level.

Numbers beginning with 1 are in the first level, numbers beginning with 2 are in the second level, and so on. This arrangement causes the digit 0 to be used to represent 10 steps so that the tenth or top level is indicated by zero and the tenth pair of contacts in each level is indicated by zero. Groups of 10 lines are referred to as lines 11-10, 21-20, 31-30, and so forth. Likewise, lines 11-50 mean a group of 50 lines. The first 10 lines consist of 11-10, and the last 10 lines consist of 51-50.

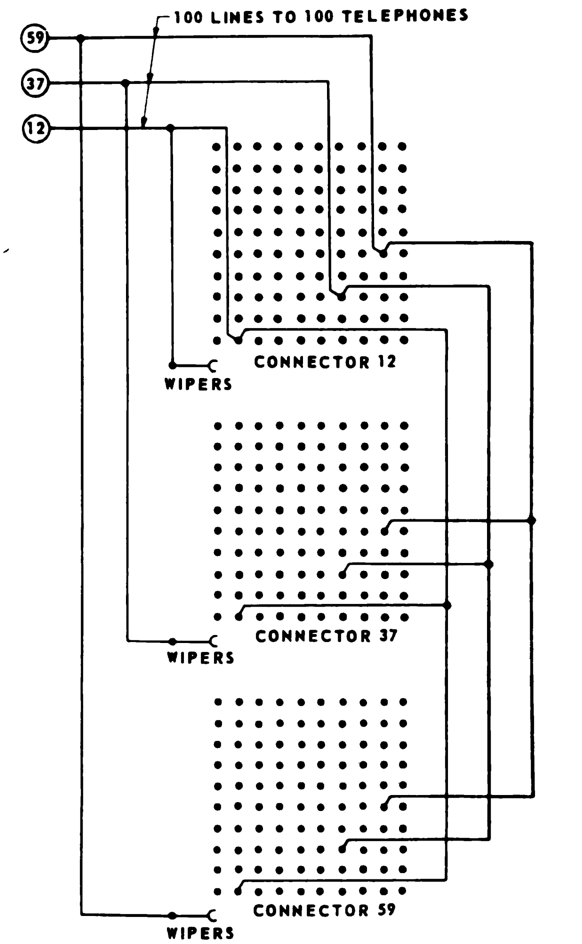
BASIC 100-LINE CONNECTOR SYSTEM

In actual practice, the switching equipment must be arranged so that any telephone in the system can connect with any other telephone in the system. This is accomplished by arranging the switches in interconnected groups. To connect Strowger switches in groups, the banks of the switches are interconnected by connecting the respective sets of contacts in each of the banks. Switches connected in this manner are

Digitized by Google

said to be multipled and the connection is usually referred to as the bank-multiple, as illustrated in figure 9-3. For simplicity, only three of the switches in this multiple are shown with an individual connector switch for each of the three telephone lines, which means that the line of each telephone is connected directly and permanently to the wipers of the connector switch assigned to that telephone. The three blocks of dots represent the banks of the three connector switches, and each dot represents a pair of contacts.

Note that each 12 set of contacts is connected to the 12 set of contacts in each of the other banks, the 37 set of contacts is connected to the 37 set of contacts in each of the other banks, and so forth. Each of the three telephones is connected not only to the wipers of its own connector, but also to a set of contacts in the bank of each of the other connectors. Telephone 12, for example, is connected to the wipers of connector 12, and telephone 12 also has an appearance in the bank of each connector, that is—it is multipled to the 12 set of contacts in each of the connector banks. Likewise, telephone 37 is connected to the wipers of connector 37 and is also multiplied to the 37 set of contacts in each of the connector banks. This multiple arrangement of the connector banks permits any telephone to call any other telephone in the system. For example, if telephone 12 calls telephone 37, telephone 12 dials the digits 3 and 7. When 3 is dialed, the wipers of connector 12 are elevated to the third level and when 7 is dialed, the wipers are rotated across to the seventh set of contacts on the third level. The connection is from this line of telephone 12 through the 37 set of contacts to the line of telephone 37.



7.78

Figure 9-3.—Basic 100-line connector system.

LINEFINDING PRINCIPLE

The 100-line connector system in figure 9-3 requires an individual connector switch for each line in the system. Because the connector is a relatively expensive switch, this system is not economical since the average telephone is used only a short time each day and the associated connector would remain idle the remainder of the time.

The linefinding principle permits a large group of lines to be served by a smaller number of switches which are common to all lines in the group. A linefinder switch and a connector switch permanently connected to each other constitute a line finder-connector link. The line-finding principle is illustrated by the single finder-connector link, and the 100-point finder bank with the associated 100-point connector bank in figure 9-4. Note that the finder wipers and connector wipers are through relays connected to each other. The banks of the linefinder switch furnish facilities for line connections for 100 telephone stations, and therefore all lines are accessible to the linefinder wipers. Because the linefinder wipers are connected through relays to the wipers of the associated connector, when the linefinder finds the calling line, the calling line is thereby extended to the wipers of a connector. Thus, a connector may become associated with any line in the system.

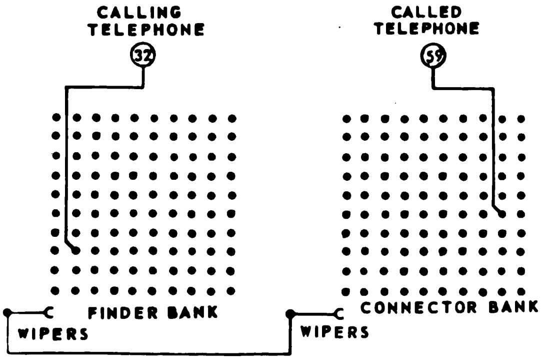
Digitized by Google

If telephone 32 desires to call telephone 59, elephone 32 removes its handset from the :radle switch. This action closes a circuit to he line-and-cut off relay (not shown) associated vith telephone 32. The relay marks the calling ine in the linefinder control bank and starts he group relays (not shown) which actuate the inefinder to search for the calling line. The inefinder steps its wipers up to the third level ınd in to the second set of contacts, and thus elephone 32 is extended through relays to the vipers of the connector. When this connection is nade, the connector will send dial tone to the :alling telephone 32 and as digits 5 and 9 are lialed, the connector wipers will step up 5 steps ınd around 9 steps to complete the connection be- ween telephone 32 and 59.

3ASIC 100-LINEFINDER CONNECTOR ;YSTEM

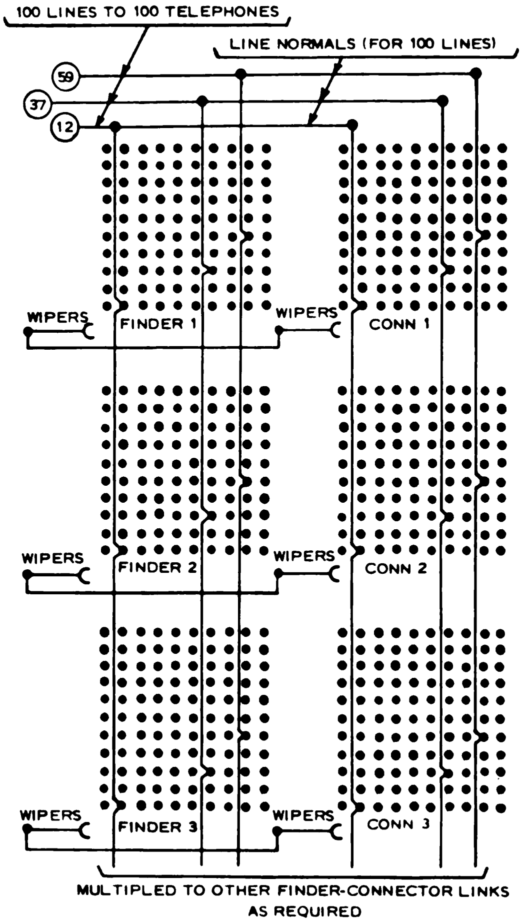
Each of the lines in the system, described vith reference to figure 9-4, has an appearance n the banks of both the linefinder and the con- ıector and thus connection is possible between ıny two telephones in the system. However, a elephone system with only one finder-connector ink would be impractical because one finder ınd one connector are required to complete a :onnection between the calling and called tele-)hones and therefore telephone service would)e limited to one call at a time.

To make several simultaneous conversa- ions, 15 finder-connector links are furnished or a 100-line system (fig. 9-5). For simplicity only 3 of the 15 finder-connector links and 3 of he 100 lines in the system are shown. Note



7.79

Figure 9-4.—Principle of linefinding.



7.80

Figure 9-5.—Basic 100-line finder-connector system.

that the banks of the finders are multipled and that the banks of the connectors are also multi- pled. The lines 12, 37, and 59 are typical of the other lines in the system. For example, the line of telephone 12 has a point of connection in the bank of each linefinder and each connector. In other words, this line is described as having an appearance in the banks of the finders and the connectors. The conductors from the connector line bank to the line of telephone 12 at the finder line bank are called LINE NORMALS.

Each pair of linefinder line wipers (fig. 9-5) is connected to a pair of connector line wipers. The wipers of the linefinder "look backward" ready to find any line desiring to make a call and the wipers of the connector "look forward" ready to connect to the dialed line. Each finder and connector that are tied together constitute

Digitized by Google

a finder-connector link. Only as many simultaneous conversations can take place as there are finder-connector links because one finder-connector link is busied for the duration of the conversation.

All of the 100 lines in the system have an appearance in the linefinder multiple and also in the connector multiple. Therefore, any idle finder can step its wipers up and around to locate any one of the 100 lines that originates a call and the associated connector can step its wipers up and around, under control of dial impulses from the calling telephone, to complete a connection to any one of the 100 telephones in the system.

To call telephone 59 from telephone 37, remove the handset from the cradle switch at telephone 37. An idle finder such as finder 1, steps up 3 levels and rotates to contacts 37. The connection is now extended through to the connector associated with the finder (in this case connector 1), and dial tone is received at the calling telephone 37. When the digits 5 and 9 are dialed, the wipers of the connector switch step up to the fifth level and rotate in to contacts 59. The connection is now completed from telephone 37, through finder-connector link 1, and back over the line normals of line 59 to telephone 59. The connector switch now tests telephone 59, and if it is not in use, ringing current is sent out over the line to operate the ringer of telephone 59. If telephone 59 is found to be in use, a busy signal is returned to the calling telephone 37. In figure 9-6 the finder and connector banks are each represented by 10 horizontal lines and the switch mechanisms are represented by the rectangles above the banks. The group of finders in the multiple is controlled by a group of control relays and a distributor (which is also a relay group). One line-and-cut-off relay is associated with each line, whereas one finder control and distributor equipment is common to 50 lines.

The distributor preselects the finder which is to search for the next calling line. When the line-and-cut-off relay associated with the calling line marks the calling line in the linefinder bank multiple and starts the control relays which control the finder, the finder automatically steps its wipers up and around until it finds the calling line. With the linefinder wipers resting on the set of contacts associated with the calling line, the calling line is extended through relays, to the connector wipers.

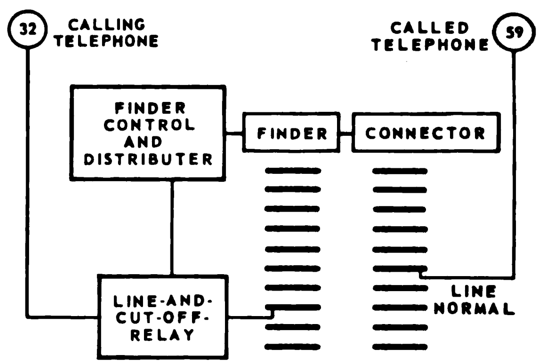
To call telephone 59 from telephone 32, remove the handset from the cradle switch at telephone 32. Line-and-cut-off relay 32 operates and marks the position of line 32 in the finder banks and also sends a START SIGNAL to the finder control. The start signal causes the finder control to start a preselected idle finder searching for the calling line. When the finder finds the calling line, the line-and-cut-off relay 32, which is a two-step relay, now operates the remainder of its contact springs to cut off its own winding from the line. The finder cuts through (extends the connection through to the connector switch) and the control relays release to normal in preparation for actuating the next finder.

At this point line 32 is made busy at the connector banks to guard against intrusion from any incoming call. Also, the connector switch sends dial tone to the calling party to indicate that the connector circuit is ready to receive the dialed impulses and the call proceeds as previously explained.

Only one linefinder is shown in figure 9-6. In practice the 15 linefinders furnished for the 100-line system are arranged in two groups designated A and B with each group equipped with its own finder control and distributor equipment. Group A consists of linefinders 1 through 8 and group B consists of linefinders 9 through 15.

BASIC SELECTOR SYSTEM

The system described in figure 9-7 has a capacity of 400 lines. The mechanical structure of the selector is similar to a linefinder and connector. It has the same familiar bank, wipers, and mechanism to step the wipers up and in. The



7.81

Figure 9-6.—Block diagram of 100-line finder-connector system.

Digitized by Google

selector faces forward toward the called line as does the connector. A linefinder and a selector permanently connected through relays to each other constitute a linefinder-selector link.

The 400-line shipboard dial telephone system is divided into four boards of 100 lines each. Each board is served by a group of connectors the banks of which are in multiple with each connector having access to all the lines in its board. The purpose of the selector is to choose the proper group of connectors and then hunt for an idle connector in that group. The group selection, or the vertical stepping of the selector, is controlled by the dial at the calling telephone. The rotary motion, or the trunk-hunting action, is controlled by the rotary interrupter springs of the selector.

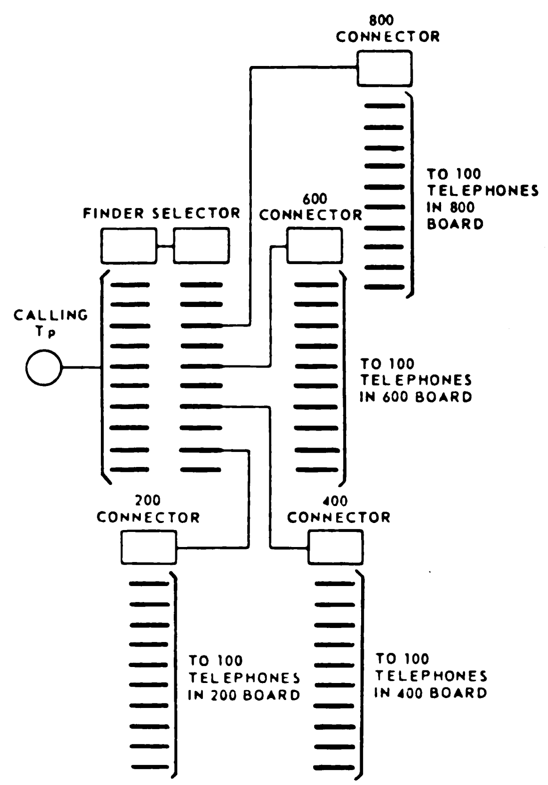
The banks of the selector switch furnish facilities for a maximum of 100 trunk connections. In the 400-line system, only 90 connections are used on any one selector bank. In other words, only 9 of the 10 levels are used because the first level of all selectors are busied out. Because the linefinder wipers are connected through relays to the wipers of the associated selector, when the linefinder finds the calling line, the calling line is thereby extended to the wipers of a selector. Thus, a selector may become associated with any line in a particular board.

For simplicity, only one link and only one connector in each of the four boards are shown in figure 9-7. After the finder switches the calling line through to the selector, the first digit dialed by the calling party steps the selector up to a certain level. The selector then steps around automatically until it finds a nonbusy contact. This contact leads to an idle connector from which the connection to the called line is made by the next two dialed digits.

The banks of the finders are multipled, and all the lines in the 200 board, for example, have an appearance in the banks of the finders in the 200 board. The selector banks are also multipled, but instead of telephone lines being connected to the multiple, a certain number of individual connectors in each board are connected in multiple. The connectors, in turn, have their banks multipled, and the conductors from the connector banks are connected to individual telephone lines, called line normals.

Each pair of linefinder line wipers is connected to a pair of selector line wipers. The wipers of the linefinder "look backward" ready to find any line in a particular board desiring to make a call and the wipers of the selector "look forward" ready to connect to the dialed group of connectors. The wipers of the connectors also "look forward" ready to connect to the dialed line. Because the linefinder link is busied for the duration of the conversation, only as many simultaneous conversations can take place as there are finder-selector links.

All the lines in the 200 board, for example, have an appearance in the linefinder multiple so that any idle finder in the 200 board can step its wipers up and around to locate any one of 100 lines which desires to make a call. Likewise the finder's associated selector can step its wipers up and around to complete a connection to any one of 40 connectors. One of the connectors will then step its wipers up and around (under control of dial impulses from the calling telephone) to complete a connection to any one of the 100 lines in its board. In each board there are 15 linefinders permanently connected to 15 selectors. In each board there are also



7.82

Figure 9-7.—Block diagram of basic selector system.

Digitized by Google

15 connectors and these connectors are available to selectors in any board. In the complete system there are 60 linefinders, 60 selectors, and 60 connectors, which makes possible a maximum of 60 simultaneous conversations.

To call telephone 659 from telephone 432, remove the handset from the cradle switch at telephone 432. The line-and-cut-off relay 432 associated with the calling line marks the calling line in the linefinder bank multiple and starts the group relays which control the finder, the finder automatically steps its wipers up and around until it finds the calling line. With the linefinder wipers resting on the set of contacts associated with the calling line, the calling line 432 is extended through relays to the selector wipers. The selector sends dial tone to the calling parts to indicate that the selector circuit is ready to receive the dialed impulses.

The calling party at telephone 432 dials number 659. When the digit 6 is dialed, the selector switch wipers will step up to the sixth level, then step around to hunt for an idle connector trunk in the 600 board. When a nonbusy trunk is found, the wipers will come to rest and extend the line of telephone 432 to the connector. Trunk-hunting action takes place after the digit 6 is dialed. This action is so rapid that the calling line is switched through to the connector before the next digit 5 is dialed.

After the selector has switched the line of telephone 432 through to a connector, the connector is ready to receive the dialed impulses of the last two digits. When the digits 5 and 9 are dialed, the connector switch wipers will step up and around and come to rest on the 59 set of contacts. The connection is now completed from telephone 432, through the finder-selector link, the connector, and over the line normals to telephone 659. The connector switch now tests line 59, and if the telephone is not in use, ringing current is sent out over the line to operate the ringer associated with telephone 659. When the handset at telephone 659 is removed from the cradle switch, ringing current is cut off and the talking circuit is completed between telephones 432 and 659. If, however, telephone 659 is in use, busy tone is sent back to telephone 432 to indicate that the called line is in use and that the calling party should hang up and try again later.

TELEPHONE STATION EQUIPMENT

The telephone instrument is a compact unit designed for transmitting and receiving speech, and for signaling the desired station. It consists essentially of a transmitter, receiver, dial, and ringer. The transmitter provides the means for changing sound into an undulating current that may be transmitted over an electrical circuit. The receiver provides the means for changing the undulating current back into sound. The dial, when operated, causes a series of interruptions (impulses) in the current flowing in the line circuit. The ringer provides an audible signal when the station is called.

TYPES OF TELEPHONES

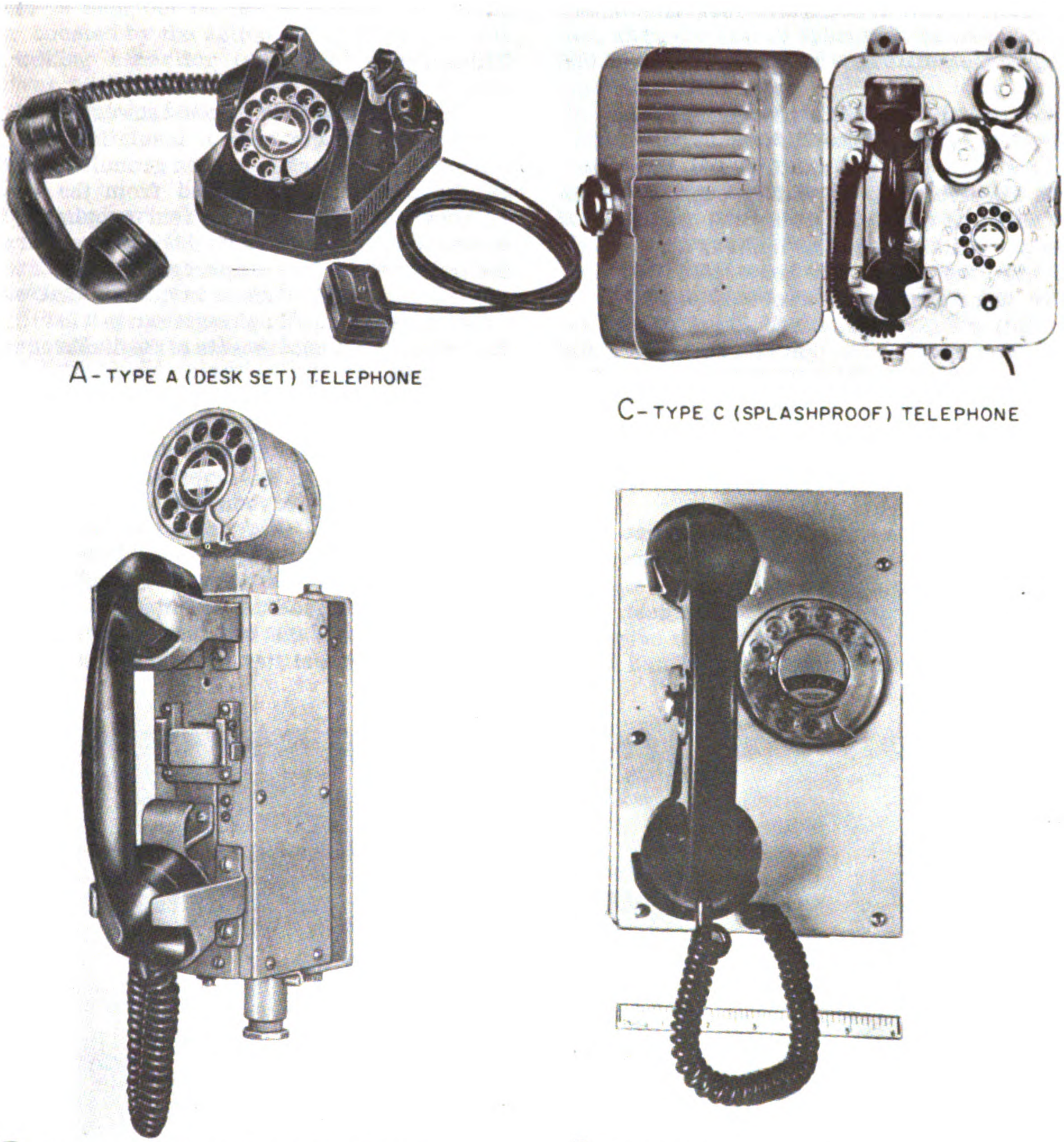
The types of telephones furnished with the dial telephone system are illustrated in figure 9-8. The types differ mainly in the form in which the components are assembled. The components perform the same function, but the form and mounting for each type is of special design and depends on whether the instrument is to be used in a protected or an exposed location.

The TYPE A desk set telephone (fig. 9-8A) is installed in staterooms, cabins, offices, and similar stations. The desk set consists of a phenolic case (containing the ringer, dial, and other working parts), a handset, and connecting cord with a terminal block for making the line connections.

The TYPE F bulkhead telephone (fig. 9-8B) is installed in all stations except those on weather decks and those designated as type A stations. The type F telephone is a nonwatertight unit designed for mounting on a bulkhead or on the side of a desk. It consists essentially of a metal housing on which are mounted the handset, dial, and ringer. The line connections are made at a terminal block inside the housing.

The TYPE C splashproof telephone (fig. 9-8C) is installed at stations on weather decks and other stations exposed to moisture. The type C telephone is designed for bulkhead mounting and consists essentially of a metal housing on which are mounted the handset and dial which are enclosed in a splashproof box. The connections

Digitized by Google



A-TYPE A (DESK SET) TELEPHONE

C-TYPE C (SPLASHPROOF) TELEPHONE

B-TYPE F (BULKHEAD TYPE) TELEPHONE

D-TYPE (G) BULKHEAD TELEPHONE

7.83

Figure 9-8.—Telephones.

to the line are made at a terminal strip inside the housing.

The type G bulkhead telephone (fig. 9-8D), previously installed only on submarines, is now being installed aboard surface ships. Another enclosure is provided for this type of telephone that makes it adaptable for desk mounting.

Digitized by Google

The main assemblies that comprise a telephone instrument are the handset and base.

HANDSET

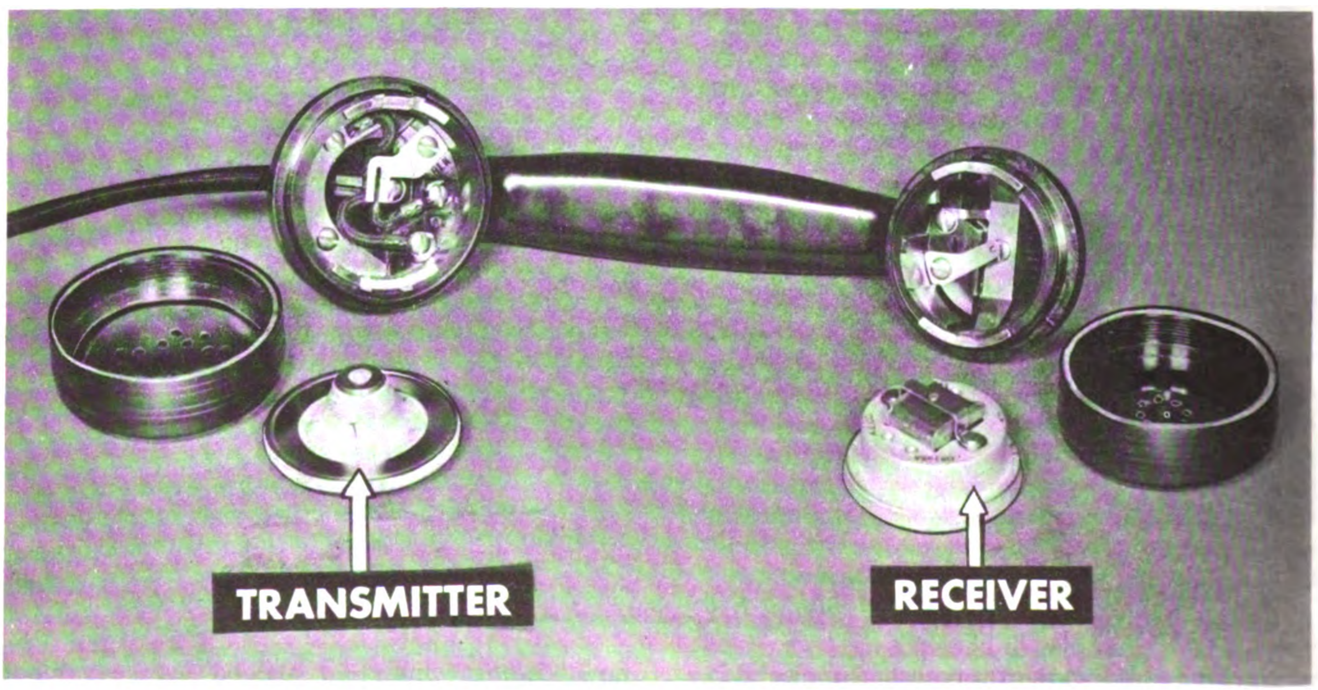
The standard handsets (fig. 9-9), consist of a conveniently shaped handle with two mounting cups, one for the transmitter and the other for the receiver. The mounting cups are at an angle with the handle to bring the transmitter the proper distance from the lips, for the average user, when the receiver is centered on the ear.

The transmitter and receiver are held in the mounting cups by an ear cap for the receiver and a mouthpiece for the transmitter. Both retaining pieces screw on the handset handle. In order to prevent the possibility of inserting the transmitter into the receiver mounting cup and vice versa, the transmitter is made to fit only into the transmitter cup, and the receiver to fit only into the receiver cup.

The transmitter and receiver units are both of the capsule type. Connections from the cord conductors are brought out to contact spring clips in the mounting cups of the handset. The connection between the transmitter or receiver unit and the cord conductors is completed when the capsule is in contact with the contact spring clips.

Transmitter

The transmitter unit consists essentially of a metal diaphragm and an insulating cup containing loosely packed carbon granules. As soon as the handset is removed from the cradle, or hook switch, direct current supplied by the common battery at the switchboard flows through the transmitter. The diaphragm is mechanically connected to the carbon button so that sound waves striking the diaphragm cause it to vibrate. The mechanical movements of the diaphragm are transmitted to the carbon granules. When the carbon granules are compressed by an inward movement of the diaphragm, the resistance is lowered and more current flows through the transmitter. When the diaphragm relaxes, the pressure on the carbon granules is reduced, the resistance is increased, and less current flows. Thus, as long as the diaphragm is vibrating from the sound waves, the resistance of the carbon granule chamber is constantly changing, which in turn causes the current through the transmitter to undulate accordingly.



7.84

Figure 9-9.—Telephone handset.

Digitized by Google

This undulating current, called the VOICE CURRENT, is sent out on the telephone line after being boosted by the action of the induction coil and talking capacitor (explained later). The receiver at the other end of the line converts the voice current back into sound waves.

Receiver

The receiver unit is of the permanent magnet polarized type. It consists essentially of a powerful permanent magnet with two soft-iron coil-wound pole pieces and a diaphragm contained in a protective shell. The diaphragm is mounted under a slight tension so that it is pulled toward the pole pieces by the permanent magnet. The voice currents, flowing through the coils about the two pole pieces, set up magnetomotive forces that alternately aid and oppose the magnetic flux of the permanent magnet. This action causes the receiver diaphragm to be attracted with alternately greater and lesser force. As the diaphragm moves back and forth it reproduces the vibrations of the distant transmitter, and the sound waves thus produced are heard at the other end of the telephone connection.

BASE

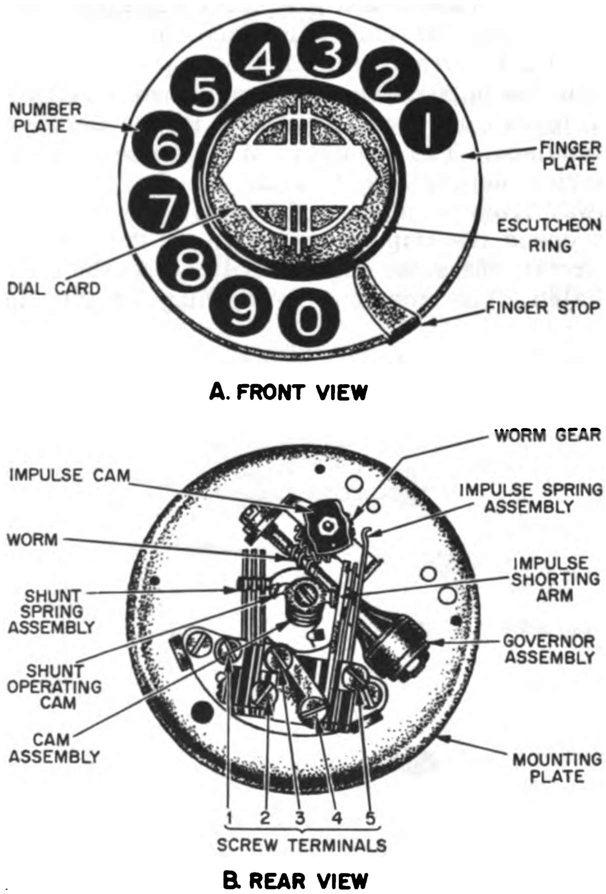
The base includes the dial, hook switch, ringer, two capacitors, and induction coil. The telephones (fig. 9-8) include the same combination of parts and assemblies, but the bases on which the parts are mounted differ somewhat, and the mounting arrangement differs considerably.

Dial

The dial (fig. 9-10) enables the calling party to control the automatic switching mechanisms which establish the telephone connection. The principle functions of the dial are to (1) deliver impulses to the line, (2) short-circuit the parts of the telephone that introduce unnecessary resistance in the dialing circuit, and (3) prevent the dialed impulses from clicking in the receiver.

The principal parts and assemblies of the dial are compactly assembled on a mounting plate (fig. 9-10). These parts and assemblies are (1) finger plate (with 10 holes), (2) number plate, (3) governor assembly, (4) impulse cam and springs, (5) impulse shorting arm, (6) shunt cam and springs, and (7) driving mechanism. The dial parts and assemblies are arranged so that when the dial is operated, the line is opened and closed at a rate of approximately 10 interruptions per second.

The finger plate is fitted to the main shaft, which rotates when the dial is turned from any number to the finger stop (fig. 9-10). Thus, as the main shaft rotates, the tension of the main spring, which is also mounted on the main shaft, is increased to provide the power needed to return the dial (main gear) to normal when the finger plate is released. When the dial is turned from normal, the ratchet pawl (fig. 9-11) slips over the ratchet gear which is mounted on the main shaft with the main gear. This prevents the main gear from rotating. When the dial restores to normal, however, the ratchet pawl engages the ratchet gear and the main gear rotates.



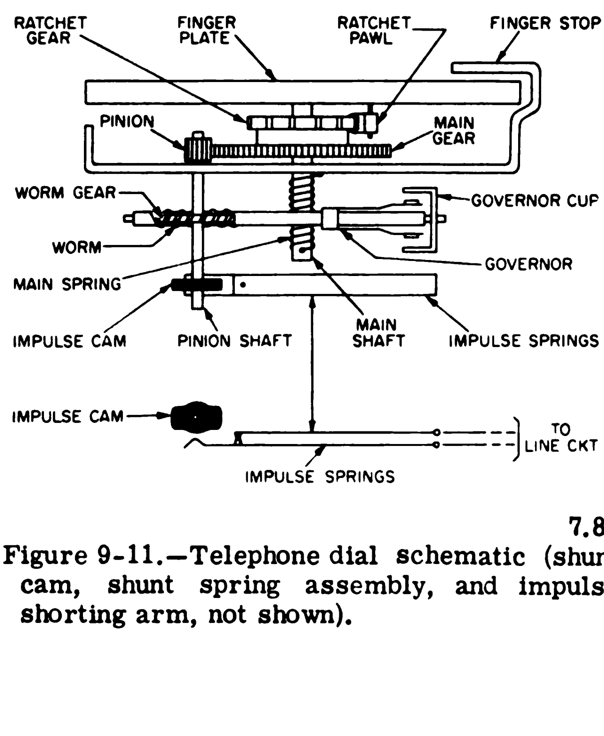
7.85

Figure 9-10.—Telephone dial.

Digitized by Google

The speed of the dial mechanism as it returns to normal under the spring tension is controlled by the GOVERNOR ASSEMBLY. The governor assembly consists of a worm gear shaft that is mechanically connected to the main gear of the dial through a gear train (fig. 9-11). Two flyball wings are attached to the worm gear shaft. A governor weight on the end of each flyball wing protrudes into the governor cup. The rotary motion of the shaft causes the flyball wings to attempt to fly outward and due to centrifugal force, friction is set up between the governor weights and the governor cup. The speed of the dial is thus regulated by adjusting the flyball wings to increase or decrease the amount of pressure the governor weights exert on the inside surface of the cup.

The IMPULSE CAM is geared mechanically to the main gear through a gear train (not shown) so that the impulse cam is caused to rotate during the time the dial mechanism is being returned to normal. The impulse springs are normally closed and are opened intermittently by the impulse cam only when the dial is returning to normal. An impulse is produced each time the impulse springs are opened. The travel from any off normal position is one series of impulses. The number of impulses in the series depends on how far the dial is turned away from normal. As the impulse cam rotates it opens the impulse springs, and thus the line circuit, the same number of times as the digits dialed. The momentary opening of the line circuit produces the dial impulses that actuate the automatic switching mechanism (Strowger switches) at the telephone switchboard to extend the connection to the line associated with the dialed number.



7.86

Figure 9-11.—Telephone dial schematic (shunt cam, shunt spring assembly, and impulse shorting arm, not shown).

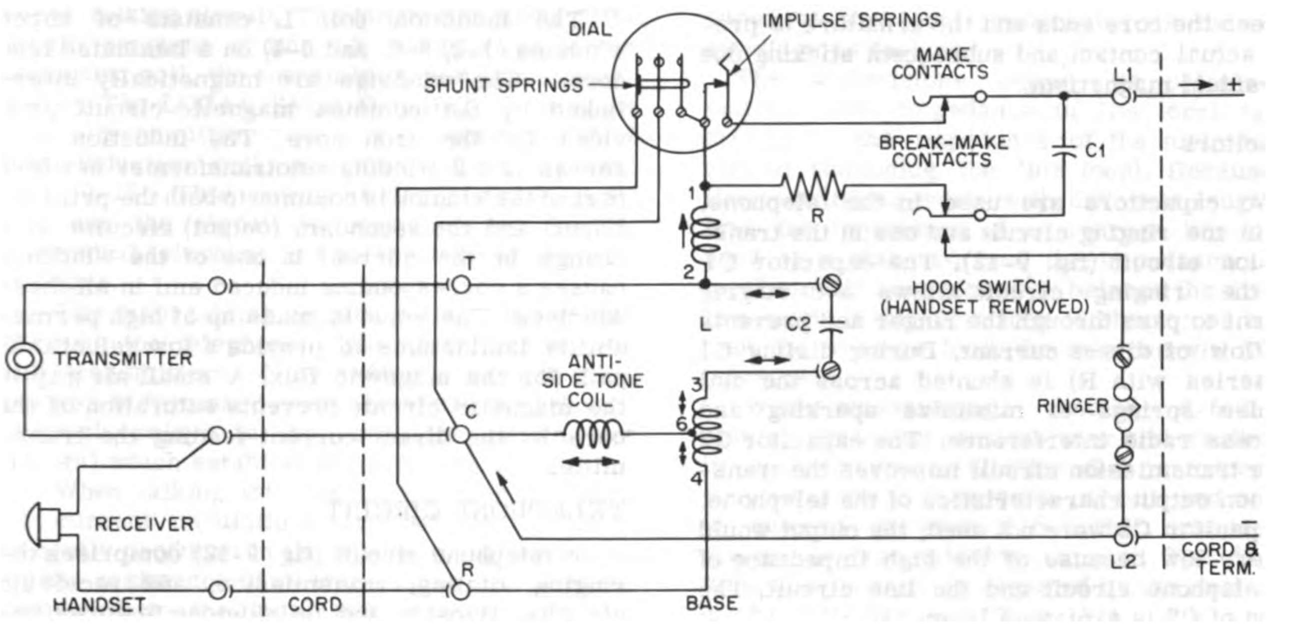
The dial has a time delay feature that separates the series of dial impulses. The time delay is the time between the last impulse of a series and the complete restoring of the dial. It is approximately equal to the time required for one impulse and is accomplished by the movement of the impulse springs away from the cam by the cam shunt assembly. The last time the cam passes, no impulse is produced. The purpose of the delay feature is to allow the relays in the Strowger switches to operate properly between each series of impulses.

The SHUNT OPERATING CAM (fig. 9-10) is mounted on the main shaft. When the dial is at normal, the shunt cam holds the shunt springs in the normally open position. When the dial is turned off normal, the shunt cam is moved out of engagement with the shunt spring assembly and the shunt springs close to shunt the receiver and transmitter. The closure of the shunt springs prevents the impulses from being heard in the receiver during dialing, and also prevents the variable resistance of the transmitter from affecting the character of the dial impulses.

Hook Switch

A representative telephone station circuit is illustrated in figure 9-12. It is not desirable to have both the talking apparatus (transmitter and receiver) and the signaling apparatus (ringer and capacitor, C1) connected to the line while the telephone is in use. Accordingly, the hook switch, also called the cradle switch, monophone switch, or plunger switch (fig. 9-12) is an assembly of springs arranged so that removing or replacing the handset brings about the desired circuit changes. When the handset is placed on the hook switch, the ringer is connected to the line through C1, and the transmitter, receiver, and dial are disconnected from the line. When the handset is removed from the hook switch, a pair of make contacts and a set of break-make contacts on the switch (1) connect the transmitter, receiver, and dial to the line; (2) disconnect the ringer from the line; and (3) connect C1 across the dial impulse springs. The hook switch on all types of telephones has the same function, but the mechanical arrangement differs.

Digitized by Google



7.87

Figure 9-12.—Schematic diagram of telephone C circuit.

Ringer

The ringer (fig. 9-13) is of the polarized, untuned type commonly called the STRAIGHT-LINE ringer (bell). It is suitable for use on both individual and party lines and is called UNTUNED because it will operate over a wide range of frequencies.

The ringer consists of a hard-steel permanent magnet, a soft-iron electromagnet, a pivoted armature carrying a clapper rod and clapper, and a gong or set of gongs. The electromagnet is U-shaped with a coil around each leg. The soft-iron armature is pivoted at its center, and lies in front of the two poles of the electromagnet, but does not quite complete the magnetic circuit. The permanent magnet is used to polarize the armature ends of the electromagnet. The armature end of each coil has a consequent north polarity produced by the permanent magnet. The two ends of the armature have consequent south poles produced by the permanent magnet.

The coils are wound on the pole pieces so that when current flows in one direction (fig. 9-13) the mmf of coil 1 aids the permanent magnet flux and the mmf of coil 2 opposes it. Thus, coil 1 increases the strength of the north pole at the armature end of coil 1 and coil 2 attempts to establish a south pole at the armature end of coil 2. Because like poles repel and unlike poles attract, the armature moves clockwise and the clapper strikes the gong at the right.

When the ringer current reverses, the mmf of the coils reverses. Thus, coil 2 strengthens the north pole at the armature end of coil 2 and coil 1 attempts to establish a south pole at the armature end of coil 1. The armature moves counterclockwise and the clapper strikes the gong at the left. The gongs ring once for each half cycle of ringing current. The ringing current is 20 cycles per second.

When no current flows through the coils, the armature south poles attract the north poles at the armature end of the coils and the clapper moves either to the right or the left depending on which air gap is the shortest. A biasing spring (not shown) is provided to give the armature a definite position when the gongs are silent. This spring holds the clapper against one gong and prevents the gong from tingling when the other party on the line is dialing (biasing springs on commercial telephones prevent clapper operation when the wrong polarity of ringing current is received in selective ringing on four-party lines). Small pieces of nonmagnetic material are placed

Digitized by Google

between the core ends and the armature to prevent actual contact and subsequent sticking due to residual magnetism.

Capacitors

Two capacitors are used in the telephone, one in the ringing circuit and one in the transmission circuit (fig. 9-12). The capacitor C1 in the ringing circuit allows a-c ringing current to pass through the ringer and prevents the flow of direct current. During dialing C1 (in series with R) is shunted across the dial impulse springs to minimize sparking and suppress radio interference. The capacitor C2 in the transmission circuit improves the transmission output characteristics of the telephone. If capacitor C2 were not used, the output would be very low because of the high impedance of the telephone circuit and the line circuit. The action of C2 is explained later.

Induction Coil

The induction coil L couples the transmitter and receiver units to the line (fig. 9-12). It also increases the output volume by boosting the voice current undulations developed by the transmitter and prevents or decreases SIDETONE. Sidetone occurs when a person hears his own voice in the receiver while talking into the transmitter.

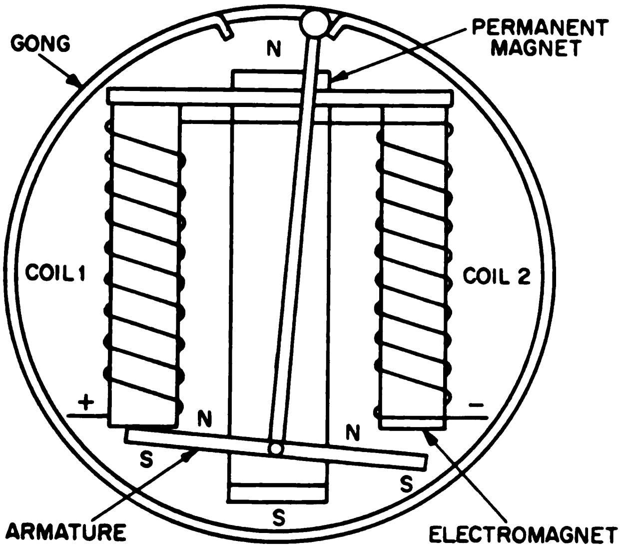


Figure 9-13.—Polarized ringer.

The induction coil L consists of three windings (1-2, 3-6, and 6-4) on a laminated iron core. The windings are magnetically interlinked by the common magnetic circuit provided by the iron core. The induction coil serves as a 3-winding autotransformer in which part of the winding is common to both the primary (input) and the secondary (output) circuits. Any change in the current in one of the windings causes a corresponding induced emf in all three windings. The core is made up of high permeability laminations to provide a low reluctance path for the magnetic flux. A small air gap in the magnetic circuit prevents saturation of the core by the direct current feeding the transmitter.

TELEPHONE CIRCUIT

A telephone circuit (fig. 9-12) comprises the ringing, dialing, transmission, and receiving circuits. Booster and antisidetone features are also included in the circuit. Note that the handset is removed from the hook switch so that the transmitter, receiver, and dial are connected to the line, and the ringer is disconnected from the line.

Ringing Circuit

The ringing circuit consists of line L1, ringing capacitor C1, make-contacts on the hook switch, the ringer, and line L2, (fig. 9-12). This circuit condition exists when the handset is placed on the hook switch. When the handset is removed from the hook switch, the ringing capacitor C1 is transferred from the ringer to the dial impulse springs, as previously mentioned, to prevent excessive sparking at the contacts of the impulse springs.

Dialing Circuit

The dialing circuit consists of line L1, the hook switch, the dial impulse springs (shunted by resistor R and capacitor C1, in series), the dial shunt springs, and line L2 (fig. 9-12). When the dial is operated, the dial shunt springs close to shunt the transmitter, receiver, and induction coil so that they will not affect the impulses sent out by the dial.

Transmission Circuit

The transmission circuit includes two distinct circuits, the main talking circuit, and the

Digitized by Google

local talking circuit. The MAIN TALKING CIRCUIT consists of line L1, winding 1-2 of the induction coil, the transmitter, and line L2 (fig. 9-12). The LOCAL TALKING CIRCUIT consists of the transmitter, capacitor C2, winding 3-6 of the induction coil, and the antisidetone coil (fig. 9-12). This circuit is designated "local" because the circuit is completed within the individual telephone and not through the line conductors.

The main talking circuit is also the d-c path through the telephone. The direct current for the transmitters of the calling and called telephones is furnished by the automatic switchboard through relays in the connector switch (not shown) which establish the connection.

When talking into the transmitter, two sets of current undulations are set up: (1) those directly produced in the line due to the variations in the resistance of the transmitter; and (2) those produced in the local talking circuit by the charging and discharging of capacitor C2, caused by the varying potential drop across the transmitter.

The local talking circuit current undulations are best understood if it is kept in mind that the capacitor C2, is connected across the transmitter, directly on one side and through winding 3-6 of the induction coil and the antisidetone coil on the other side. Thus, the resistance variation introduced by the action of the transmitter causes the voltage to vary on the plates of capacitor C2. Alternating currents will then flow in the local talking circuit as the capacitor C2 adjusts the charge on its plates to the varying difference of potential across the transmitter.

The resulting alternating currents flowing in winding 3-6 of the induction coil, considered as the primary of the autotransformer, will induce voltages in the secondary winding 1-2. The change in current that occurs in winding 1-2 is of greater magnitude as a result of the change of produced current in winding 3-6 by the transmitter. The induced voltage in winding 1-2 aids the voice currents directly delivered to the line via the main talking circuit and thus a BOOSTER feature is achieved.

It is important that the transmitter of the calling telephone produces a large effect on the receiver of the called telephone and little or no effect on the local receiver. Accordingly, the telephone circuit is designed so that the local transmitter action produces a minimum of current flow through the local receiver. The means used to lower sound in the local receiver, introduced at the local transmitter is called the antisidetone feature.

The antisidetone feature is obtained by matching the impedance of the local talking circuit to the impedance of the main talking circuit (including the line loop). Because the line conditions vary with different lengths of line, the impedance of an average line loop is used as a standard, and the impedance of the local circuit is arranged to balance the average line loop. If any line loop is shorter or longer than the average loop, the sidetone will tend to increase.

When transmitting, winding 3-6 is the primary of the autotransformer and winding 1-2 is the secondary. Winding 6-4 is inductively coupled to the transmission circuit, and voltage is induced in winding 6-4 that opposes the change in transmission current. The desired inductive balance is obtained by the impedance of the antisidetone coil so that a minimum of voltage exists across the receiver terminals, resulting in little or no sound in the receiver during transmission.

Receiving Circuit

The receiving circuit also includes two distinct circuits, the main receiving circuit, and the local receiving circuit. The MAIN RECEIVING CIRCUIT consists of line L1, winding 1-2 of the induction coil, the transmitter, and line L2 (fig. 9-12). This circuit is the same as the main talking circuit during transmission, except winding 1-2 now becomes the primary of the autotransformer instead of the secondary. The LOCAL RECEIVING CIRCUIT includes capacitor C2, windings 3-6 and 6-4 of the induction coil, the receiver, and transmitter (fig. 9-12). As previously explained, the antisidetone feature prevents the local transmitter from affecting the receiving circuit.

During the reception of speech, the voice currents are received via the main talking circuit which include line L1, winding 1-2 of the induction coil, the transmitter, and line L2. The voice currents flowing in winding 1-2 of the induction coil, considered as the primary of the autotransformer, will induce voltages in the secondary windings 3-6 and 6-4. (Because of the antisidetone feature the local transmitter has no effect on the receiving circuit.) The a-c voltage induced in windings 3-6 and 6-4 causes signal currents to flow through the receiver which (by action of the diaphragm) reproduces the tone

Digitized by Google

and words of the person speaking into the transmitter at the other end of the connection.

TELEPHONE CONNECTIONS

All telephones are provided with screw-type terminals and therefore soldering is not necessary in order to connect or replace a telephone. All conductors are color-coded and the correct termination for each conductor is shown in terms of the color code on the circuit label inside the telephone base or on the wiring diagram. When changing or replacing any wiring in or to a telephone, check the new connections against the circuit label inside the telephone or the applicable wiring diagram.

The several types of telephones can be connected for one-party service or two-party service. For a ONE-PARTY line two conductors are required to extend the connection between the telephone instrument and the automatic switchboard. These are the line conductors designated L1 and L2 on the circuit labels and telephone wiring diagrams. On a one-party line the ringer is across the line and the line conductors are also the conductors for the ringer circuit. This arrangement is called METALLIC RING.

For a TWO-PARTY line three conductors are required to extend the connection between the telephone instrument and the automatic switchboard. The two line conductors are designated L1 and L2 and the third conductor, which is connected to a ground (positive battery) common to all ringer circuits in the shipboard dial telephone system, is designated G.

When two telephones are connected electrically to the same line circuit, their ringers cannot be connected across the line unless one telephone is to be an extension telephone. When two-party service with individual ringing is desired, the two telephones must be arranged so that ringing current will operate only the ringer of the called telephone. Thus, to obtain separate ringer circuits for the two telephones, the ringer of one telephone is connected between the positive line conductor L1, and ground (positive ring), whereas, the ringer of the other telephone is connected between the negative line conductor L2, and ground (negative ring).

Therefore, on party lines it is necessary that the ringers be connected to the proper side of the line. The telephone system is arranged so that the side of the telephone line on which ringing current is applied is determined by the telephone number. 400-line telephones assigned numbers starting with even digits have ringers connected between the positive side of the line (L1) and ground. On the other hand, telephones assigned numbers starting with odd digits have ringers connected between the negative side of the line (L2) and ground.

Type A Telephone

The type A telephone (fig. 9-14) is equipped with a terminal subassembly inside the base and a line-and-cord terminal block on the end of the desk set cord. The line wires L1 and L2 from the automatic switchboard terminate at the line-and-cord terminal block and the wiring of the telephone instrument terminates at the instrument terminal subassembly. The desk set cord extends the connection between the telephone wiring at the instrument subassembly and the line wiring at the line-and-cord terminal block.

The type A telephone is connected for ONE-PARTY line service (metallic ring) by connecting at the line-and-cord terminal block, the red-coded and white-coded wires to terminal L2, and the black-coded wire to terminal L1. Proper operation of the ringer is determined by dialing, from a nearby telephone, the number assigned to the telephone just connected. The ringer should ring.

The type A telephone (fig. 9-14) is connected for TWO-Party line service (ground ring) by connecting, at the line-and-cord terminal block, the black-coded line wire to terminal L1, the white-coded line wire to terminal L2, and the red-coded ground wire to terminal 4G. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line wire connections at the line-and-cord terminal block. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, remove the base plate and reverse the ringer terminals 5 and G. Repeat the test. If the ringer still taps, increase the tension of the biasing springs. The biasing springs should be as nearly parallel as possible to the ringer coil cores. To increase the tension in the biasing springs bend the lower mounting lug (not shown) downward with a pair of pliers. Repeat the test.

Digitized by Google

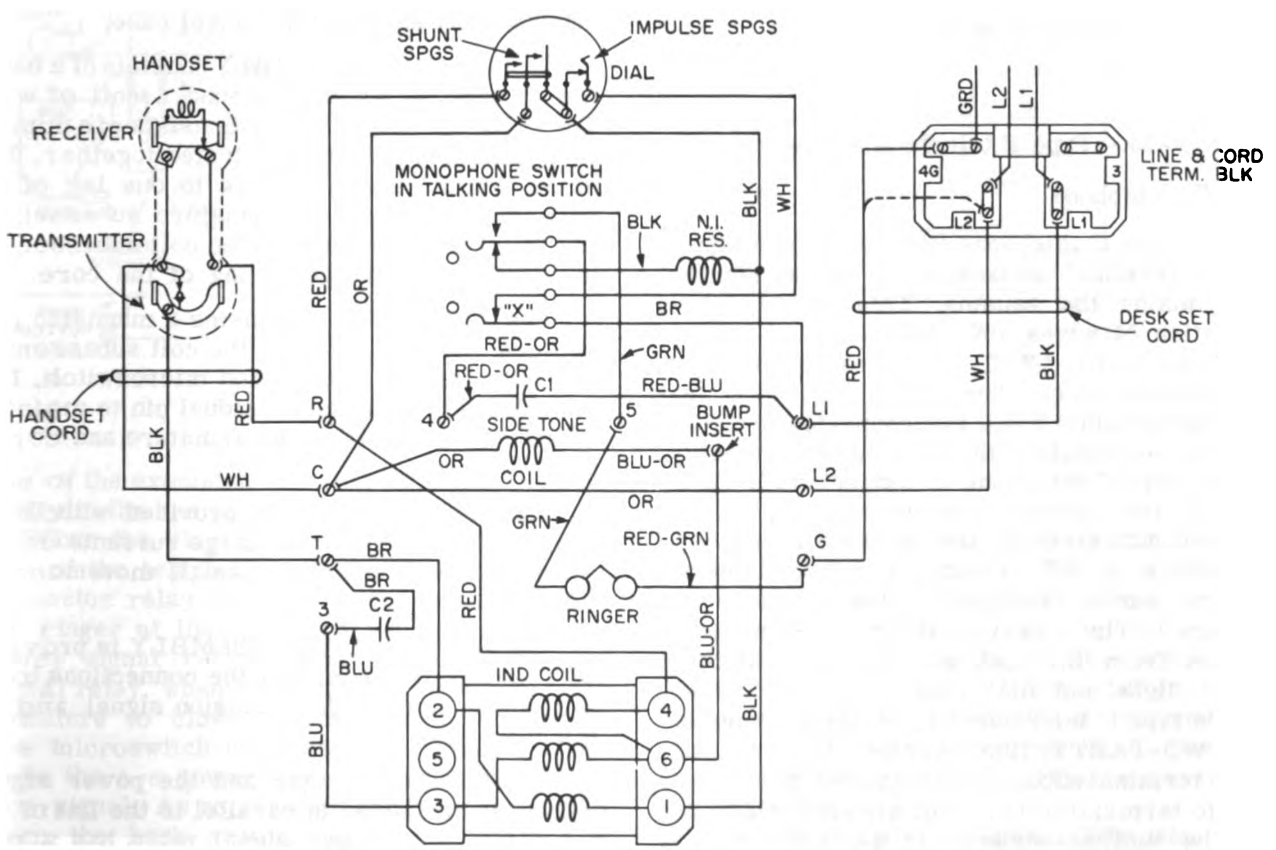
Type F Telephone

The type F telephone (fig. 9-15) is equipped with a terminal subassembly mounted on the bottom cover plate inside the telephone housing. The ship's cable, consisting of line wires J95 and JJ95, battery-connected wire JJ9, and ground-connected wire J9, enters through a terminal tube at the bottom of the housing.

The type F telephone is connected for ONE-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal L2, the line wires J95 and JJ95 to terminal L1 and L2, respectively, the ground-connected wire J9 to terminal G, and the battery-connected wire JJ9 to terminal B. Remove the handset from the hook switch. The dial lamp should light and a dial tone should be heard. From a nearby telephone, dial the number assigned to the telephone just connected. The ringer should ring.

The type F telephone (fig. 9-15) is connected for TWO-PARTY line service by connecting at the terminal subassembly, the red-blue ringer wire to terminal G, and the ship's cable wires J95, JJ95, J9, and JJ9 to terminals L1, L2, G, and B, respectively. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line-wire connections at terminals L1 and L2. Repeat the test.

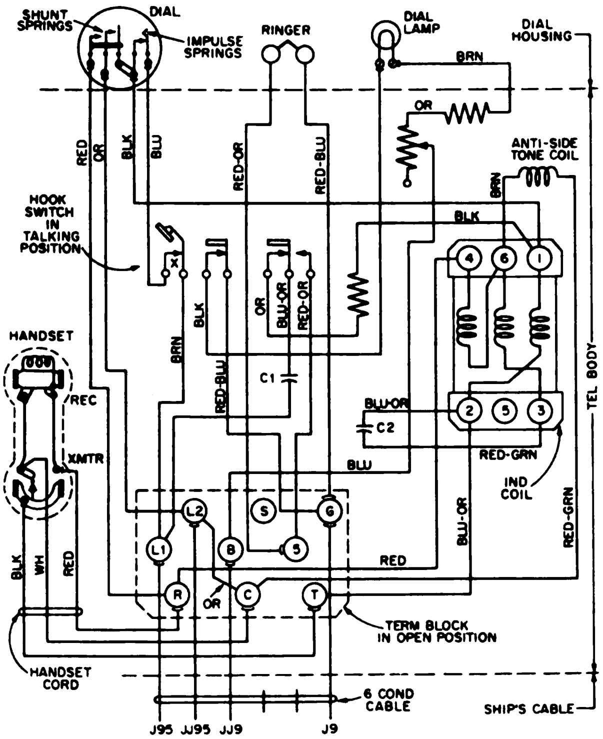
At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, reverse the red-blue and the red-orange ringer connections at terminals 5 and G. Repeat the test. If the ringer still taps, increase the tension of the biasing spring (not shown) by bending the end mounting lug with a pair of pliers. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard. Replace the handset.



7.89

Figure 9-14.—Type A telephone wiring diagram.

Digitized by Google



7.90

Figure 9-15.—Type F telephone wiring diagram.

Type C Telephone

The type C telephone (fig. 9-16) is equipped with a terminal subassembly and a terminal block inside the housing. This ship's cable, consisting of wires J95, JJ95, J9, and JJ9 are connected to L1, L2, G, and B, respectively, on the terminal block. The wires L1, L2, G, and B on the terminal block are connected to corresponding terminals on the terminal subassembly.

The type C telephone is connected for ONE-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal 4 (L2). From a nearby telephone, dial the number assigned to the telephone just connected. The ringer should ring. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard.

The type C telephone (fig. 9-16) is connected for TWO-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal 3 (G). From a nearby telephone, dial the number assigned to the telephone just connected. If the telephone ringer does not ring, reverse the line-wire connections at terminals L1 and L2. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, reverse the ringer connections at terminals 3 and 5 on the terminal subassembly. Repeat the test. If the ringer still taps, increase the tension of the biasing spring as previously explained. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard.

POWER SIGNAL RELAY

As previously stated, when a telephone is installed in a noisy location, an extension signal may be connected through a power signal relay to the telephone line. The extension signal used with the dial telephone system is a 115-volt 60-cycle motor-operated horn.

The power signal relay (fig. 9-17) includes: (1) coil subassembly, (2) core subassembly, (3) armature, (4) microswitch, and (5) terminal subassembly enclosed in a steel case.

The COIL SUBASSEMBLY consists of a bakelite frame on which is wound a coil of wire. The CORE SUBASSEMBLY consists of a number of U-shaped laminations riveted together. Two brass brackets are riveted to one leg of the core for mounting the armature subassembly and the relay terminals. The coil subassembly is attached to the other leg of the core.

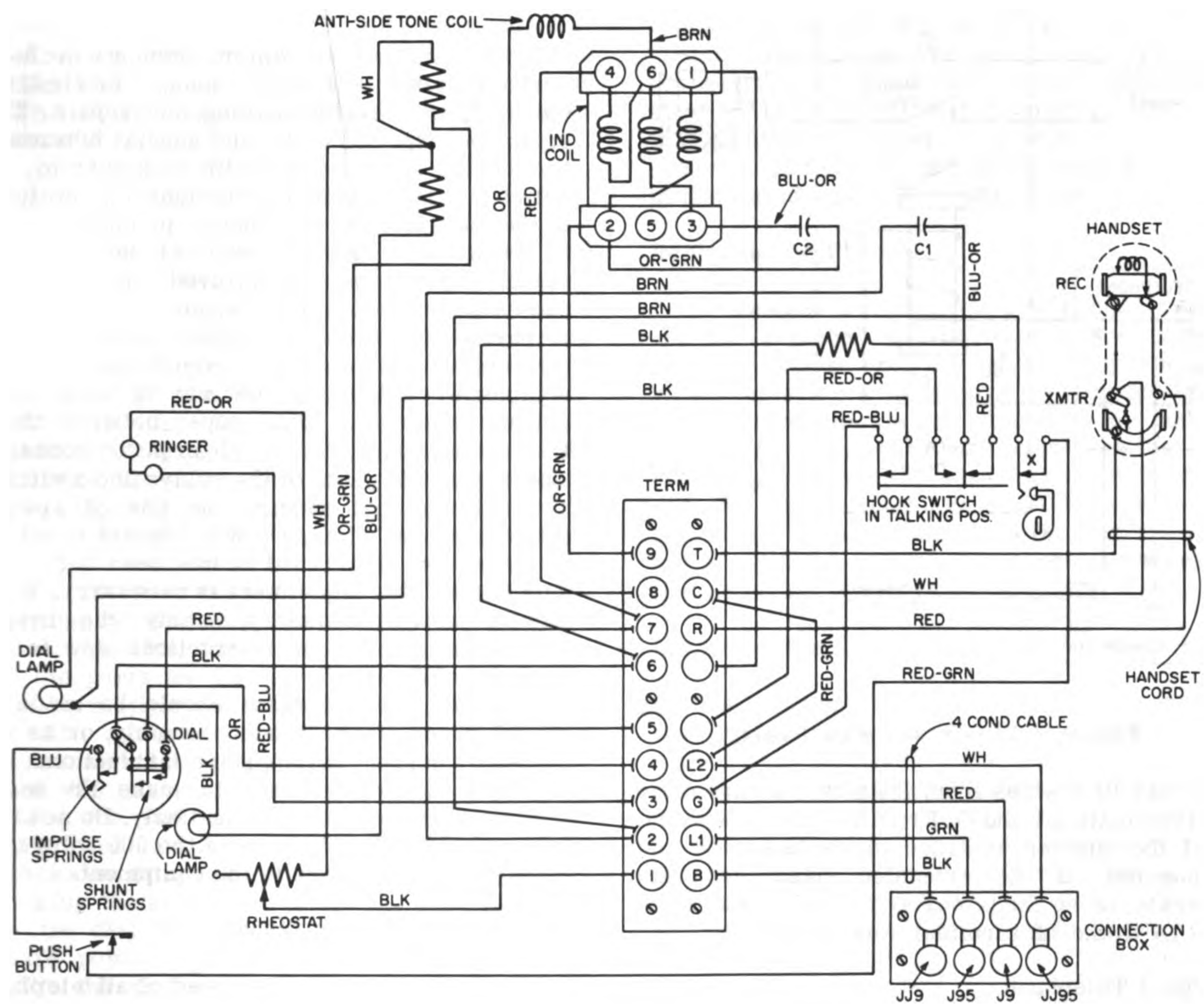
The ARMATURE completes a magnetic path between the two poles of the coil subassembly and actuates the snap-action microswitch. It is provided with a brass residual pin to maintain a small space between the armature and core to prevent sticking.

The MICROSWITCH is provided with large contact surfaces so that large currents can be controlled with relatively small movements of the armature.

The TERMINAL SUBASSEMBLY is provided with terminals for making the connections to the a-c power source, the extension signal, and the telephone line.

The telephone ringer and the power signal relay are connected in parallel to the line of the telephone. The power signal relay has a pair of microswitch contacts, one of which is connected to one side of the extension signal and the other to the a-c power supply. The other

Digitized by Google



7.91

Figure 9-16.—Type C telephone wiring diagram.

side of the extension signal is connected permanently to the a-c power supply.

When the ringing current is applied to the line of the telephone through the winding of the connector relay F, the current energizes both the ringer at the telephone and the coil of the power signal relay. The coil of the power signal relay, when energized, actuates the relay armature to close the microswitch contacts. The microswitch contacts, when closed, complete the a-c power circuit to sound the extension signal. As soon as the handset is removed from the hook switch, the ringing current is removed from the line, the power signal relay restores, and the circuit to the extension signal is opened at the microswitch contacts.

Type F Telephone

When a type F telephone is installed in a noisy location, an extension signal is connected through a power signal relay to the telephone line. When the telephone is arranged for extension signal ringing, it is recommended that the instrument be connected for ground ring irrespective of whether it is a one-party or two-party line, in order to eliminate any possibility of the extension signal being actuated during dialing.

At the terminal subassembly (fig. 9-15), connect the red-blue ringer wire to terminal G, the ship's cable wires J95, JJ95, J9 and JJ9 to terminals L1, L2, G, and B, respectively, and

Digitized by Google

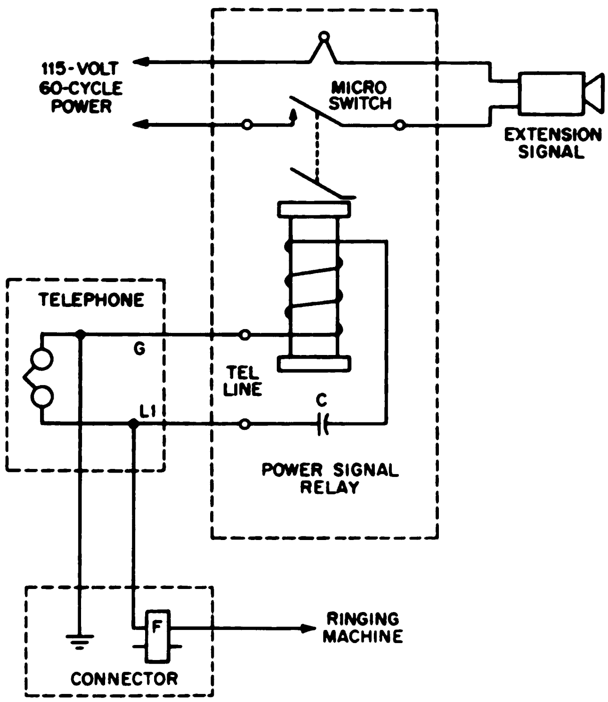


Figure 9-17.—Power signal relay.

the two line wires from the power signal relay to terminals L1 and G. From a nearby telephone, dial the number assigned to the telephone just connected. If the extension signal does not operate, move the power signal relay lead from the L1 to the L2 terminal. Repeat the test.

Type C Telephone

When a type C telephone is installed in a noisy location, it is arranged for extension signal ringing and connected for ground ring irrespective of whether it is a one-party or two-party line.

At the terminal block (fig. 9-16) the ship's cable wires J95, JJ95, J9, and JJ9 are connected to terminals L1, L2, G, and B, respectively, and the two line wires from the power signal relay to terminals L1 and G. At the terminal subassembly, connect the red-blue ringer wire to terminal 3 (G) and the wires from the terminal block to the corresponding terminals, L1, L2, G, and B. From a nearby telephone, dial the number assigned to the telephone just connected. If the extension signal does not operate, move the power signal relay lead from terminal L1 to terminal L2. Repeat the test.

MAINTENANCE

Dial telephone system maintenance includes periodic tests and inspections, lubrication, cleaning, and troubleshooting and repair. Test equipment, special tools, and special lubricants and charts are provided with each system, and detailed maintenance instructions are included in the manufacturer's technical manual.

Cleanliness is very essential due to the low voltages and currents involved. Dirt and dust can cause insulation failures, and high resistance or partially open contacts. Use a vacuum cleaner for removing dirt and dust from the switchboard equipment. Relay contacts may be cleaned by pulling a strip of bond paper between them. Use a burnishing tool to clean pitted contacts. The adjustable parts of the relays and switches are delicate and require the use of special tools to adjust them. Do not attempt to adjust a switch or relay until it has been definitely determined that adjustment is necessary. When adjustment is necessary, study the manufacturer's adjustment instructions and follow them carefully.

Periodic ground tests should be made on all telephone lines at least monthly, or as required by current maintenance instructions. If a 500-volt megger is used to make the tests, test each conductor to ground only. Do not test between the twisted pairs as the 500 volts may damage the capacitors in the equipment.

TELEPHONE INSPECTIONS

Periodically check the speed of all telephone dials by dialing the digit O. The dial should return to its normal position in approximately 1 second. Inspect and tighten all mouthpieces and earpieces; replace if broken. Replace frayed, worn, or noisy cords. To check for a noisy cord, roll the cord back and forth between the hands while listening for a clicking or crackling noise in the receiver. Conduct a transmission test over each telephone by talking with another person.

TELEPHONE REPAIRS

In general, when it is necessary to work on a telephone it should be taken out of service by disconnecting the L1 and L2 line wires. The line wires can be disconnected in the type A telephone at the cord terminal block located at the end of the desk set cord, and in the types, C, F, and G telephones at the terminal strip

Digitized by Google

inside the housing. This procedure prevents the unnecessary operation of the automatic switches that seize and hold busy a conversation link at the switchboard. To prevent reconnecting line wires in reverse, they should be marked when disconnected.

Removing the Dial Card

The dial card is removed by inserting the special dial tool under the escutcheon ring (fig. 9-10), near the digit "5" finger hole. Press the tool down against the locking lever underneath the card and move the tool counterclockwise to the digit "6" finger hole. This action unlocks the card assembly. Lift the escutcheon ring at the digit "6" finger hole with the tip of the tool and withdraw the card assembly. The escutcheon ring, the celluloid cover, the dial card, and the dial card clamping plate will release as one assembly. The parts of this assembly can be released by turning the assembly clamping plate in a counterclockwise direction. Notice the relative position of the parts as they are removed so that they can be easily reassembled.

The components of the card assembly are reassembled by placing the celluloid cover and then the dial card into the escutcheon ring. Place the dial card clamping plate over the dial card and turn the clamping plate in a clockwise direction to engage the tongue, thereby locking the assembly. Mount the card assembly on the dial, with the locking lever on the finger plate pointed midway between digits "6" and "7". Insert the small lug on the escutcheon ring into the slot located above the finger stop and press the assembly down into the finger plate. Hold the assembly in place and insert the dial tool under the escutcheon ring near the digit "7" finger hole. Press the tool down against the locking lever underneath the card and move the tool in a clockwise direction to the digit "6" finger hole, thereby locking the card in place. Remove the tool.

Replacing the Dial

To replace the dial of any type of telephone, expose the interior, as previously described, and disconnect the four conductors at the rear of the dial. Remove the three screws and lockwashers that hold the dial in place and lift out the dial. Mount the new dial and replace the lockwashers and screws. Connect the four conductors to the dial in accordance with the circuit label inside the telephone. Dials are properly adjusted and lubricated before shipment and should operate for long periods of time without attention. However, if minor adjustment are required the proper procedures are listed in the manufacturer's technical manual.

Replacing the Cords

A handset or cord on a telephone can be readily replaced because cords are carried (already made up) in the spare parts box. When replacing a handset or cord, refer to the circuit label inside the telephone or make a wiring sketch so that the cord can be connected properly. All wires are color coded, and the connections are made by screw-type terminals. Always anchor the tie cord securely using sufficient slack in the conductor wires so that no strain is placed on the wires.

Replacing the Transmitter and Receiver Units

The transmitter and receiver are both of the capsule type and thus are completely enclosed self-contained units. These units cannot be opened without damage. In the event of trouble the entire unit must be replaced.

The transmitter unit is held in place in the mounting cup by two retaining spring clips and is secured by the mouthpiece. Connections to the electrodes are through springs. To remove the transmitter unit, hold the handset in a horizontal position (facing up) and unscrew the mouthpiece. If the hand slips, wrap a piece of friction tape around the mouthpiece to provide the necessary friction. Lift the transmitter unit out of the housing, with the fingers engaging the outer edge of the unit between the two retaining spring clips.

To replace the transmitter unit, hold the handset in a horizontal position, as previously explained. Insert the outer edge of the unit against the movable retaining spring clip (located in the cup) and snap into place, pressing only on the outer edge of the transmitter. Then screw on the mouthpiece.

The receiver unit is held securely in place by the ear cap. Connections to the electrodes are through springs. To remove the receiver unit, hold the handset in a horizontal position (ear cap facing up) and unscrew the ear cap. Place the hand over the receiver housing and

Digitized by Google

turn the handset over. The receiver unit will drop out and into the hand.

To replace the receiver unit, hold the handset in a horizontal position, as previously explained. Place the receiver in the cup and screw on the ear cap.

Some of the common dial telephone faults are discussed briefly below.

NOISY CONNECTIONS.—Noisy connections are caused by partial shorts or grounds on the line, worn handset or desk set cords, noisy transmitters, and loose connections in the telephone.

CLICKS IN RECEIVER.—Clicks in the receiver while dialing are usually caused by failure of the shunt springs to make contact when turning the dial. If this condition is not corrected after cleaning the contacts, look for a broken shunt spring connection.

CALLED STATION DOES NOT RING.—If the bell at a called station does not ring, the fault can be caused by an open ringer coil or capacitor, an improper adjustment of the ringer, or reversed or loose connections at the ringer terminals. Also, the bell will not ring properly if the gongs have become loose or if the position of the gongs has shifted with respect to the clapper.

CANNOT ANSWER.—If a party at a called telephone is signaled but cannot be heard, the fault can be caused by a shorted transmitter or shorted contact of the dial shunt springs. Also, if the hook switch springs fail to operate, the ringer will not be cut off when the handset is removed at the called station.

CANNOT HEAR WELL.—If a telephone has poor reception, the trouble may be caused by improper contact of the contact springs in the receiver housing, a loose receiver cap, a worn receiver cord, or loose connections inside the telephone.

CANNOT BE HEARD WELL.—If a telephone has defective voice transmission, the fault is probably in the transmitter unit. To loosen the carbon granules, hold the handset in a horizontal position and shake it, using a circular motion. If the carbon granules are not loosened by this method, strike the transmitter end of the handset sharply with the palm of the hand. Also, check the contact springs in the transmitter for a tight, clean connection to the unit.

CANNOT CALL.—If a call cannot be made from a telephone, first determine if the line relay operates when the handset is removed at the calling station. If the line relay does not operate, short circuit the line terminals at the switchboard. If the line relay now operates, check for an open line between the switchboard and calling telephone.

WRONG NUMBERS.—The most frequent cause of connections with the wrong telephone is due to jiggling the cradle switch before starting to dial. When the cradle switch is moved up and down rapidly, the result is a series of impulses similar to those sent out by the dial. Keeping the finger on the dial while it is restoring to normal may also result in wrong connections.

TESTING EQUIPMENT

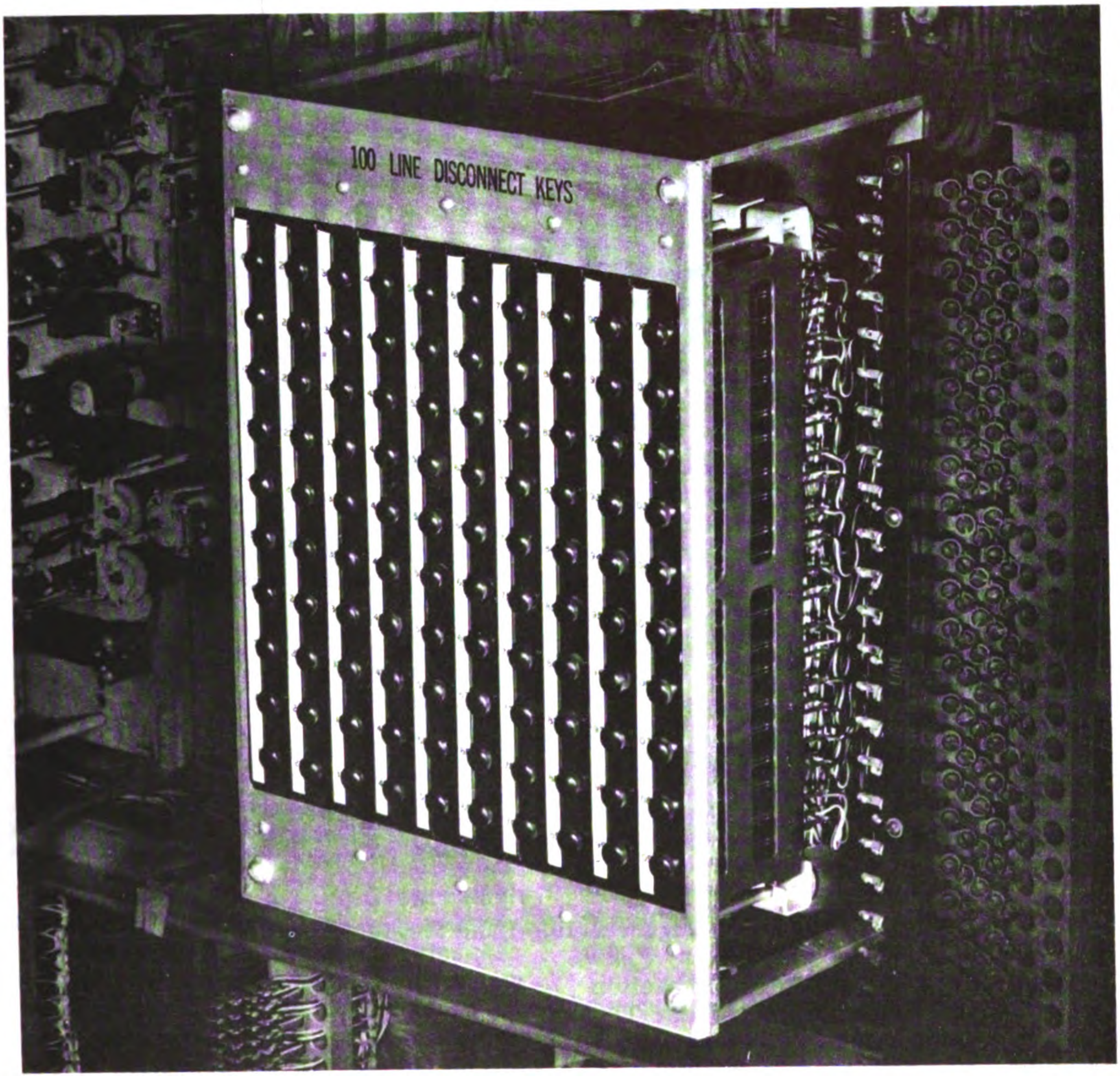
Testing equipment is provided for use in detecting and locating nonstandard conditions in the dial telephone system. This equipment comprises (1) a line disconnect key panel, (2) a hand test telephone, (3) a test set, (4) a portable resistance text box for conducting spring-margining tests on relay springs, (5) a current flow test set, and (6) a line routiner.

A knowledge of the testing equipment is necessary to keep the telephone system operating at a maximum efficiency. Therefore, the more important test equipment listed above will be discussed here.

LINE DISCONNECT KEY PANEL

The line disconnect key panel (fig. 9-18), mounted in the finder board is equipped with 100 keys (one for each line connected to the switchboard). Thus, any line can be disconnected from the switchboard for testing purposes or isolating a faulty line. Nonessential lines (white keys) should be cut out under emergency and battle conditions. Each line disconnect key has the same number as its associated line. When the key is in the NORMAL position, the telephone line is connected to the associated line relay in the automatic switchboard. When the line disconnect key is operated (pulled out) the

Digitized by Google



27.208

Figure 9-18.—Line disconnect key panel.

connection is opened between the telephone line and the associated line relay.

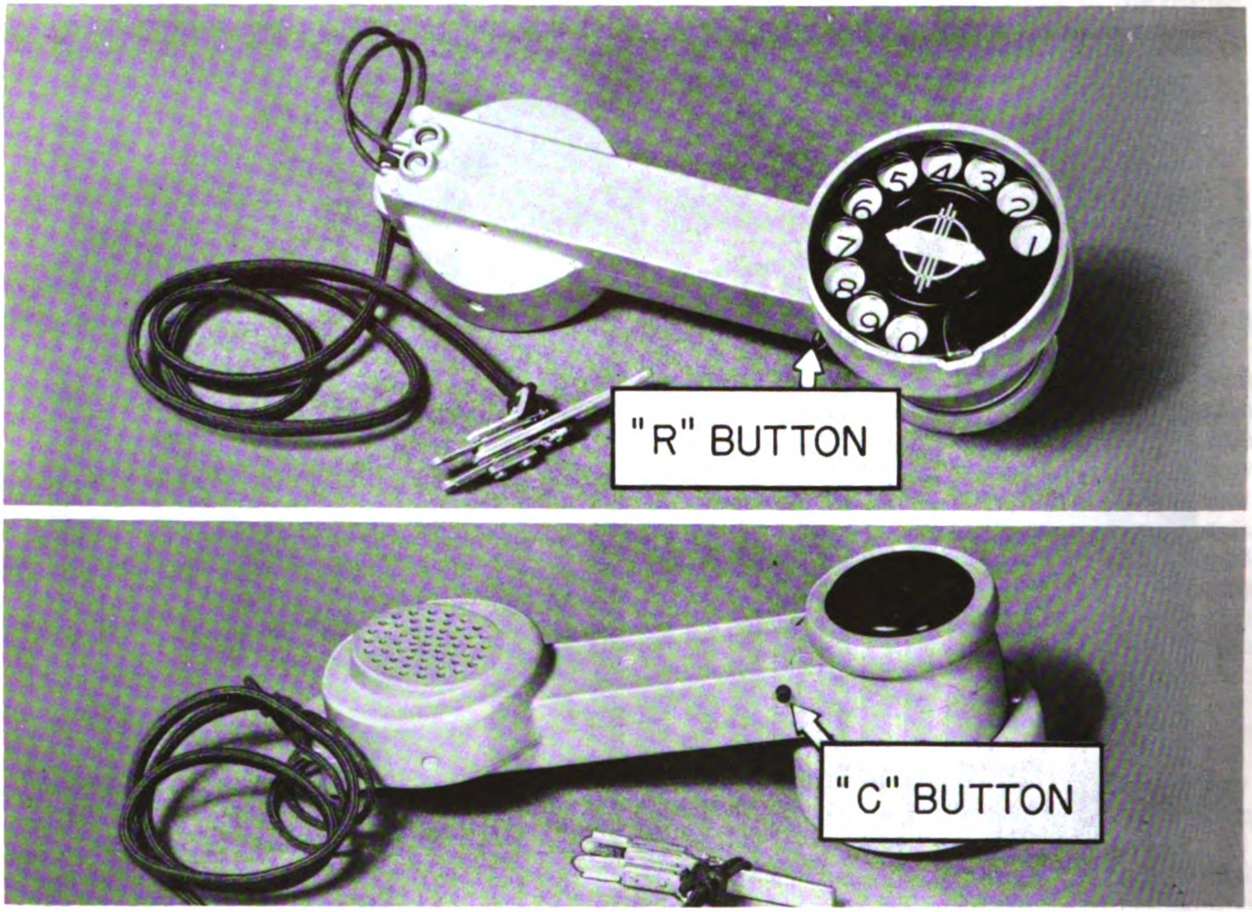
The line disconnect key can be locked in the OPEN position by inserting a cotter pin in the hole provided in the key shaft. This locking arrangement can be used to prevent ring-back tone from being returned to the calling station when the line disconnect key is associated with an unassigned line.

HAND TEST TELEPHONE

The hand test telephone is mounted on the rear of the finder board by a spring clamp. The hand test telephone can be used independently or in conjunction with the test set, depending on the type of tests to be conducted.

The hand test telephone (fig. 9-19), consists of a conveniently shaped handle with a transmitter at one end, and a receiver and dial placed back-to-back at the other end. A 2-conductor test cord with a test plug is connected to the transmitter end of the case. Two pushswitches marked C and R respectively are located externally on opposite sides of the handle toward the receiver end. A capacitor, an impedance coil, and a resistor are mounted inside the case.

Digitized by Google



27.209

Figure 9-19.—Hand test telephone.

When pushswitch C is depressed, a capacitor is connected in the transmitter circuit. The capacitor cuts off the talking circuit to permit listening only, and also prevents interference with dial pulses when plugging in the hand test telephone. Pushswitch C is released when dialing the switch being tested, or, if the switch is already in use, when using the hand test telephone to talk to another party.

When pushswitch R is depressed, a 1200-ohm resistor is connected in series with the transmitter. This resistor is used to test the operation of Strowger switches. However, this button is not used normally because the hand test telephone is provided with a 1000-ohm resistor (in addition to the 1200-ohm resistor) that automatically provides a high resistance in series with the line when testing Strowger switches.

LINE ROUTINER

The line routiner is test equipment used in testing lines of the shipboard dial telephone system. The routiner consists of two units—a test connector and a portable line test set. The test connector is located in the rear section of the 400-line cabinet.

Test Connector

The test connector is a Strowger switch mechanism which in appearance is similar to a regular connector. The circuit of the test connector, however, differs considerably from that of a regular connector in that (1) the test connector is actuated to elevate and rotate its wipers without pulses from a dial, and (2) the circuit of the test connector includes facilities for testing for the presence of line faults.

Digitized by Google

Line Test Set

The line test set includes an ohmmeter, a rheostat, three keys, and a test cord and plug. The set plugs into the test jack on the test connector and may be connected either before the testing starts or when the connector stops because of a line fault. The line test set determines the nature and resistance of the fault.

A fault which measures between 10,000 and 50,000 ohms will not interfere with the operation of the telephone apparatus but it does indicate a possible future source of trouble and should be corrected. A fault which measures less than 10,000 ohms will interfere with dialing.

Loop Resistance

For successful operation of automatic switching equipment, lines must be maintained within certain limitations of line loop resistances. Line loop resistance is the metallic resistance of the line conductors, and is the resistance measured between the automatic switchboard and the telephone instrument (exclusive of the instrument).

There are two types of line loop resistance—high loop and low loop.

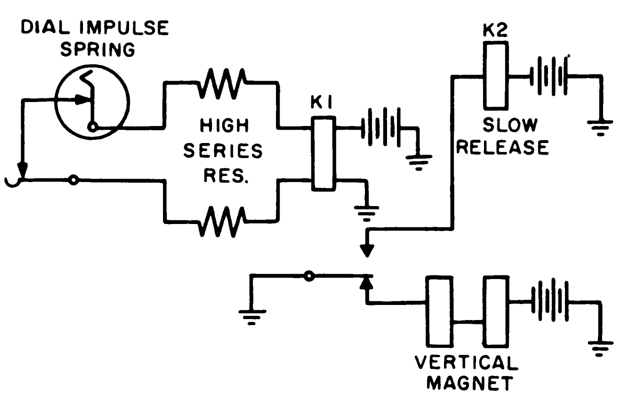
The effect of high fault loop resistance may best be analyzed by considering a line of rather high series (line loop) resistance such as shown in figure 9-20. When relay K1 operates, it sends a pulse of current to slow-to-release (SR) relay K2, and when relay K1 releases, it sends a pulse of current to the vertical magnet. If there is too much resistance in the line, relay K1 will be slow to operate and will fall away quickly on dial impulses because of the low magnetic saturation of its core. Since relay K1 falls away quickly, the pulse of current to relay K2 is too short, and relay K2 will not remain operated. The vertical magnet, on the other hand, gets too long a pulse (sometimes called a "heavy" pulse).

The second type of line fault loop resistance is low loop resistance. If there is negligible line loop resistance and low insulation resistance (fig. 9-21), a high leakage current (which constitutes a low-resistance shunt) results, and line relay K1 is held partly magnetized even after the dial impulse springs have opened the circuit. Thus, relay K1 operates too fast at the beginning of a dial pulse and releases too slowly at the end of a dial pulse. The shunt tends to maintain relay K1 operated when the dial impulse springs break because of the battery current through the shunt. Since relay K1 remains operated for a relatively long time, the vertical magnet gets too short a pulse ("light" pulse).

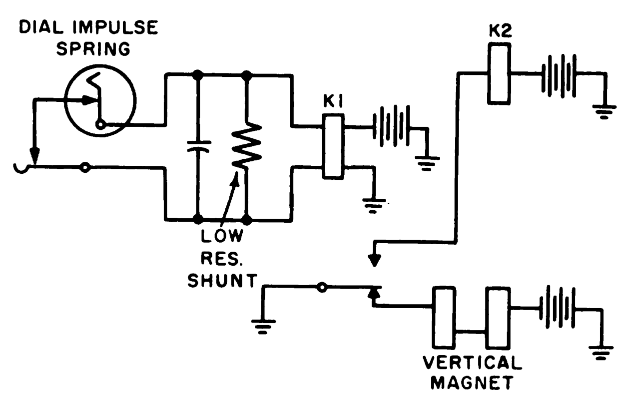
CURRENT-FLOW TEST SET

The successful operation of automatic switchboard circuits requires that the relays in such circuits perform to exact operate and nonoperate values. The operate and nonoperate requirements for each relay in a given circuit are listed in the manufacturer's technical manual.

To determine that a relay operates within the required limits, it is preferable to test



27.210
Figure 9-20.—High loop resistance circuit.



27.211
Figure 9-21.—Low loop resistance circuit.

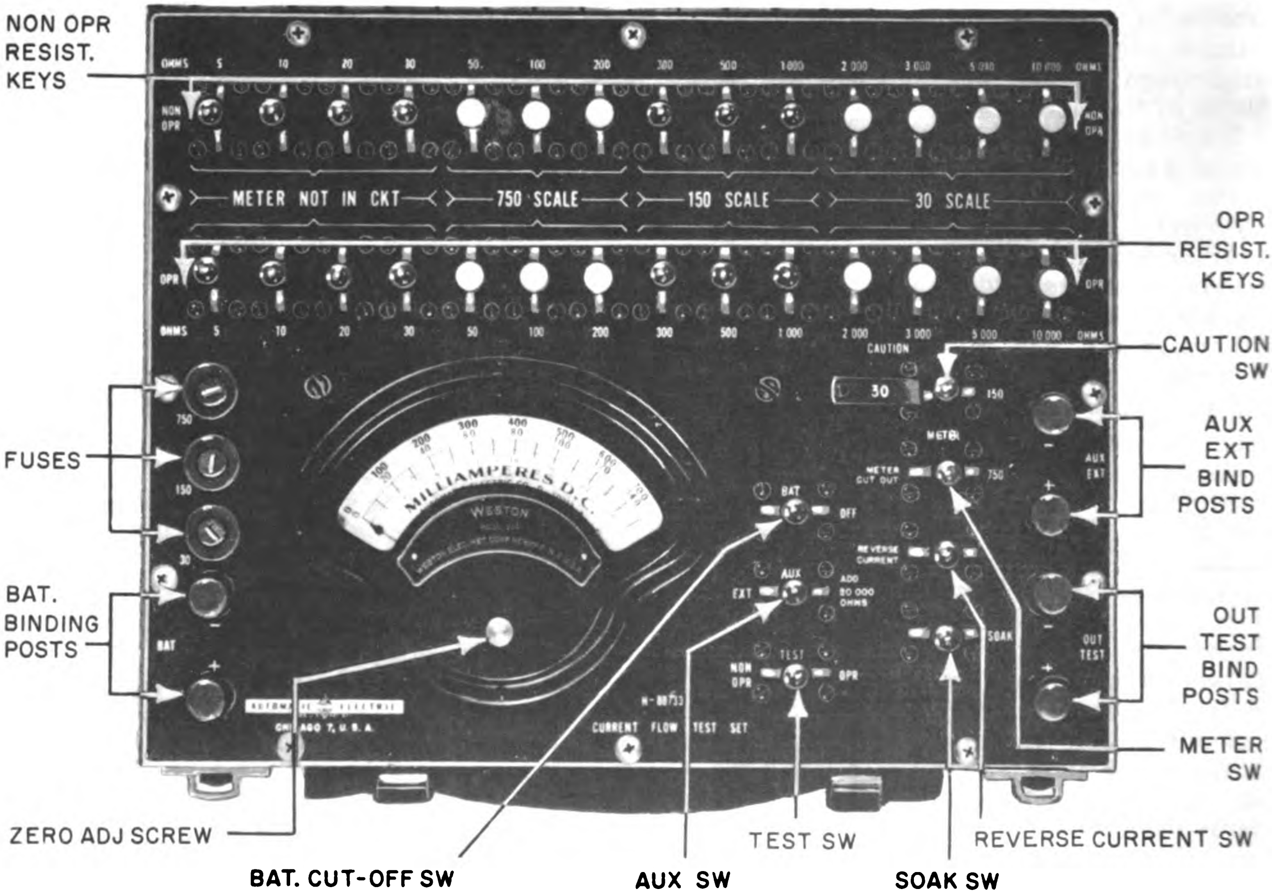
Digitized by Google

the relay with known values of current. The current-flow test set (fig. 9-22), is a means by which known values of current are directed to the relay under test. The ammeter on the test set indicates the value of the current in the test circuit, and the key-controlled resistances are a convenient means by which the flow of current in the test circuit is regulated. The test set has facilities for connecting a total of 42,215 ohms into the test circuit, 22,215 ohms by means of the resistance keys, and 20,000 ohms by operation of the auxiliary switch.

Current-flow Test Circuit

The circuit for the current-flow test set is always brought through the test switch regardless of how the set is used. Connections to the relay under test are always made at + OUT TEST which means the test circuit is not closed until the test switch is operated either to OPR or NON OPR. A typical test circuit is shown in figure 9-23.

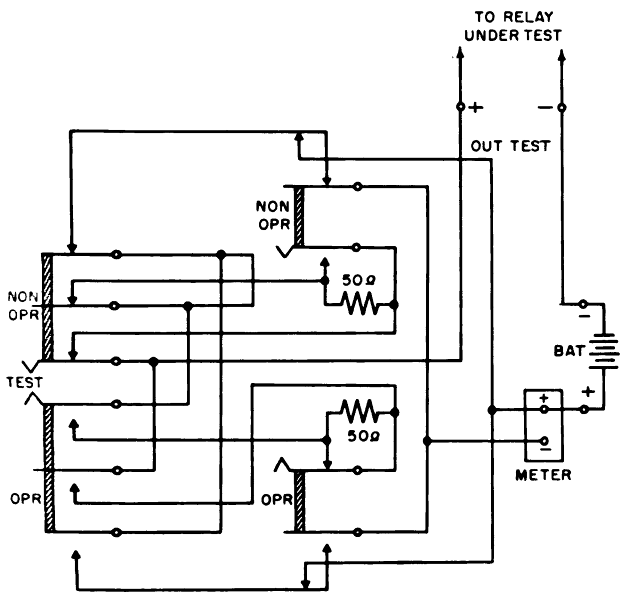
Assume that a relay winding is connected across the OUT TEST binding posts, and that a battery is connected to the BAT binding posts. Also assume that the BAT key (not shown) is at normal, that the 50-ohm NON OPR resistance key is operated, and that the test switch is thrown to NON OPR. The test circuit is from battery on the - BAT binding post, through - OUT TEST and the winding of the relay under test. The circuit continues back through + OUT TEST, through the first pair of make springs in the nonoperate section of the TEST switch, and through the NON OPR 50-ohm resistance, through the second pair of make springs in the nonoperate section of the TEST switch, through the third pair of make springs in the nonoperate section of the TEST



27.222

Figure 9-22.—Current-flow test set.

Digitized by Google



27.213

Figure 9-23.—Current-flow test set circuit, partial schematic.

switch, and through make springs on the NON OPR 50-ohm resistance key, to the negative terminal on the meter, through the meter and finally back to the positive battery on the + BAT binding post. This is the basic test set circuit and, as may be seen, the meter will measure the current flowing through the winding of the relay. The current may be increased or decreased by operating additional resistance keys.

Uses

The main function of the current-flow test set is to provide means by which current of a known value may be directed to the relay under test. In addition to its main function, however, the test set is designed to perform the following auxiliary functions.

1. It provides facilities for reversing the polarity of current flow in the test circuit without changing any leads.
2. It provides means by which a "saturate" current may be directed to the relay which is to be tested.
3. It is arranged so that it may be used as a resistance box.
4. It is arranged so that it may be used merely as a direct current milliameter to measure current up to 750 ma.

Digitized by Google

CHAPTER 10

SOUND RECORDING AND REPRODUCING SYSTEMS

Sound recording and reproducing systems are used on board ships and at shore stations to monitor radio and sound-powered telephone circuits for short-memory and permanent-record applications and to record signals for future analysis for instrumentation applications. They are used also to train, entertain, and provide religious services for personnel and for office functions, such as dictation, conference, and telephone recording.

SOUND RECORDING AND REPRODUCING TECHNIQUES

The basic techniques of recording and reproducing sound are (1) mechanical, (2) photographic, and (3) magnetic. The recording medium may consist of a disk, film, tape, or wire, which is usually determined by the recording technique.

MECHANICAL TECHNIQUE

In the mechanical recording technique, the material is mechanically cut (engraved) or deformed (embossed) as it is driven past a stylus, or cutting needle, to form a spiral groove in the recording material and thus preserve the pattern of the sound. The sound pattern can be engraved on disks and embossed on disks or films. Engraving disks are 6 1/2, 8, 10, 12, and 16 inches in diameter, and embossing disks are 7 1/2 and 16 inches in diameter. Embossing films are 60-foot continuous loops that are 35 millimeters wide.

Disk Recording

The components necessary to mechanically record sound are (1) a microphone, (2) an audio amplifier, (3) a recording head, (4) a stylus, and (5) a recording medium. The microphone converts the sound waves produced by the voice into corresponding electrical signals that are applied to the amplifier. The output of the amplifier is fed to the recording head, which converts the electrical signals into mechanical energy causing a lateral movement of the stylus. The stylus either engraves or embosses the recording medium as it moves from side to side.

In disk recording a vinalyte disk is rotated at a constant speed, and an engraving or embossing stylus forms a spiral groove in the disk. The RECORDING HEAD, which contains the stylus is driven radially across the disk by a positive drive similar to the lead screw in a lathe (fig. 10-1). The lead screw is geared to the disk drive so that as the disk rotates, the stylus advances radially at a constant speed. In most cases the recording spiral groove begins at the circumference of the disk and ends near the center.

The electric signal received by the recording head causes the stylus to swing from side to side. The lateral motion cuts or deforms the sound pattern on the walls of the groove. Thus, the stylus produces a continuous spiral groove that has small lateral variations that correspond to the audio signals.

The frequency of the sound being recorded determines the frequency of the lateral swings of the stylus, and the volume of the sound determines the amplitude of the swings. The louder the sound picked up by the microphone at a given time, the farther outward will extend the loops of the groove from the middle line of the sound pattern. The higher the pitch of the sound picked up by the microphone, the closer together will be the loops of the groove.

The components necessary to play back a disk recording are (1) a playback head, (2) a stylus, (3) an audio amplifier, and (4) a loudspeaker. When a disk recording is played back, the disk is rotated at the same speed as that at which the recording is made. The playing

Digitized by Google

7.49

Figure 10-1.—Disk recording.

stylus, or needle, rests in the groove. The playback head into which the stylus is mounted converts the mechanical movements into corresponding electrical signals, which are applied to the audio amplifier. The output of the audio amplifier is fed to a loudspeaker, which converts the electrical signals into corresponding audio signals.

Film Recording

Mechanical film recording utilizes a 60-foot endless loop of specially treated 35-mm cellulose acetate film. The recording stylus embosses a groove along the film in the same manner as the sound grooves are embossed on the vinalyte disk. An automatic tracking device shifts the recording head sideways across the film at the end of each complete loop of film so that each loop has many independent sound grooves. A tracking counter near the recording head shows which of the available 120 tracks on the film is being used.

When a film recording is played back, the tracking counter is set for the track that contains the desired recording. A log sheet with each length of film lists a record of the contents of each track. The film moves under the playback head, and the playing stylus is moved from side to side by the sound groove in which it rests. The lateral movement of the stylus induces a signal voltage in coils of the playback head, which is fed to the audio amplifier. The output of the amplifier is reproduced as sound waves by the loudspeaker. As in disk recording, sound recorded on film forms a permanent record and cannot be erased.

PHOTOGRAPHIC TECHNIQUE

In the photographic recording technique, the sound is recorded by exposing a moving photosensitive film to a beam of light, which is modulated by the sound pattern being recorded. When the film is developed, it can be reproduced by passing the sound track, which contains the light and dark areas, through a beam of light focused on a photoelectric cell. The output of the cell is fed to an audio amplifier, and then to a loudspeaker, which reproduces the electrical signals into sound waves. The methods of recording sound photographically are (1) variable area and (2) variable density recording.

Variable Area Recording

In variable area recording, the sound pattern is recorded by a small mirror mounted on a sensitive galvanometer. The modulated current

Digitized by Google

produced by the sound vibrations on the microphone is amplified and fed to a sensitive galvanometer consisting of a fine loop of wire. A small mirror is attached to this loop and the loop is suspended in a magnetic field (fig. 10-2). A beam of light from a high intensity lamp passes through

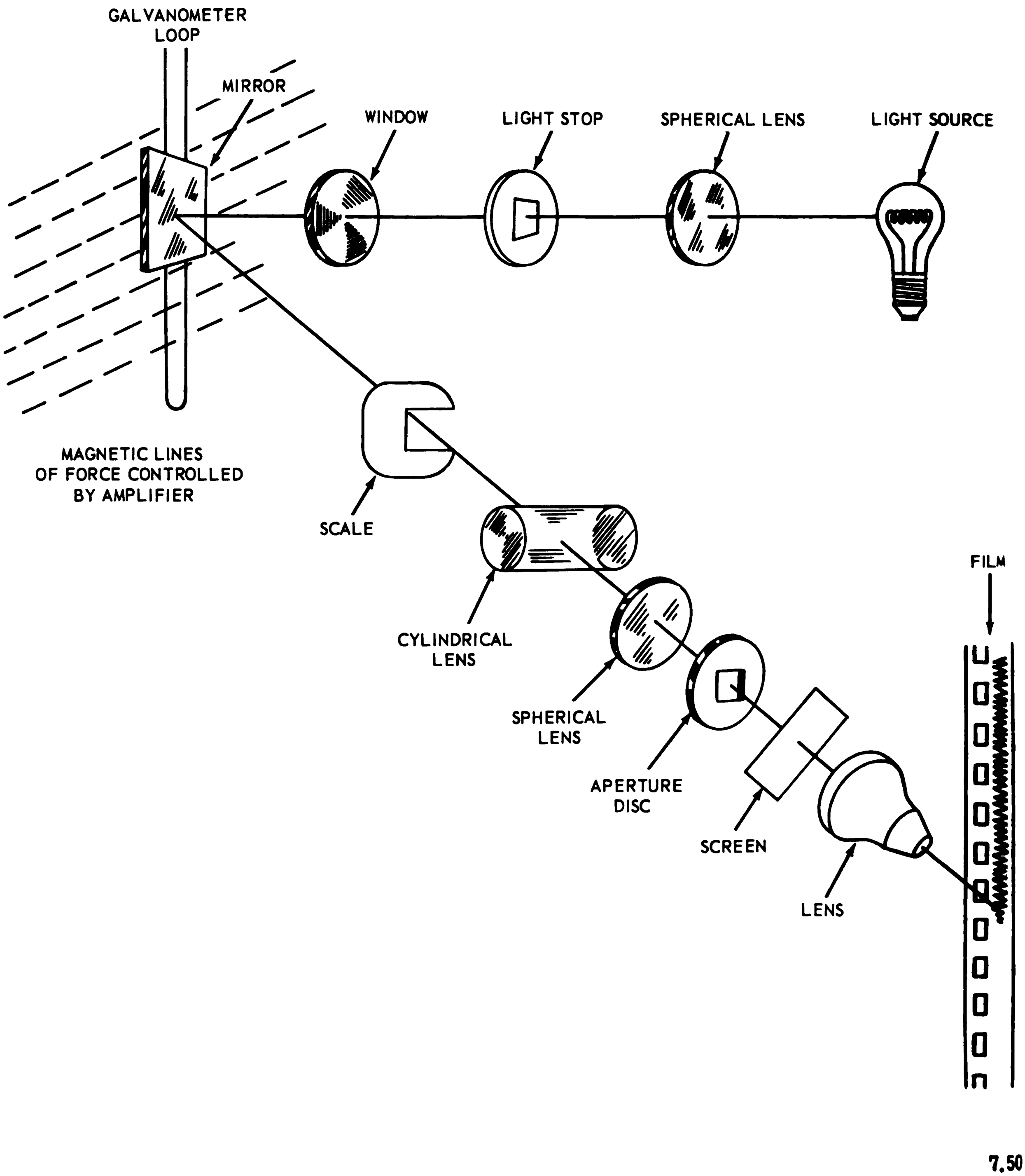


Figure 10-2.—Variable area recording.

Digitized by Google

a condenser lens and is focused on the galvanometer mirror from which it is reflected through another condenser lens to a slit or aperture. The resulting slit of light passes through a projector lens onto the film. When current flows through the galvanometer, the wire loop is set in vibration, carrying the mirror with it to trace a line of light not to exceed the width of slit across the sound track of the film. This type of sound track has a constant density and a varying width along one edge of the film.

Variable Density Recording

In variable density recording, the sound pattern is recorded by varying the densities of the image, which is produced by light passing through a special type of light valve, as shown in figure 10-3A. The light valve consists of a duralumin ribbon loop, suspended between the two pole pieces of a powerful electromagnet. The two halves of the ribbon loop are connected to a recording amplifier. The loop opens and closes in response to the input signals to allow varying amounts of light to expose the film as shown in figure 10-3B and C. This type of sound track has a varying density and a constant width along one edge of the film.

MAGNETIC TECHNIQUE

In the magnetic recording technique, a permanent magnetic material is magnetized in accordance with the pattern of the sound, as the recording medium is driven past a recording head. Similar to mechanical recording, the sound waves are picked up by a microphone, converted to corresponding electrical signals, and amplified. Unlike mechanical recording, the amplified electrical signals are applied to the recording head, which orients the magnetic particles in the tape or wire.

The recording head consists of coils wound on an iron core similar to an electromagnet. During one-half cycle, the signal current flows through the coils in one direction. The iron core becomes magnetized, and established a north and a south pole at the ends of the U-shaped electromagnet. A magnetic field exists in the air gap between the poles. When the direction of the current through the coils is reversed, the direction of the lines of force across the air gap is reversed. If a magnetic wire is placed across the gap of the magnet, most of the lines of force would be confined within the wire, and it would become magnetized.

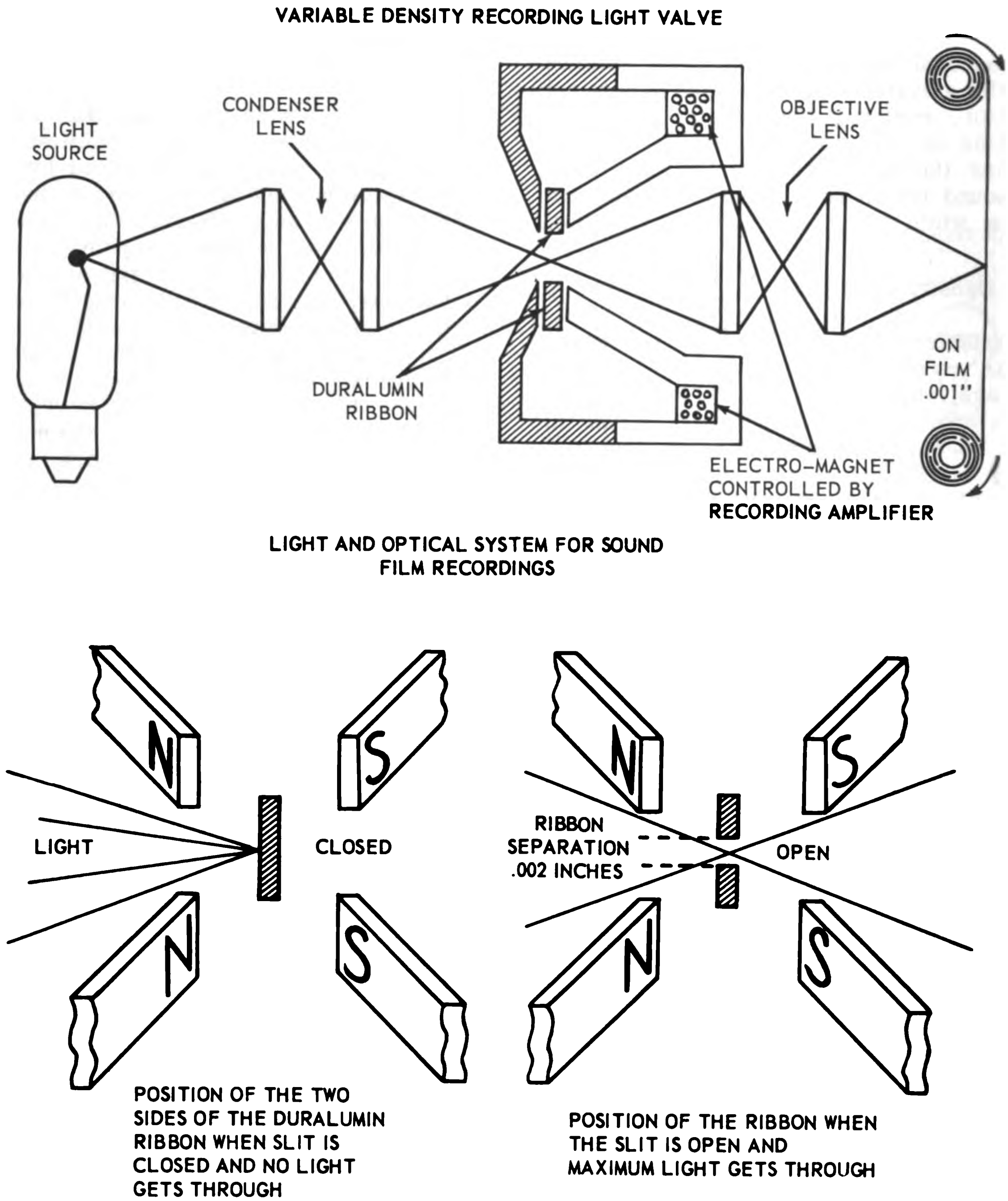
Wire Recording

In magnetic wire recording (fig. 10-4) the output signal from the audio amplifier causes an alternating current to flow through the coils of an electromagnet in the recording head. The current sets up an a-c field of signal frequency across the gaps between the pole pieces (fig. 10-4A). A stainless steel magnetic wire or nonmagnetic wire plated with magnetic material 4 mils in diameter is drawn axially through the gap at constant speed. The signal constitutes a varying mmf, which orients the molecules in the wire according to the signal pattern. The degree of orientation is proportional to the magnitude of the signal current. Thus, more energy is stored in the magnetic field of the wire with a strong signal than with a weak signal. After recording, a sucession of magnetic field patterns differing from each other in length, intensity, and direction (polarity) exists throughout the length of the wire.

When a magnetic recording is played back, the wire or tape is run through a playback head in the same direction and at the same speed that it was during recording (fig. 10-4B). A series of magnetic fields exists along the length of the recorded wire. Each field has a north and a south pole region. The lines of force extend externally from a north pole to a corresponding south pole for that region. The intensity of these magnetic fields is in proportion to the number of lines representing them.

When one of the magnetic fields lies immediately across the gap between the pole pieces of the playback head (fig. 10-4B), most of the magnetic lines of force are directed through the wire, and only a part extends out into the space surrounding the wire. As the wire moves across the gap, the varying lines of force induce an emf of signal frequency in the coil. Thus, as the recording wire is drawn across the slot of the playback head, a succession of emf's is induced in the coil. These emf's differ from one another in direction, duration, and intensity, and represent the electrical equivalent of the signal on the wire. The signals are amplified by the audio amplifier and converted into sound waves by the loudspeaker.

Digitized by Google



7.51

Figure 10-3.—Variable density recording.

Tape Recording

In magnetic tape recording, a flat paper or plastic tape is used as the recording medium (fig. 10-5). The magnetic fields that comprise the sound pattern are established on the tape, which either contains or is coated with very fine steel particles (fig. 10-5A). The recording head

Digitized by Google

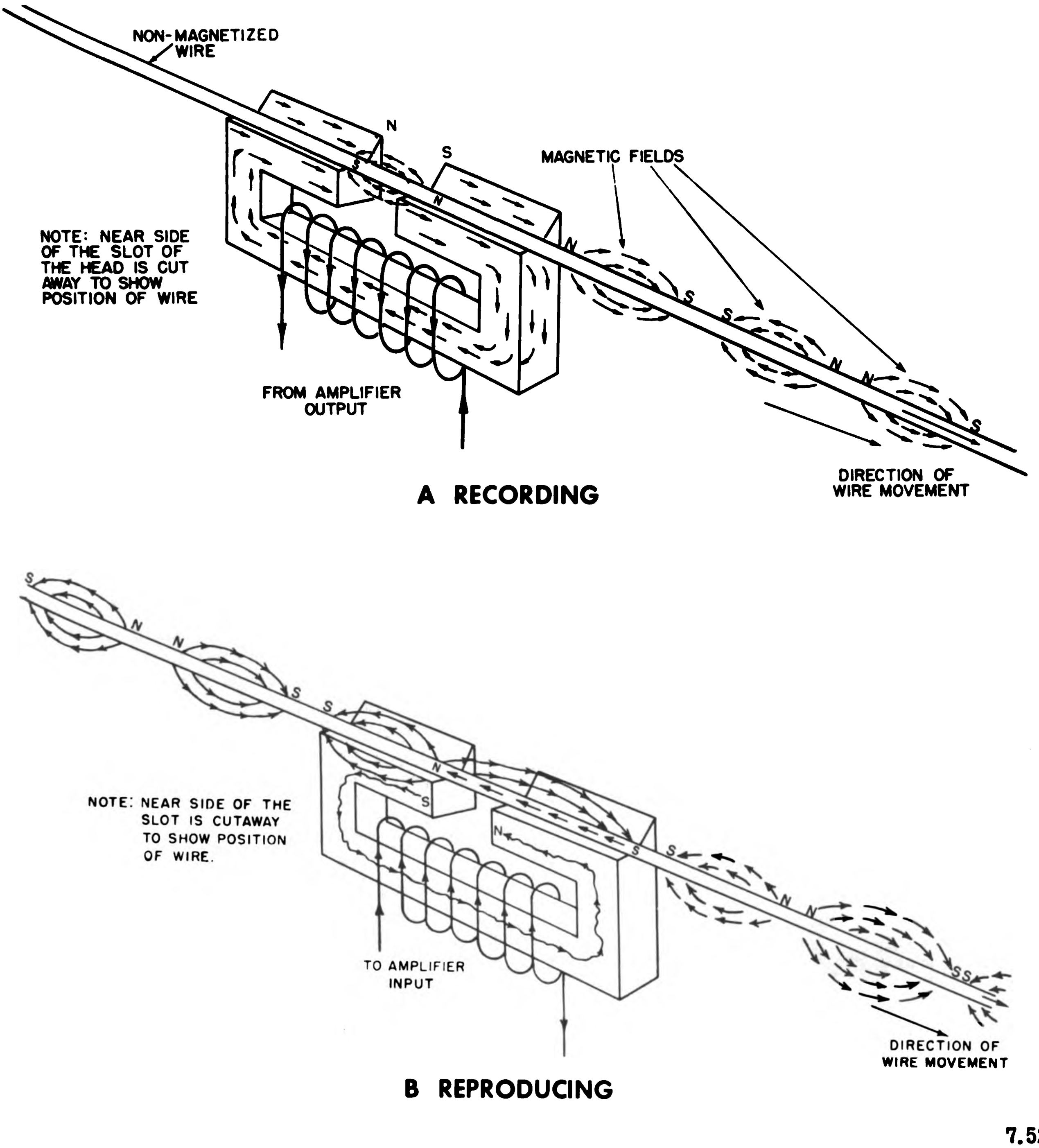


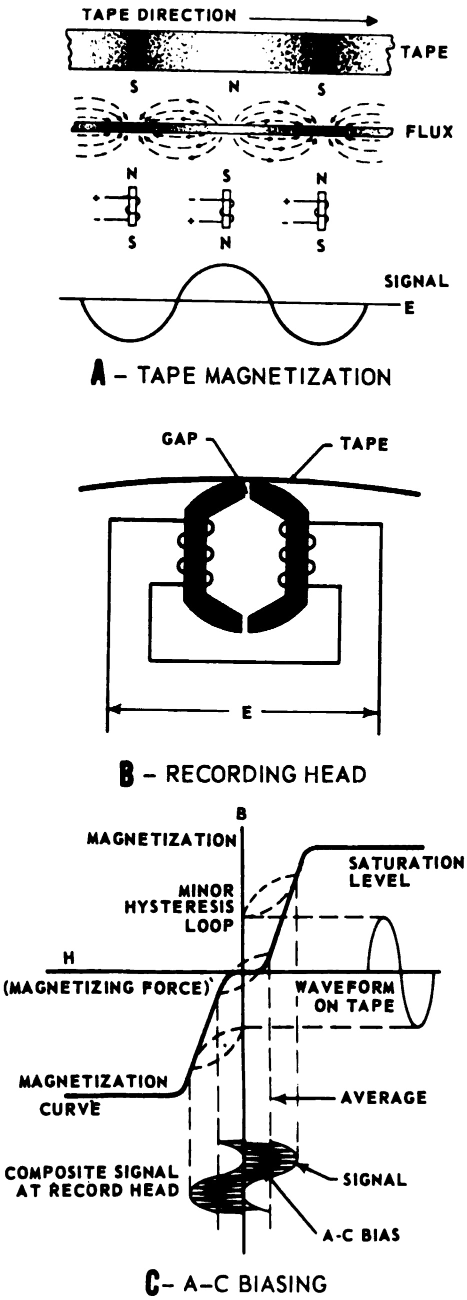
Figure 10-4.—Wire recording.

and its air gap (fig. 10-5B) comprise a series magnetic circuit. The principle involved is the same as that for wire recording, but tape recording has the advantage of being easier to handle and less expensive.

A-C Biasing

In most all magnetic recording, an a-c bias is used on which the audio signal is superimposed and applied to the recording head. This bias is

Digitized by Google



7.53

Figure 10-5.—Tape recording.

a relatively high-frequency, a-c signal, that is above the audio range, and therefore cannot be heard during playback. A-c biasing is used to obtain a substantially linear relationship between the flux density in the recording medium and the magnetizing force. Thus, the induced signal voltages are related linearly to the recording fields.

The magnetization curve (heavy line) of the iron oxide used as the recording medium is similar to that shown in figure 10-5C. At points near the origin the curve is nonlinear, and without some corrective factor the signal recorded on the tape would not be directly proportional to the signal applied to the recording head. This condition would cause distortion when the tape was played back.

The distortion is greatly reduced by mixing a high-frequency, constant-amplitude signal with the audio signal. The a-c bias is placed in series with the audio signal. This connection causes the average bias to be shifted in a positive direction on the positive alternations of the audio signal and in a negative direction on the negative alternations of audio signal. If the audio signal being recorded is of sine waveform, the flux pattern will be of sine waveform. The waveform is developed from the vertical to horizontal projections obtained from the magnetization (transfer) curve shown in figure 10-5C.

While the tape is in the recording gap the a-c bias causes the magnetization of the iron oxide to follow the dashed line loops (minor hysteresis loops). As the tape leaves the gap the influence of the mmf is reduced to zero and the degree of magnetization existing at that time depends on the remnant magnetism or that remaining when the magnetizing force is removed.

After the recording process, the flux pattern on the tape is proportional in magnitude and direction to the signal being recorded. If the tape is then moved past a reproduce head that is like the record head, the flux on the tape will induce a voltage in the coil of the reproduce head. This voltage comprises the audio signal.

Notice that the a-c bias keeps the remnant flux sufficiently removed from the origin (zero magnetization with zero magnetizing force) to prevent distortion of the audio signal. The flux pattern established by the a-c bias (100,000 cps) is of sufficiently high frequency not to be heard.

Erasing

The recorded sound track on a magnetic recording medium can be erased (by a special erase head) and the medium used again for further recording. The erase head is located

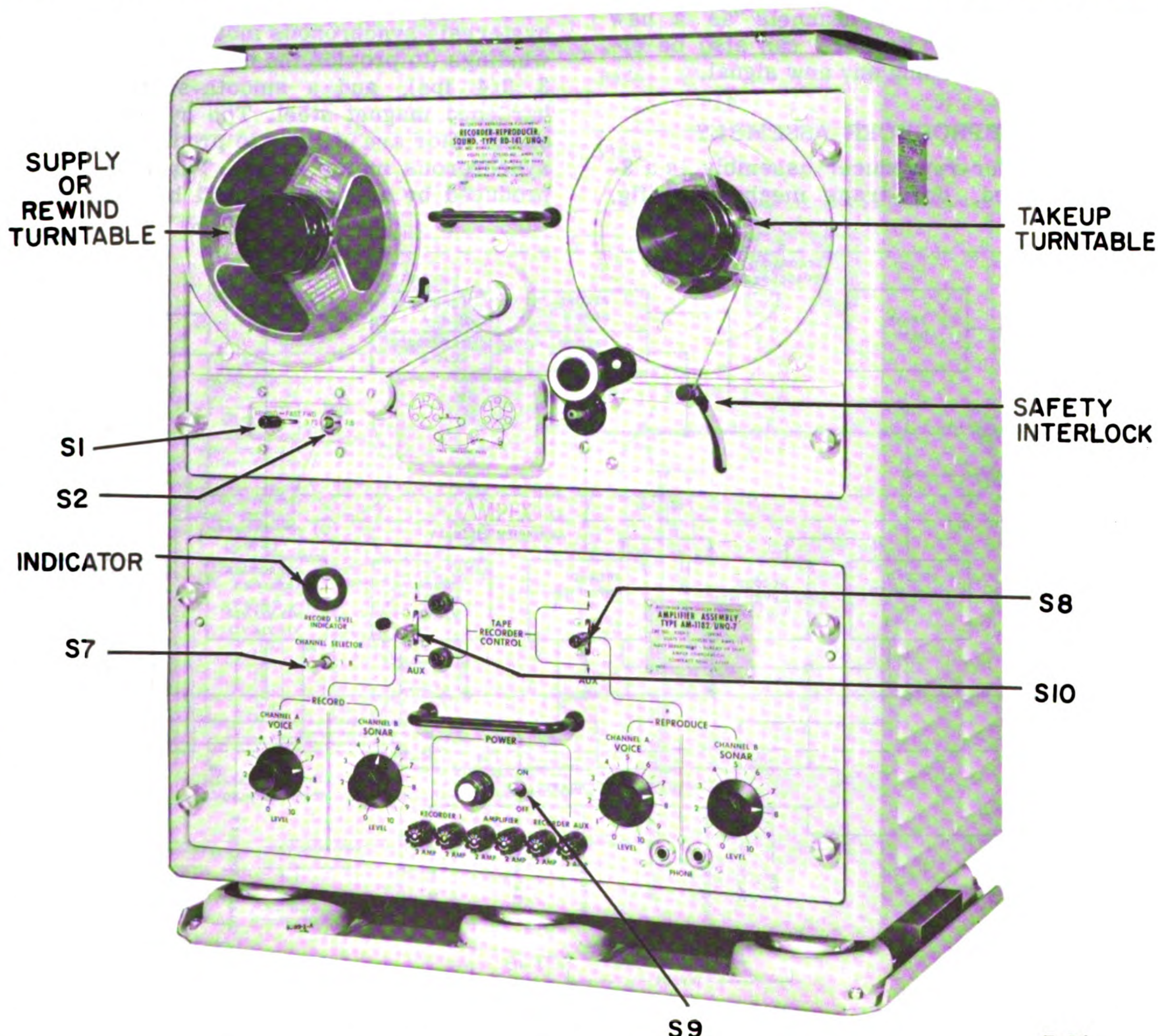
Digitized by Google

so that the wire or tape must pass through it before reaching the recording head. A high-frequency, a-c signal is fed to the erase head and thus cancels the magnetic fields from a previous recording by completely disorienting the magnetic particles in the wire or tape.

SOUND RECORDER-REPRODUCER SET

The sound recorder-reproducer set (fig. 10-6) is a dual track magnetic tape recorder and reproducer. The equipment consists of (1) a recorder-reproducer assembly, (2) an amplifier assembly, and (3) a remote control unit (not shown). The recorder-reproducer and amplifier assemblies are located in the upper and lower compartments, respectively, within a cabinet. The assemblies are equipped with rails to facilitate removal from the cabinet for servicing. External wiring to the equipment is connected to a terminal board located on a tray between the assembly compartments in the cabinet. The remote control unit is provided to start and stop the recording function at a location removed from the recorder-reproducer.

A block diagram of the sound recorder-reproducer system is illustrated in figure 10-7. The recorder-reproducer assembly consists of a 2-speed, dual-track magnetic tape transporting mechanism. The amplifier assembly consists



7.54

Figure 10-6.—Sound recorder-reproducer set.

of a dual record amplifier subassembly, dual reproduce amplifier subassembly, power supply subassembly, and record level indicator subassembly.

Two information channels are provided—channel A is for voice recording and channel B for recording sonar information. The input signal to channel A can be derived from a microphone or line input, whereas the input to channel B must be derived from a line input.

Recordings can be made at tape speeds of 7 1/2 or 3 3/4 inches per second (ips). Recording and reproducing can take place simultaneously, or the reproducing can be performed subsequent to the recording process. The equipment automatically erases prior recordings simultaneously on both channels as a new recording is made. Erasure can also be effected without recording any new signal.

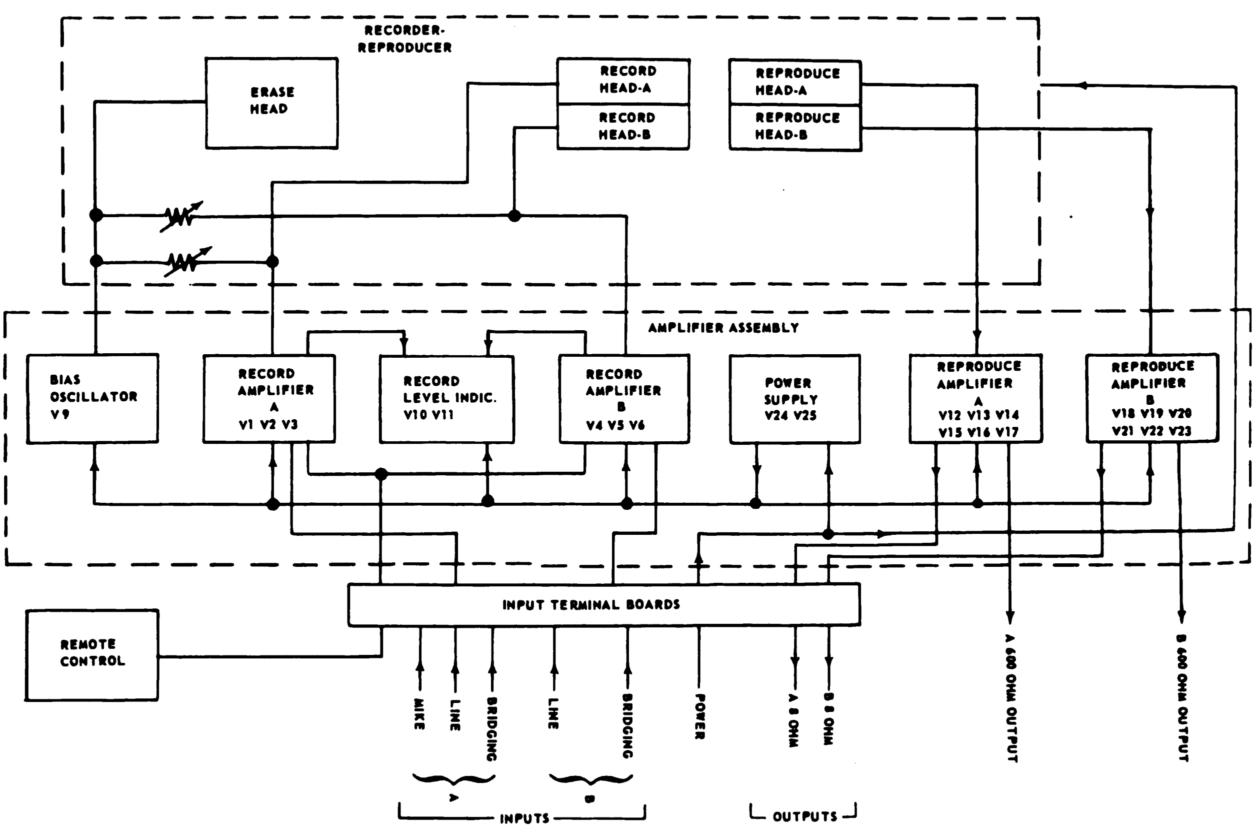
RECORDER-REPRODUCER ASSEMBLY

The recorder-reproducer assembly is a 3-motor, 2-speed, dual-track mechanism (fig. 10-8) consisting of (1) tape-drive components, (2) rewind and takeup components, (3) head assembly, and (4) control box. Provisions are made for stopping mechanical operation at the end of a reel or if tape breakage occurs, and to warn the operator at the remote control unit when operation approaches the end of a reel. Tape speed and fast winding are controlled by switches on the front panel of the recorder-reproducer.

Tape-Drive Components

The tape-drive components comprise a capstan drive motor, capstan, and capstan idler.

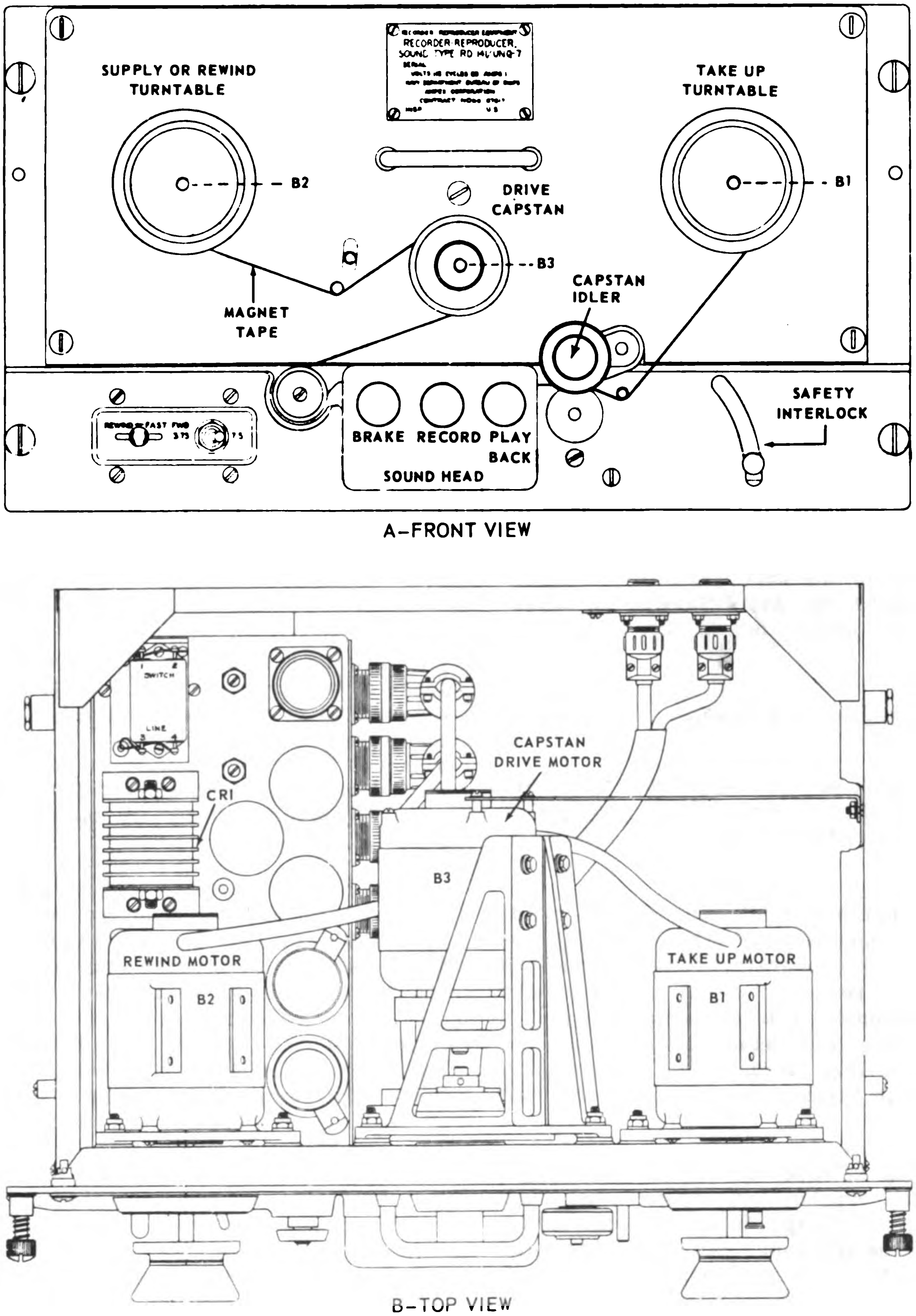
The capstan drive motor B3 (fig. 10-8) is a hysteresis synchronous motor having two stator windings (to provide the tape speeds of 7 1/2 and 3 3/4 ips), and a smooth-surface rotor of hardened magnet steel. The hysteresis losses of the rotor are utilized to produce the effective synchronous motor action. The load torque is produced by an angular shift between the axis



7.55

Figure 10-7.—Block diagram of sound recorder-reproducer system.

Digitized by Google



7.56

Figure 10-8.—Recorder-reproducer assembly.

Digitized by Google

of the rotating primary (stator) mmf and the axis of the secondary (rotor) magnetization. The torque is substantially the same from standstill up to synchronous speed. This type motor is limited to small sizes because of the small torque that can be derived from the hysteresis losses. When power is applied, the drive motor will start and the capstan will rotate.

The CAPSTAN is belt-driven from a flywheel pulley attached to the shaft of the drive motor. The drive belt tension is maintained by a springloaded pivot arm on which is mounted the CAPSTAN IDLER. The capstan idler consists of a rubber-tired idler wheel mounted on an arm which is attached to the shaft of a rotary solenoid. When the capstan idler solenoid is energized, it moves the idler arm against the capstan, providing a bearing surface for the capstan, which drives the magnetic tape at a constant speed.

A TAPE guide positions the tape vertically with respect to the head assembly. A REEL IDLER smooths out any transient variations in tape speed originating in the tape supply reel.

Rewind and Takeup Components

The rewind and takeup components are identical in construction. Each consists of an induction motor, brake drum, and turntable.

The rewind motor B2, and takeup motor B1, are so connected that when power is applied, one motor operates at full torque and the other at reduced torque. In the record or reproduce mode, A series resistor is placed in each rewind and takeup motor circuit to reduce the normal torque of the motors while optimum tape tension is obtained at each reel.

The reels of tape are isolated from each other by the capstan and capstan idler. The capstan pulls the tape from the supply reel, overcoming the difference in torque of the rewind motor, which provides hold-back tension. A tape loop will be thrown when any malfunction of the equipment allows the feed rate to exceed the takeup rate. If the loop is sufficiently large, or if tape breakage occurs, the safety switch arm will be released to actuate the safety switch, and stop the equipment.

In the FAST FORWARD MODE of operation, the series resistor is removed from the takeup motor circuit, and a resistor is placed in the rewind motor circuit. The takeup and rewind motors operate at full and reduced torques, respectively, and the capstan pulls the tape from the supply reel (on the rewind turntable) to the takeup reel (on the takeup turntable), overcoming the reduced torque of the rewind motor. The tape tension is proportional to the difference in the forces exerted at the periphery of the two reels.

In the REWIND MODE of operation, the foregoing procedure is reversed. The resistor is removed from the rewind motor circuit, and a resistor is placed in the takeup motor circuit. The rewind motor will operate at full torque, the takeup motor at reduced torque, and the tape will be pulled from the takeup reel to the supply reel being held under tension by the reduced torque of the takeup motor.

When the equipment is being operated in any mode of tape travel, the correct tape tension is determined by the power applied to the rewind and takeup motors. However, when power is removed from these motors the forces exerted on the tape are removed, and the tape tension must be maintained by the operation of the brakes.

The brakes consist of brake drums attached to the shafts of the takeup and rewind motors and brake bands equipped with high-tension and low-tension springs, which determine the braking force applied for each direction of rotation. The brake bands are held from contact with the brake drums by the brake solenoid when the equipment is operated under any mode. When power is removed from the equipment the solenoid is deenergized and allows the brake bands to move into contact with the brake drums. To avoid throwing tape loops as the tape comes to a stop, it is necessary that the braking force on the trailing turntable (turntable from which tape is being pulled) always be greater than that which is applied to the leading turntable (turntable which is taking up the tape). However, the braking differential must not be so great that the tape is in danger of being deformed or broken.

Digitized by Google

Head Assembly

The head assembly consists of an erase, record, and reproduce head (fig. 10-8). In the record or reproduce modes of operation, a point on the tape will pass over the erase, record, and reproduce heads in that order. The outer tracks of the record and reproduce heads are for channel A, and the inner tracks are for channel B. The erase head is full track, and thus erases the full width of the tape on both channels.

Control Box

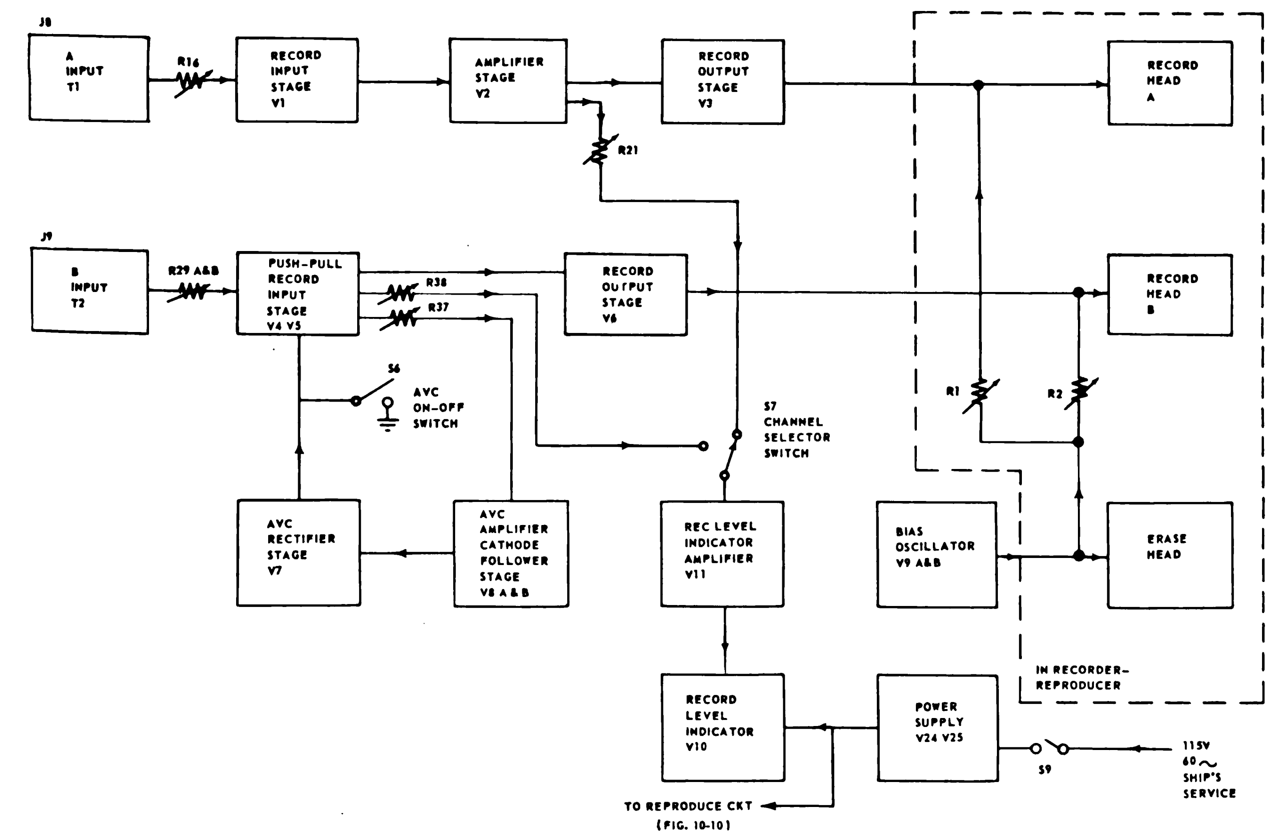
The control box contains the electrical components associated with the control of tape motion. These components include the time delay relay, takeup relay, rewind relay, play relay, rectifier, and filter circuit to provide 115-volt, d-c power to operate the relays and solenoids. Also included are the resistors and capacitors for the takeup, rewind, and drive motors, the control switches, and reel-end warning mechanism. The rewind-fast forward switch S1, and tape speed switch S2, protrude through an opening in the front panel of the recorder-reproducer assembly (fig. 10-8).

AMPLIFIER ASSEMBLY

The amplifier assembly is divided into the (1) record, (2) reproduce, and (3) power supply subassemblies.

Record Subassembly

The record subassembly is illustrated by the block diagram in figure 10-9. It consists of the two record amplifiers, the AVC circuit for the channel B record amplifier, the bias oscillator, and the record level indicator.



7.57

Figure 10-9.—Block diagram of record circuit.

Digitized by Google

The record amplifier (voice) for channel A (fig. 10-9) will accept inputs of 150-ohm microphone, 200,000-ohm balanced bridging line, and 600-ohm balanced line. The input connections depend on which type is desired. The microphone connects directly to the step-up input transformer T1. Resistors in the cabinet wiring (not shown) provide the matching impedance and signal attenuation for the 200,000-ohm balanced bridging line and the 600-ohm balanced line. The secondary of T1 is connected through the record level control R16, to the grid of V1, which is a triode-connected pentode to reduce noise. The plate of V1 is R-C coupled to the grid of V2. The signal from V2 is applied to the grid of the record output stage V3. The output stage V3, drives the record head through the record head relay (not shown).

A feedback resistor in the cathode circuit of V3 provides inverse feedback to the grid to furnish a constant current versus frequency characteristic in the amplifier output. A series resonant circuit (resonant at approximately 11 kc) is connected across the feedback resistor. As the signal frequency approaches this resonant condition, the resistor is shunted by the decreasing impedance of the resonant circuit, resulting in a higher signal amplitude at the plate of V3. Thus, high-frequency preemphasis is accomplished to compensate for the droop in the record- and reproduce-head characteristics caused by core losses, self-demagnetization of the tape at short wavelengths, and the wavelength approaching the gap dimensions. The signal fed to the record level indicator is picked up at the record level calibration potentiometer R21, between V2 and V3. The high-frequency record bias, derived from the bias oscillator V9, is adjusted in amplitude in the recorder-reproducer assembly and mixed with the signal to be recorded.

The record amplifier (sonar) for channel B (fig. 10-9) will accept inputs of 30,000-ohm balanced bridging line and 600-ohm balanced line. The input connections depend on the type desired. The 30,000-ohm balanced bridging input is connected to the primary of the input transformer T2, through isolating resistors in the cabinet wiring (not shown). The balanced 600-ohm line is connected across a matching resistor (not shown) and then through the same isolating resistors to the input transformer T2.

The signal at the balanced secondary of T2 is applied through the dual record level control R29A and R29B, to the grids of the push-pull amplifier input stage V4 and V5. The output of V4 and V5 is transformer coupled to the grid of the record output stage V6. Low-frequency compensation is employed in the plate circuit of the push-pull input stage V4 and V5, to extend the l-f recording capabilities of this amplifier.

The output signal of V6 is fed through the record head relay K6 (not shown), mixed with the high-frequency record bias derived from the bias oscillator V9, adjusted in the recorder-reproducer assembly, and delivered to the record head. Two signals, one to be delivered to the record level indicator V11, and one to be delivered to the AVC circuit V8, are adjusted at the potentiometers R38 and R37, respectively. A series resonant circuit across the V6 cathode inverse feedback resistor provides high-frequency preemphasis in the same manner as the channel A record amplifier, V3, previously described.

The AVC circuit (fig. 10-9) derives its signal voltage from the potentiometer R37, across the secondary of the V4-V5 output transformer in the channel B record amplifier. The adjusted voltage is amplified by V8B and fed to the grid of the cathode follower stage V8A. The output of V8A supplies the signal voltage to the AVC detector stage V7, which is a twin diode rectifier, the sections of which are connected in parallel. The rectified AVC voltage is filtered and applied to the grids of the push-pull input stage, V4 and V5, of the channel B record amplifier to limit its gain in accordance with the amplitude of the input signal.

The switch S6, is the AVC on-off switch (fig. 10-9). When S6 is in the OFF position, the grids of the push-pull input stage, V4 and V5, of the channel B record amplifier are returned to ground through the dual record level control, the AVC voltage is shorted to ground, and thus the AVC circuit does not operate. The AVC circuit utilizes a voltage-delay feature so that the AVC action does not function until the signal reaches a certain preadjusted amplitude. This action is accomplished by applying a positive bias voltage to the cathode of the detector stage V7, so that it will not conduct, and consequently cannot develop the AVC voltage until the peak signal exceeds the bias (delay) voltage.

The bias oscillator V9 (fig. 10-9) provides both the high-frequency record bias and the erase current. It consists of twin triode V9A and V9B, which is a conventional Colpitts push-pull oscillator operating at a nominal frequency of 100 kc. The exact frequency, however, is

Digitized by Google

not critical. Any signal at the grid of V9A is amplified in the plate circuit, coupled to the grid of V9B, and appears at the plate of V9B. The signal is then coupled back to the grid of V9A in phase with the original signal to produce positive feedback and oscillation.

The energy from V9 is taken from the secondary of the associated output transformer (the primary of which is the oscillator tank coil) through the record head relay K6 (not shown) to the erase head. The record bias current is adjusted and delivered to the record heads (fig. 10-9) through potentiometer R1 (channel A) and through potentiometer R2 (channel B) located in the recorder-reproducer assembly. Plate voltage is applied only when the equipment is operated in the record mode. The noise balance control (not shown) is common to both grids of V9, and is adjusted to eliminate distortion in the oscillator waveform, which would cause a d-c component in the record head and tend to magnetize the head.

The record level indicator (fig. 10-9) consists of a cathode-ray tube V10, and a signal amplification stage V11. The signal voltage for the record level indicator is derived from the potentiometer R21 (channel A) and potentiometer R38 (channel B) connected in the grid circuits of the final stage of each record amplifier before the high-frequency preemphasis is applied. Potentiometers R21 and R38 are used to calibrate the record level indicator. The signals are routed to the channel selector switch S7, to select the channel to be visually monitored by the level indicator.

An individual signal is fed from switch S7 to the grid of the amplifier V11, the output of which is fed to the vertical deflection plates of V10. The horizontal sweep for V10 is provided by a sinusoidal, 60-cycle voltage (approximately 10 volts) derived from the secondary of the power supply transformer. This arrangement provides a sweep of approximately 1/8 inch to prevent burning of the phosphor on the tube, and to furnish width to the cathode-tube presentation. The half-wave rectifier V24, supplies-600 volts, direct current to the grids of V10, and the full-wave rectifier V25, supplies plate voltage to V11 when the power switch S9, is in the ON position.

External adjustments to the level indicator can be made by means of controls located on the back of the record level indicator subchassis. These controls include horizontal centering, vertical centering, focus, and intensity.

Reproduce Subassembly

The reproduce subassembly is illustrated by the block diagram in figure 10-10. It consists of two identical reproduce amplifiers, one for channel A, and one for channel B.

The reproduce amplifier for channel A (fig. 10-10) consists of a 6-stage, resistance-coupled audio amplifier with a transformer-coupled push-pull output. The leads from the reproduce head enter the amplifier assembly at J11 and connect to contacts of the reproduce head relay K10 (not shown). These relay contacts connect the reproduce head to the grid of the input stage V12A, of the reproduce amplifier.

A reproduce equalization circuit consisting of a relay (K9) and either of two resistors, depending on the position of the tape speed switch S2 (fig. 10-6), is included in the plate circuit of V12A. Relay K9 is controlled by the tape speed switch on the recorder-reproducer and selects the appropriate equalization circuit for the speed involved.

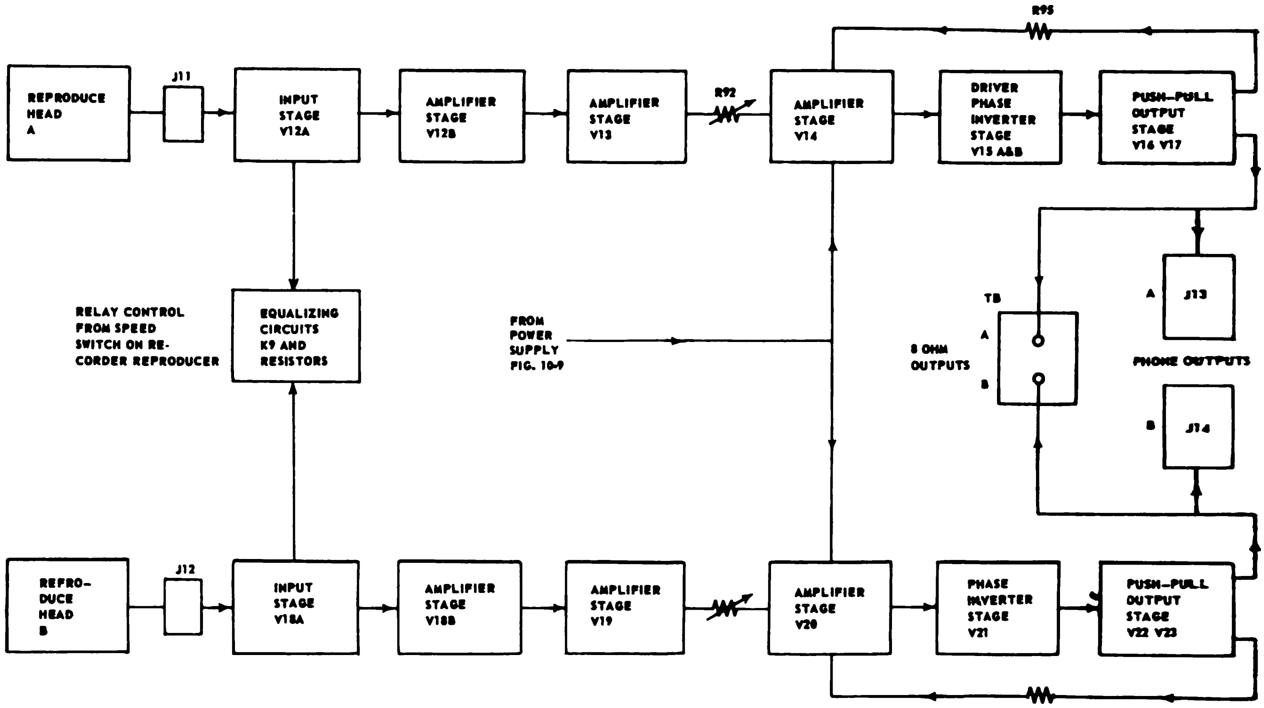
The input stage V12A, is followed by V12B, V13, the reproduce level control R92, triode V14, driver stage V15A, phase inverter stage V15B, push-pull output V16 and V17, and the output transformer. A negative feedback of approximately 10 db is obtained from the tertiary winding on the output transformer. The tertiary winding is connected through R95 to the cathode of V14.

The cathodes of V15A and V15B are not grounded directly, but are fed to contacts of the reproduce switch S8 (fig. 10-6) to ground. Thus, when S8 is in the neutral (middle) ungrounded position the reproduce amplifier is disabled to prevent the reproduction of any material when the tape is operated in the fast forward or rewind mode. Plate voltages are applied to all stages when the power switch S9, is in the ON position. The output transformer is connected to two parallel outputs, one of which is a 2-circuit phone plug on the front panel of the amplifier assembly and the other output is on the terminal boards in the cabinet.

Power Supply Subassembly

The power supply furnishes all the power requirements for the entire equipment except for the 115-volt, d-c power supplied by the rectifier CR1 (fig. 10-8) in the control box to operate the solenoid and relay in the recorder-reproducer assembly.

Digitized by Google



7.58

Figure 10-10.—Block diagram of reproduce circuit.

The a-c power input to the power transformer is controlled by the on-off power switch S9 (fig. 10-9) located on the front of the amplifier assembly. The half-wave rectifier V24 (fig. 10-9) supplies the -600 volts d-c for the cathode-ray tube V10, in the record level indicator. This voltage is filtered. The full-wave rectifier V25, supplies the plate voltage for all the other tubes in the amplifiers. This voltage is also filtered. Additional resistor-capacitor filter sections are provided as decoupling networks for various circuits in the amplifiers.

OPERATION

The operating controls and indicators for the recorder-reproducer set are located on the front panels of the recorder-reproducer assembly and on the amplifier assembly (fig. 10-6). Two headphone jacks, one for channel A and one for channel B, are located on the front panel of the amplifier assembly. High impedance headphones can be plugged into these jacks to provide monitoring of the reproduce output of either channel.

The record switch S10, and the reproduce switch S8, each has two positions designated 1 and AUX. The AUX position, and the AUX indicator are not normally activated but are provided for use if an auxiliary recorder-reproducer is added to the system.

Recording

To place the equipment in the record mode, install a full reel of magnetic tape on the left-hand (supply or rewind) turntable and an empty reel on the right-hand (takeup) turntable (fig. 10-6). The tape threading path between the reels is engraved on the front panel of the recorder-reproducer assembly. Hold the tape by one finger on the hub of the takeup reel and rotate the reel several revolutions in a counterclockwise direction to anchor the tape on that reel. Continue turning the takeup reel until the tape tension holds the safety arm in the upper portion of its clearance slot.

Schematic diagrams of the amplifer and recorder-reproducer assemblies are shown in figures 10-11 and 10-12, respectively.

When S9 (fig. 10-11) is placed in the ON position, a-c power is applied through F5 and F6 to the T6 primary. It is also applied through F2,

Digitized by Google

terminals 6 and 5 of J15, terminal G of J2, through terminals 4 and 6 of S2, to B3, returning via terminal A of J2 to F1. Motor B3 will start. The circuit to CR1 is also completed from F2 and F1 via terminals N and A on J2.

The d-c control power circuit is from F2 to terminal N on J2, CR1, and S5 in the operated position where the circuit then branches. One branch extends to S1 via contacts 8-9 of K4. The other branch extends to contacts 8-9 of K2 and K3 and contacts 4-5 of K1 to terminal L of J2. From terminal L the circuit branches to contact 1 of S10, contact 7 of S8, and contact 4 of K7.

Next, connect a signal, corresponding to that which will normally be recorded, to the inputs of either or both channels and place the channel selector switch S7 (fig. 10-6) in either A or B position to select the appropriate channel on which the record level is to be set. Observe the vertical amplitude of the signal on the record level indicator. If necessary, adjust the appropriate record level control until the signal peaks occupy the space between the upper and lower horizontal lines. Reverse the position of the channel selector switch S7, and repeat the foregoing procedure for the other channel.

The equipment is now ready to record simultaneously on both channels at normal operating level. To start the recording process, hold the record safety interlock to the left (fig. 10-6) and place the record switch S10, in position 1. The tape will start in motion and the record indicator 1 on the amplifier assembly will light (fig. 10-6). Reset the record level control(s) if necessary.

When the record switch S10 (fig. 10-11) is placed in position 1, contacts 1-2 complete the d-c circuit to the coil of relay K7 from terminals L and A on J2. Contacts 4-12 of relay K7 complete the circuit across terminals L and M of J2, through the coil of play relay K4 (fig. 10-12), and through the capstan idler solenoid, L1, causing the idler to force the tape against the capstan and start tape motion. Contacts 5-6 of relay K7 (fig. 10-11) complete the circuit to apply a-c power to the record indicator in the remote control unit (not shown) and contacts 1-11 break to open the circuit to the standby indicator in the remote control unit. Contacts 10-14 and 8-9 of relay K7 complete the circuit to apply B+ power to the final stages of the record amplifiers and to the bias oscillator. Contacts 7-13 of relay K7 complete the circuit to light the record 1 indicator.

When the play relay K4 (energized through contacts 4-12 of relay K7) operates, contacts 7-8 complete the d-c circuit to the brake solenoid, L2, which pulls the brakes from contact with the brake drums (fig. 10-12). Contacts 5-6 of relay K4 complete the a-c circuit to the takeup motor B1, and the rewind motor B2, through R4 and R6, and the normally closed controls 4-5 of relays K2 and K3, respectively.

When the reel-end warning switch S3 (fig. 10-12) is actuated by the angle of the tape as it leaves the supply reel, the flasher switch motor FL1, is energized through contacts 5-6 of play relay K4 and contacts 1-2 of switch S3. The flasher switch motor intermittently opens and closes the circuit to the record indicator on the remote control unit, causing the indicator to flash on and off.

The recording process can be stopped at any time by returning the record switch S10, to the NEUTRAL (middle) position (fig. 10-6). It is not necessary to manipulate the record safety interlock. Thus, the recording function can be started or stopped whenever it is desired through the run of a reel, with the equipment returning to the standby condition whenever the record switch S10, is in the neutral position. The tape-motion components will be automatically deactivated at the end of a reel.

Recording from Remote Control Unit

The remote control unit (not shown) provides the remote operator with facilities for placing the equipment in the record mode of operation from the standby condition. The standby indicator denotes that power is applied and that tape is threaded at the recorder-reproducer. It does not denote that proper tape speed is selected or that the recording levels have been adjusted. The standby indicator will not light when power is not applied, or when the tape is not properly threaded, or if the equipment is being used to reproduce a previously recorded tape.

The record indicator on the remote control unit denotes that the equipment has been placed in the record mode of operation either at the recorder-reproducer. The record indicator will start flashing on and off approximately five minutes before the end of a reel of tape. This action will occur only when the end of the reel is approached with the equipment in the record mode. The record indicator will be extinguished and the standby indicator will light.

Digitized by Google

The standby record switch on the remote control unit simply parallels the record switch S10, on the recorder-reproducer set. Thus, if either switch is in the RECORD position, it is not possible to stop the record mode at the other location. It is possible to place the equipment in the record mode when a previously recorded tape is being reproduced. Therefore, the standby record switch on the remote control unit should only be moved from its STANDBY position when the standby indicator is lighted. A previously recorded tape will be erased if run with the equipment in the record mode.

Reproducing

To place the equipment in the reproduce mode, operate the power switch S9 to the ON position and the tape speed selector switch S2 (fig. 10-6) to the speed position in which the recording was made. When the reproduce switch S8 is in position 1, tape motion will start and the reproducing function will be in process on both channels simultaneously.

When the reproduce switch S8 is in position 1, contacts 7-8 (fig. 10-11) complete a d-c circuit across terminals L and M on J2 through the coil of the play relay K4, and the capstan idler solenoid L1 to terminal A on J2 (fig. 10-12). The capstan idler forces the tape against the capstan to start tape motion. The operation of play relay K4 is the same as that described for the recording function. The reproduce switch S8 also opens the circuit through contacts 1-3 to extinguish the standby indicator at the remote control unit (not shown).

When the tape speed selector switch S2 is in the 7 1/2 speed position (fig. 10-12), the circuit to the equalization relay K9 is interrupted at contacts 1-2, and K9 is not energized. Contacts 4-5 and 8-9 of relay K9 (fig. 10-11) select the 7 1/2 speed equalization circuits for the reproduce amplifiers. When the tape speed switch S2 is in the 3 3/4 speed position, contacts 1-2, complete a circuit through the equalization relay K9, via terminals S and H on J2 and contacts 10 and 11 on S8. Contacts 5-6 and 7-8 of relay K9 select the 3 3/4 speed equalization circuits for the reproduce amplifiers.

Contacts 4-5 of the reproducer switch S8 provide the ground return for the cathodes of the phase inverter stages V15A and V15B of the reproduce amplifiers.

To stop the reproduce funciton, return the reproduce switch S8 to the NEUTRAL position. Thus, the reproduce function can be started and stopped as desired through the run of a reel, with the equipment returning to the standby condition when the reproduce switch is in the NEUTRAL position. The tape-motion components will be automatically deactivated at the end of a reel.

Simultaneously Recording and Reproducing

To record and reproduce simultaneously, place the equipment in the record mode. Operate the power switch S9 (fig. 10-6) to the ON position and the tape speed selector switch S2 in the appropriate position to select the desired recording speed.

Connect a signal corresponding to that which will normally be recorded to the inputs of either or both channels and place the channel selector switch S7 in either the A or B position to select the appropriate channel on which the record level is to be set. Observe the vertical amplitude of the signal on the record level indicator, and, if necessary, adjust the appropriate record level control. Reverse the position of the channel selector switch S7, and repeat the check on the amplitude of the signal.

The equipment is now ready to record simultaneously on both channels at normal operating level. To start the recording function, hold the record safety interlock to the left and place the record switch S10, in position 1. The tape will start in motion, and the record indicator 1 will light. Reset the record level control if necessary.

Place the reproducer switch S8 in position 1. The information being recorded on both tracks of the tape will now be reproduced. The tape passes over the erase, record, and reproduce heads in succession. Adjust the reproduce level controls for the desired output level on both channels.

Acoustical feedback may result when recording from a microphone and simultaneously reproducing from a loudspeaker at the same location. This condition can be prevented by proper placement of the microphone and loudspeaker and appropriate adjustment of the reproduce level control so that little or none of the loudspeaker output is fed back into the microphone. A slight time delay will be noticed between the introduction of the input signal and the acoustical output of that signal at the loudspeaker because of the placement of the record

Digitized by Google

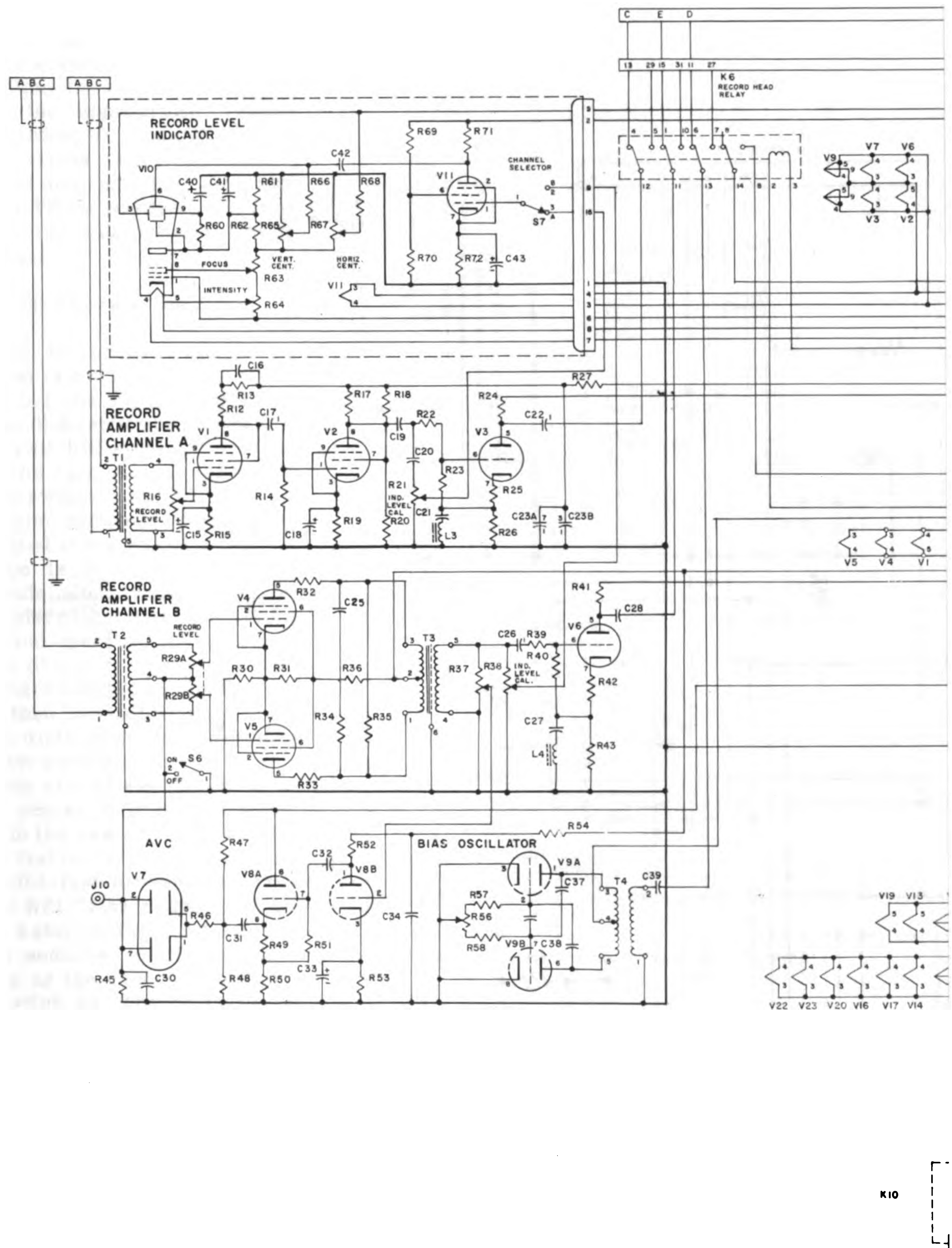
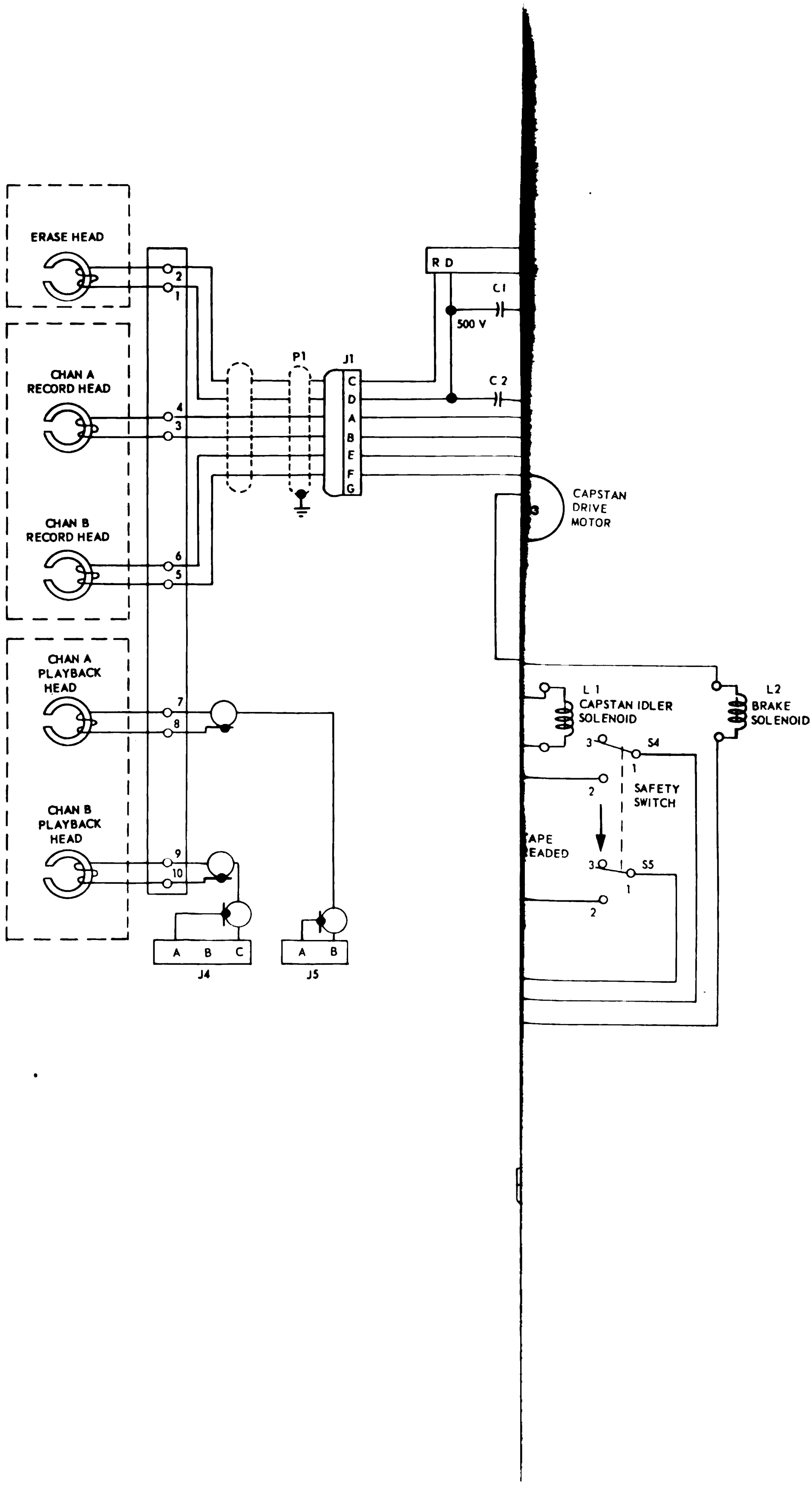


Figure 10-11.—Schematic diagı

Digitized by Google



Digitized by Google

and reproduce heads and the consequent tape-travel time between the two heads.

To stop either the record or reproduce function, return the appropriate switch to the NEUTRAL position. To stop both the record and reproduce functions (and tape motion) return both the record and reproduce switches S10 and S8 to the NEUTRAL position. The tape-motion components will be automatically deactivated at the end of a reel.

Rewind and Fast Forward Operation

If the tape is threaded on the recorder-reproducer and is not in motion, it can be moved rapidly in either the forward (fast forward) or reverse (rewind) direction by placing the rewind-fast forward switch S1 in the appropriate position (fig. 10-6). The tape motion can be stopped by returning this switch to the NEUTRAL position. The tape-motion components will be automatically deactivated at the end of a reel.

If the tape is in motion in the record or reproduce mode when the fast forward rewind switch S2 is placed in other than the NEUTRAL position, normal operation will continue until the record switch S10, and reproduce switch S8 are returned to their NEUTRAL positions. The tape motion will then immediately go into the fast winding mode dictated by the position of the fast forward rewind switch S1.

If either the record switch S10 or reproduce switch S8 is placed in position 1 when the tape is in motion in the rewind or fast forward mode, the rewind or fast forward operation will continue until the rewind-fast forward switch S1 is returned to the NEUTRAL position. The tape will then come to a stop, and after a delay of approximately three seconds, it will start in response to the setting of the record switch S10 or the reproduce switch S8. The delay is introduced to prevent the tape from breaking or stretching, which would probably occur if the capstan idler should engage the capstan with the tape in rapid motion.

When the fast forward rewind switch S1 (fig. 10-12) is in the FAST FORWARD position, contacts 7-9 open the circuit to extinguish the standby light on the remote control unit (not shown); contacts 1-2 energized the takeup relay K2; and contacts 4-5 complete a circuit to energize the time-delay relay K1, and allow C4A and C4B to charge.

When the takeup relay K2 operates, contacts 8-9 open the circuit (via terminals A and L on J2) to the record relay K7 in the amplifier assembly (fig. 10-11), to the play relay K4 and to the capstan idler solenoid L1 (fig. 10-12). Contacts 7-8 (relay K2) energize the brake solenoid L2, which pulls the brakes from contact with the brake drums. Contacts 4-5 remove R4 from the circuit of the takeup motor B1. Contacts 5-6 place the takeup motor B1 directly across the a-c line (terminals A, and N of J2) and the rewind motor B2, across the a-c line in series with R9. This action causes the takeup motor B1 to operate at full torque, and the rewind motor B2 to operate at reduced torque.

The time-delay relay K1 remains energized by the discharge of C4A and C4B for about three seconds after the fast forward rewind switch S1 is placed in the NEUTRAL position (fig. 10-12). Time-delay relay K1 then operates to open its contacts 4-5, which are in series with the record relay K7 (fig. 10-11), play relay K4, and the capstan idler solenoid L1 (fig. 10-12). Thus, if either the record switch S10 or the reproduce switch S8 is placed in its position 1 while the equipment is in the fast winding mode, and the fast forward rewind switch S1 is then placed in its NEUTRAL position, the 3-second delay will allow the fast-moving tape to stop before the capstan idler forces the tape against the capstan and thereby avoids breaking or stretching the tape.

When the fast forward rewind switch S1 (fig. 10-12) is in the REWIND position, contacts 10-12 open the circuit to extinguish the standby indicator at the remote control unit (not shown). Contacts 13-14 complete a circuit to the rewind relay K3, and contacts 16-17 complete a circuit to the time-delay relay K1 allowing C4A and C4B to charge.

When the rewind relay K3 operates, contacts 8-9 open the circuit to the record relay K7 (fig. 10-11), play relay K4 (fig. 10-12), and the capstan idler solenoid L1, via terminals L and M of J2. Contacts 7-8 of K3 complete a circuit to energize the brake solenoid L2, which pulls the brakes from contact with the brake drums. Contacts 4-5 remove R6 from the circuit of the rewind motor B2. Contacts 5-6 place the rewind motor B2, directly across the a-c line (terminals A and N of J2) and the takeup motor B1, across the a-c line in series with R9. Thus the rewind motor B2 and the takeup motor B1 will operate at full and reduced torques, respectively. The time-delay relay K1 provides the same delaying action previously described.

Digitized by Google

Cueing and editing can be accomplished at fast speed by changing the fast forward rewind switch S1 back and forth between the REWIND and FAST FORWARD positions. It is not necessary to allow the tape to slow down or come to a stop because the shuttling process does not damage the tape or equipment. The reproduce switch S8 may be placed in position 1 during the shuttling process to provide aural (by ear) monitoring. However, do not allow the fast forward rewind switch S1 to pause in its NEUTRAL position for more than the 3-second delay period because the equipment will automatically enter the reproduce mode.

Erasing

Erasure of a previously recorded tape without recording new information may be accomplished by installing the tape on the recorder-reproducer, turning both the record level controls to the full counterclockwise position, and running the tape in the record mode at a tape speed of 7 1/2 ips.

MAINTENANCE

If a tape recorded on the sound recorder-reproducer set does not reproduce properly, the trouble may be in either the record or reproduce circuits. Isolating the malfunctioning circuit can be easily accomplished by reproducing a standard alignment tape. If the reproduction is normal the trouble is in the components associated with the record circuit. If the reproduction is abnormal the trouble is in the components associated with the reproduce circuit.

Another method of determining whether the record or reproduce circuits is at fault is to simultaneously record the same signal on both channels. Rewind the tape and reproduce it, observing the output of both channels. Then, without rewinding the tape, transpose the reels by placing the supply reel on the takeup turntable and the takeup reel on the supply turntable. This transposition will orient the reels so that the signal recorded on one channel will be reproduced on the other channel. Reproduce the tape, comparing the output of each channel with the results noted on the previous run. If the same channel exhibits the subnormal indication the fault is in the reproduce circuit. If the trouble now appears at the output of the other channel the fault is in the record circuit.

When the faulty circuit is identified, the trouble can be further isolated by following the alignment procedures described in the manufacturer's technical manual furnished with the equipment. As previously stated, the recorder-reproducer assembly and the amplifier assembly can be extended from the cabinet and rotated so that the test points and components are readily acessible. It should not be necessary to remove these assemblies from the cabinet for ordinary servicing.

If the set will reproduce normally, but in the record mode it will not erase and will not record, even though the monitor indicators show normal input to the microphone, the trouble may be in the record head.

While this head is magnetized by the signal input during the recording process, it pulls particles of iron oxide off the magnetic tape. These particles gradually build up and in time will short-circuit the magnetic air gap of the record and erase head.

This accumulation can be removed by cleaning with a pipe cleaner moistened with cleaning or lighter fluid. This trouble may be avoided by cleaning the heads periodically.

Digitized by Google

CHAPTER 11

SOUND MOTION PICTURE SYSTEMS

In addition to sound, a knowledge of light and lenses is essential for a clear understanding of the theory involved in sound motion picture projection.

PRINCIPLES OF LIGHT

Light is radiant energy capable of affecting the eye to produce vision. Light is also defined as a form of energy that results when minute particles of a body are set into extremely rapid vibration. This vibration is usually caused by intense heat and is accompanied by extremely high temperatures.

The sun and stars are natural sources of direct radiation, both visible and invisible; whereas the moon and planets are natural sources of indirect radiation by reflection. The incandescent electric lamp is an artificial source of direct radiation that gives off light because of the high temperature of its filament, which is heated by an electric current.

PROPAGATION OF LIGHT

Light is a form of wave motion propagated through certain uniform media or through empty space with an exceedingly great, but finite and measurable, velocity (fig. 11-1). A light wave is a transverse wave the vibrations of which are perpendicular to the direction of propagation, as illustrated in figure 11-1A. The amplitude of a light wave, like that of a water wave, is the height of the crest or the depth of the trough.

The wavelength λ is the distance between successive points in identical stages of motion of a light wave. Wavelengths are indicated in figure 11-1A, as the distance from the crest of one wave to the crest of the next wave.

The wavefront is a line connecting particles of the medium over which the disturbance is momentarily uniform. Wavefronts are indicated in figure 11-1A, by portions of concentric circles. Thus, a wave emitted from a point source S with equal velocity in all directions would have a succession of expanding spherical wavefronts.

A light ray is a straight line extending in the direction of propagation from the light source. The term "ray" can be used to refer to the light

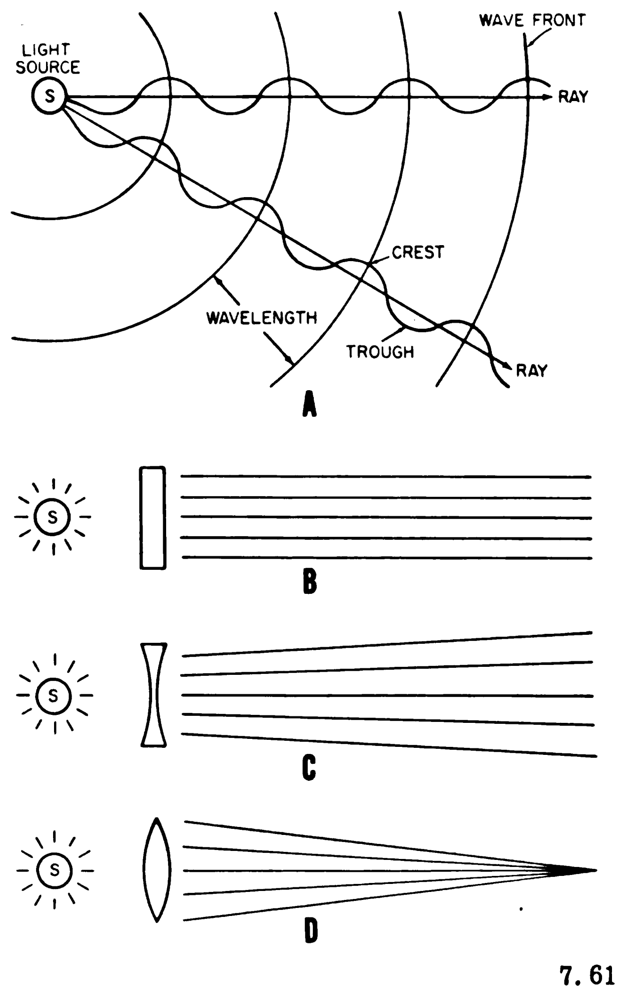


Figure 11-1.—Propagation of light waves.

Digitized by Google

itself or to the lines that represent its path. A wavefront moving outward is assumed to be perpendicular to the ray a short distance from the light source.

A parallel beam of light is a bundle of parallel rays (fig. 11-1B); a cone of light is a narrow bundle of diverging rays (fig. 11-1C); and a pencil of light is a narrow bundle of converging rays (fig. 11-1D).

The rays of light from a large source such as the sun diverge very little, and for practical purposes are considered to be parallel. On the other hand, the rays of light from artificial sources, such as incandescent and arc lamps, spread out as they are propagated through space and diverge as they move farther from the source. For practical purposes these rays are considered as originating from a point source.

VELOCITY OF LIGHT

Light travels at a definite speed in any one medium. The speed of light is approximately 186,000 miles per second in a vacuum, is slightly lower in air, and appreciably lower in water, glass, and other media. The velocity of light is related to its frequency and wavelength in a formular similar to that relating the velocity of sound to its associated frequency and wavelength.

$$v = f\lambda$$

CHARACTERISTICS OF LIGHT

A beam of light must cover a greater area as it moves farther from the source because the light from a point source spreads out in all directions. Thus, the intensity (brightness) of light decreases with distance. The inverse-square law applies to this decrease in intensity with an increase in distance—that is, the light intensity is inversely proportional to the square of the distance from the source. The eye cannot form a quantitative estimate of the degree of brightness because the pupil opens or closes to receive more or less light according to the intensity of illumination.

Certain kinds of light produce the sensation of color. The color of light is produced by the different light frequencies that have different effects on the optic nerve. The color is determined by the frequency of vibration and the associated wavelength of the light wave.

The solar spectrum contains the following colors in the order of their wavelength:

*1. Infrared	6. Blue
2. Red	7. Violet
3. Orange	*8. Ultraviolet
4. Yellow	*9. X rays
5. Green	*10. Gamma rays
*11. Cosmic rays	

*Not visible to the naked eye.

At one extreme, red is produced by the longest waves (lower frequency) and at the other extreme, violet is produced by the shortest waves (higher frequency).

An object reflects the light associated with its own color. Thus, an object is red if it reflects red light, or blue if it reflects blue light. Sunlight contains all the colors of the visible spectrum. Colored objects look natural in sunlight because each reflects that part of the spectrum associated with its own color and absorbs the remaining light.

A brilliant red object in sunlight looks gray when illuminated by a sodium vapor light because there are no red rays in sodium vapor. The object loses its brilliant color because it absorbs the yellow light of the sodium vapor lamp and cannot reflect its natural color in the absence of the red rays.

PROPERTIES OF WAVE MOTION

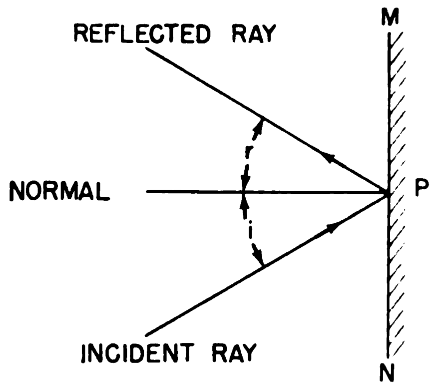
Two important properties of wave motion are reflection and refraction. Both light waves and sound waves have these properties. Sound waves were discussed earlier in the text, therefore, only light waves will be discussed here.

REFLECTION

Light waves, like sound waves, can be reflected and refracted. When a light ray strikes the surface of an opaque object, some of the light is absorbed and converted into heat, and the remainder is reflected. If the surface of the object reflecting the light is flat and polished, such as a plane mirror, the light is reflected without changing the relative arrangement of the rays, as illustrated in figure 11-2.

The ray from the source to the mirror MN, is the incident ray. The point at which the ray strikes the mirror surface is the point of incidence P. The ray that comes from the point of incidence is the reflected ray. The line perpendicular to the surface of the mirror at the point of incidence is called the normal to the surface. The angle between the incident ray and

Digitized by Google



7.62

Figure 11-2.—Reflection of a light ray.

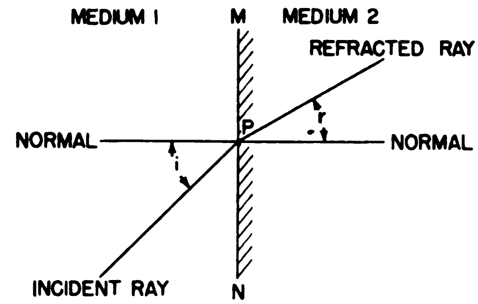
the normal to the surface is the angle of incidence i, and the angle between the reflected ray and the normal to the surface is the angle of reflection r.

In accordance with the law of reflection, angle i equals angle r. In other words, the incident ray, the reflected ray, and the normal to the surface at the point of incidence are all in the same plane, and the angle of reflection equals the angle of incidence. This statement is true for both plane and curved mirror surfaces because the incident and reflected rays travel in the same medium with the same velocity.

Light rays reflected from a concave mirror are concentrated into a very small area and are called converging rays over the distance from the mirror to the point of maximum concentration. Beyond the point of maximum concentration they are diverging rays.

REFRACTION

When light travels in one medium and encounters a second medium of different optical density, part of it is reflected and part continues into the second medium, as illustrated in figure 11-3. Unless the angle of incidence is zero, the light that enters the second medium undergoes a change of direction. The ray that enters the second medium is the refracted ray. The angle of refraction r is the angle between the refracted ray and the normal to the surface of the second medium. Reflection and refraction both occur at the boundary surface P between the two media. Thus the boundary serves as a plane surface for one ray and as a refracting surface for the other ray.



7.63

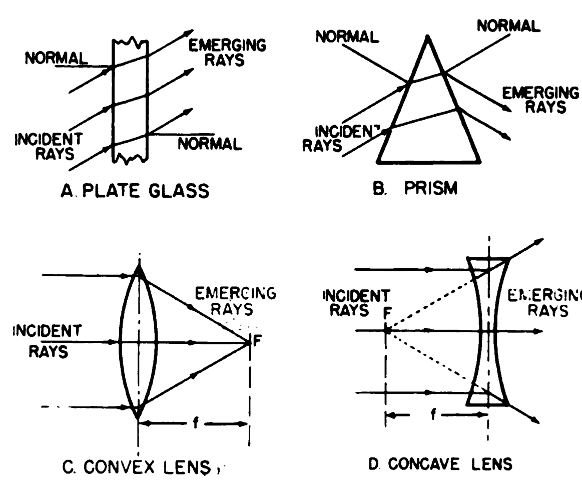
Figure 11-3.—Refraction of a light ray.

LENSES

A lens is a piece of glass or other transparent substance, the surfaces of which have been ground for the purpose of directing light rays. The refraction of light rays through various media is illustrated in figure 11-4.

If light rays pass from one medium to a denser medium having parallel faces, such as plate glass, the rays emerge from the denser medium and travel in the same direction in which they traveled prior to entering the denser medium (fig. 11-4A). Thus, light rays are offset slightly when passing through an ordinary window pane, but are not changed in direction.

If the faces of the denser medium are not parallel, the rays are permanently bent and emerge from the denser medium and travel in a direction different from that traveled before they entered the denser medium (fig. 11-4B).



7.64

Figure 11-4.—Refraction through lenses.

Digitized by Google

Hence, the light rays are bent in passing through a prism with flat surfaces. If the rays are of the same wavelength and parallel, the emerging rays are also parallel.

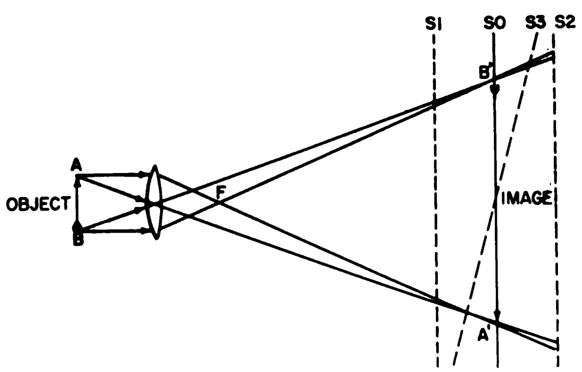
If parallel light rays pass from one medium to a denser medium having curved surfaces, such as a lens, the emerging rays are not parallel but are concentrated, or focused, to a small point. The principal focus F of the lens is the point of convergence or of divergence of the light rays.

A double-convex and a double-concave lens are illustrated in figure 11-4C and D, respectively. The rays converge to point F in the convex lens and diverge from point F in the concave lens. The distance from the principal focus F to the lens is called the focal length f. Thus, it is possible to concentrate, or to control, light rays by passing them through a dense transparent substance such as glass.

FORMATION OF IMAGES

The projection of motion pictures on a screen is based on the principle of the formation of an image by a convex lens. A lens can be used to form an image of an object on a screen if all the light radiated from each point on the object and incident upon the lens can be brought to a focus at corresponding points on the screen.

If AB represents any lighted subject such as an illuminated film (fig. 11-5), some of the rays of light from A are intercepted by the lens and are brought together at point A' on the opposite side of the lens. For simplicity, only two rays are shown. One of the rays from point A in the object passes through the optical center of the lens and strikes the screen at A'. Another ray from point A parallel to the axis of the lens is refracted by the lens and also strikes the screen at point A'. Any other ray from A, incident upon the lens, also strikes the screen at point A'. Point A' is the image of point A in the object. Similarly, all the light rays from point B in the object strike the screen at point B'. Point B' is the image of point B in the object. Every other point in the object is represented by a corresponding point in the image. Note that the rays cross as they pass through the lens, and the image on the screen is inverted with respect to the object. Hence, when motion pictures are projected, the images on the film must be upside down.



7.65

Figure 11-5.—Formation of an image by a convex lens.

For a given distance between the lens and the film, there is only one screen distance at which the picture will be sharp. Light rays from a point in the film meet at a point on the screen in the plane S0. If the screen is either nearer to the projector as S1, or farther from it as S2, the rays produce a blur because they do not all strike the same point. For any screen distance there is a corresponding film-to-lens distance that will produce a sharp picture. In practice, the screen distance is usually selected to provide the desired size picture and then the lens is moved in or out until the picture is the sharpest. This adjustment, called focusing, is accomplished by rotating the projector lens barrel to move the projection lens closer to or farther away from the film. The screen should be at right angles to the lens axis. If the screen is tipped at S3, the picture will be out of focus at the top and at the bottom, although it may be sharp at the middle.

PRINCIPLES OF SOUND MOTION PICTURES

Motion picture projection is the presentation on a screen of a series of images taken in very rapid succession by a motion picture camera. Such a presentation produces an illusion of moving images. This illusion results from viewing in very rapid succession, a series of images, each of which differs slightly from the preceding one. The eye retains an impression of the preceding image, blends it with the succeeding image, and creates an illusion of motion. In motion picture terminology an image is known as a frame.

SOUND MOTION PICTURE FILM

Sound motion picture film is available in standard 35 and 16 mm sizes. The 35-mm film

Digitized by Google

travels through a 35-mm projector at the rate of 90 feet per minute and is the standard size for the theatrical projection. The 16-mm film travels through a 16-mm projector at the rate of 36 feet per mimute and is the standard size used in the Navy. The 16-mm film is a strip of cellulose acetate, one surface of which is coated with photographic emulsion. A row of perforated sprocket holes (one hole to a frame) is on one side of the film. The sprocket holes provide a positive feed for the film through the camera and projector.

A sound motion picture film (fig. 11-6) contains two types of records: (1) a series of instantaneous photographs taken in rapid succession of a moving subject; and (2) a record of sound associated with, or appropriate to, the motion of the subject.

When the series of instantaneous photographs is being recorded by the motion picture camera, the sound is picked up by a microphone that converts the audible sound waves into equivalent variations in electric current. The electric current is amplified and then photographed on film by a camera sound recorder. The recorder is equipped with a light modulator that converts the electric current from the amplifier into equivalent light variations and photographs the variations onto the film. The sound and picture are reproduced separately. The two films are then synchronized so that when they are printed together the reproduced sound corresponds at all times to the action of the picture.

The sound associated with an individual frame is not recorded on the sound track directly opposite that frame but at a point 26 frames farther ahead. This displacement of the sound track relative to the picture is necessary for proper synchronization of sound and picture, because the sound track must pass the scanning beam when the picture is at the aperture.

When such a film is shown, the photographs are projected on a screen in the order in which they were taken and at the same rate. The sound is reproduced through an amplifier and loudspeaker, and is synchronized with the action in the picture. The effect of the rapid presentation of a large number of slightly different pictures in the proper sequence gives the illusion of a continuously moving picture, and the simultaneous reproduction of the appropriate sounds augments the realism.

Sound is recorded on film as a continuous photographic image along a narrow strip at one side of the film called the sound track (fig. 11-7).

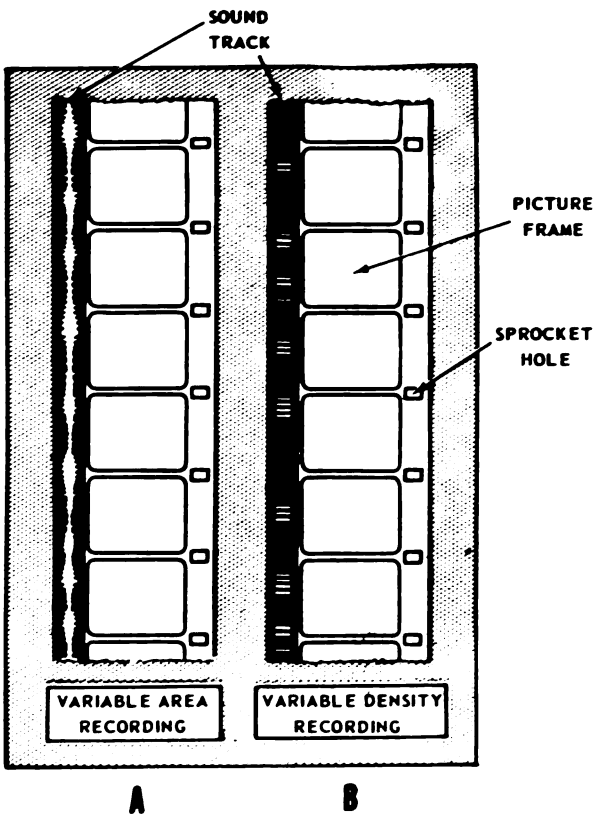
Figure 11-6.—Section of 16-mm sound motion picture film.

Digitized by Google

The two methods of recording sound photographically on film are (1) variable area recording; and (2) variable density recording. These methods are discussed below. A third method of recording sound is the magnetic tape method (discussed in chapter 10). In this method the sound is recorded on tape and the tape is attached to the edge of the film.

Variable Area Recording

Variable area recording (fig. 11-7A) is denoted by zig-zag waves along the sound track. The black areas are opaque, and the white areas are transparent. The width of the transparent area can vary from nothing up to the limits of the opaque band, depending on the instantaneous strength of the sound being recorded. It is the variation in the width of the transparent area from point to point along the track that is of importance. When there is no variation in the width of the transparent area, no sound is recorded on the film, and no sound can be produced from it.



7.67

Figure 11-7.—Sound recording of film.

Variable Density Recording

Variable density recording (fig. 11-7B) is denoted by parallel lines that vary in spacing and intensity across the sound track. If the frequency of the recorded sound is low, the width of the bands is comparatively large, and if the frequency is high, the bands of light and dark are very close together and are barely distinguishable to the eye. The variation of density between successive dark and light bands determines the amplitude of the recorded sound.

PROJECTION OF IMAGES

In sound motion picture projection each frame of the film is projected on the screen for a small fraction of a second and is immediately followed by the next frame, which is shown for an equally brief interval. A 16-mm film is projected on the screen at the rate of 24 frames every second. However, this does not imply that each frame is held on the screen for one twenty-fourth of a second. The actual time is about one half of this interval because the screen is darkened twice during each frame, once while the film is moving forward and again while a frame is being held stationary in the projector. If the light is not cut off while the film is in motion, the picture on the screen will be streaked and blurred, and if the light is not cut off at least once while each frame is stationary, an annoying flicker will result.

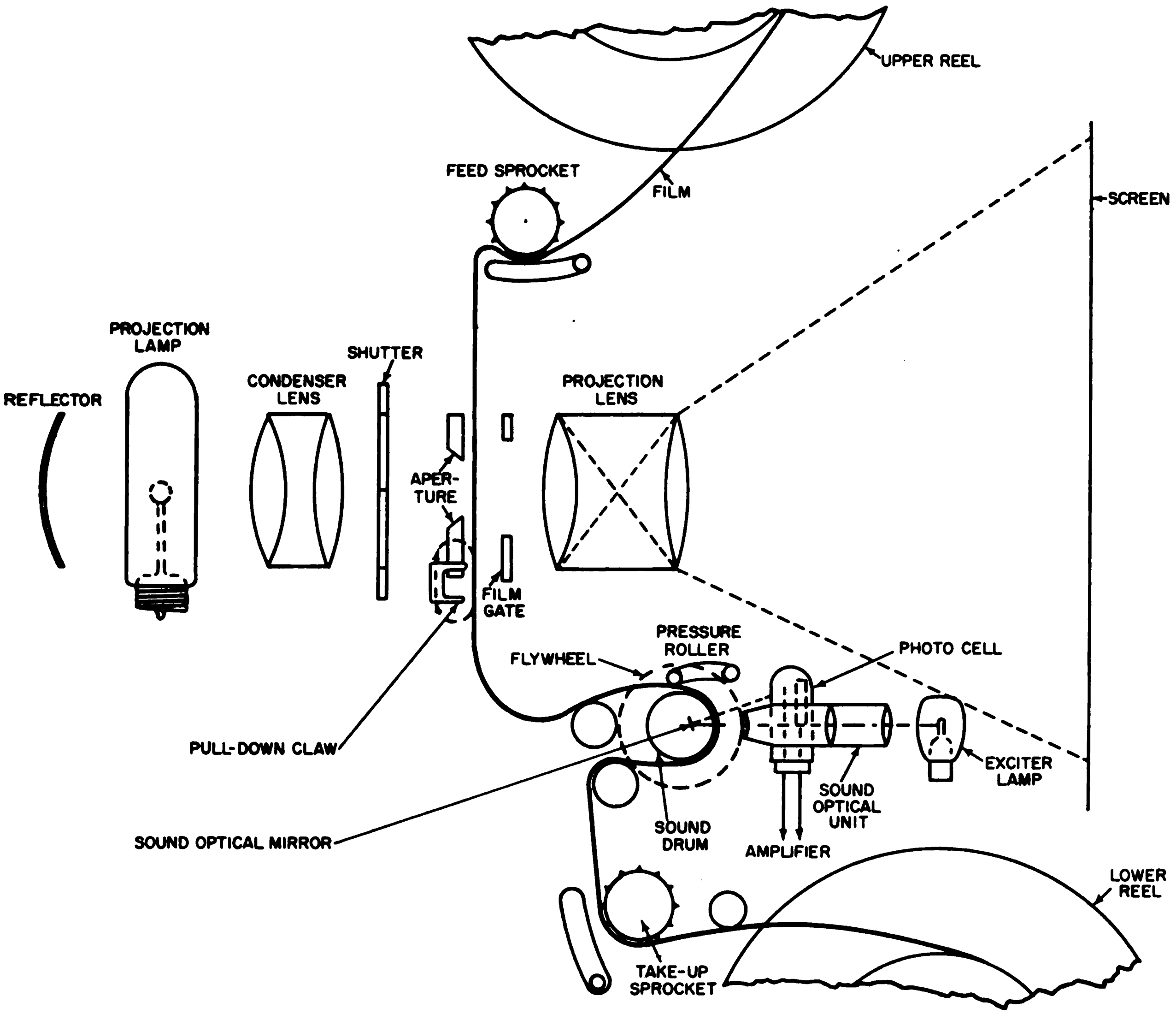
A sound motion picture projector consists essentially of a (1) projection optical system to project the picture on the screen; and (2) sound optical system to convert the variations in the sound track into audible sound waves (fig. 11-8).

Projection Optical System

The projection optical system (fig. 11-8) includes a projection lamp, reflector, condenser lens, shutter, aperture, film gate, and projection lens.

The projection lamp is a 750- or 1,000-watt concentrated-filament lamp located behind the film. The lamp provides the light beam for projecting the film image on the screen. The reflector placed behind the projection lamp recovers much of the light emanating to the rear of the lamp and directs it forward through the optical system. The condenser lens concentrates the light from the filament of the projection lamp on the film aperture.

Digitized by Google



7.68

Figure 11-8.—Pictorial diagram of a sound motion picture projector.

The shutter, placed between the condenser lens and the aperture, cuts off the light when required by a pull-down blade and an anti-flicker blade (not shown). The shutter revolves once for each frame or for each complete cycle of the intermittent shuttle (pull-down claw). The intermittent shuttle pulls the film into position in front of the aperture at the rate of 24 frames per second. Each time the intermittent shuttle moves down it advances the film one frame. During this motion, the shutter pull-down blade cuts off the light from the screen. As the intermittent shuttle moves back up, one frame of the film is held stationary in the aperture, and the shutter anti-flicker blade cuts off the light from the screen.

The aperture is a rectangular opening in a metal plate. It provides maximum brilliance in the projected picture by screening the beam of projected light from all film frames except the one positioned in front of the aperture. The film gate holds the film flat against the aperture and keeps the picture in focus.

The projection lens, located in front of the film, focuses the image of the film frame on the screen. The size of the projected image is

Digitized by Google

determined by the distance of the projector from the screen and by the focal length of the projection lens.

Sound Optical System

The sound optical system (fig. 11-8) includes an exciter lamp, optical unit, photocell, and mirror.

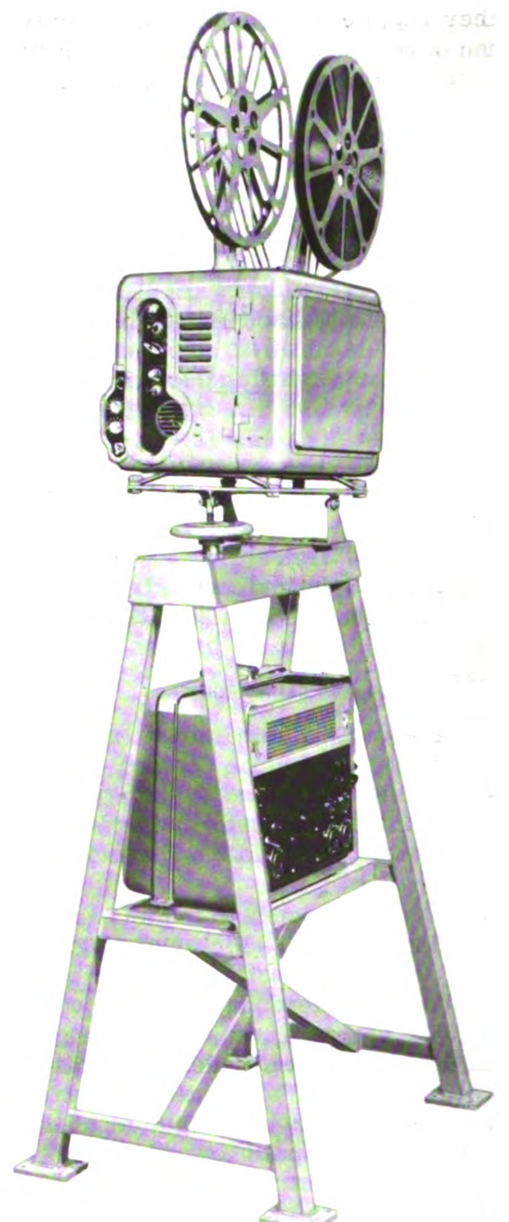
When the sound motion picture film is run through the projector, it passes around the sound drum located in front of the sound optical unit. The optical unit concentrates the light from the exciter lamp into a line about 0.001 inch wide. This line of light is slightly longer than the width of the sound track. The optical unit is adjusted so that the line comes to a sharp focus at the emulsion side of the film so that its center coincides with the center of the sound track. The point on the sound track where this line is focused is called the scanning point. This portion of the film overhangs the back edge of the sound drum. The light that passes through the sound track falls on the light pipe prism which reflects it to the anode of the photocell.

In variable area recording the wave images on the sound track vary the amplitude of the scanning beam as it passes through the sound track. These variations in the scanning beam produce corresponding variations in the electron emission through the photocell. These variations are converted into voltage variations across a resistor and are fed to an amplifier (not shown). The output of the amplifier is converted into audible sound waves at the loudspeaker.

The greater the width of the sound waves or the greater the variation of density of the sound track bands (depending on the type of sound recording), the greater will be the variations in the amount of light that reaches the photocell. The recorded sound track interposed between the light source and the photocell determines the variation in the intensity of light transmitted to the photocell and the rapidity with which the variations in light intensity occur. Thus, the variations in light intensity control the magnitude and frequency of the electric impulses to the amplifier.

SOUND MOTION PICTURE PROJECTION EQUIPMENT

The sound motion picture system, circuit MP is designed for use as an aid in training, briefing, and entertaining naval personnel. The system comprises a motion picture projector, external amplifier (fig. 11-9), and one or more external loudspeakers. The equipment is readily portable and can be operated in any average-size room, small theatre, or in shipboard hangars or topside where 115-volt single-phase power is available.



7.69

Figure 11-9.—Motion picture projector with external amplifier.

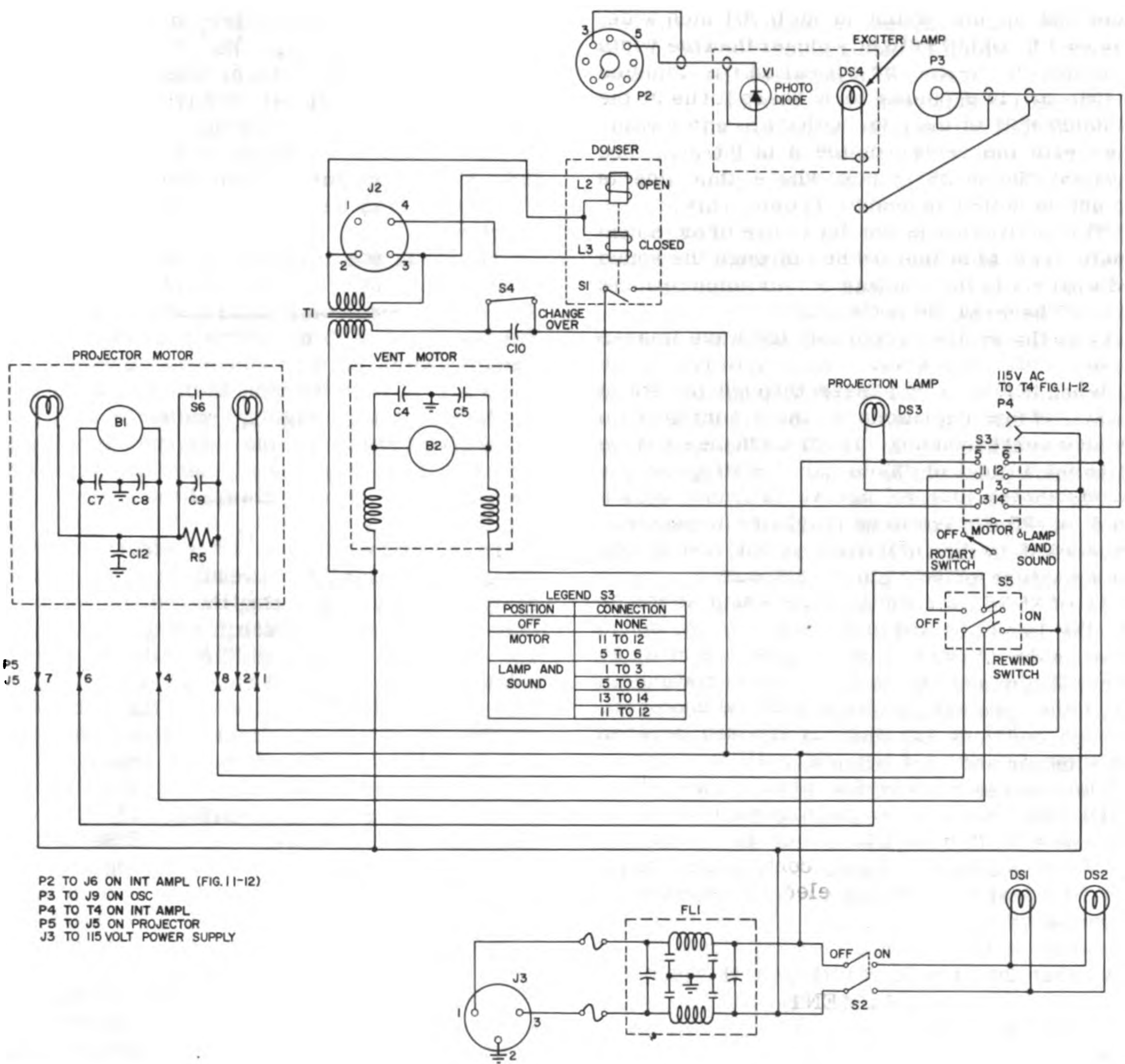
Digitized by Google

PROJECTOR

The projector consists of a sound motion picture projector, an internal amplifier, and an internal loudspeaker contained in a metal case. The operating switches and controls are located on a panel at the rear of the case. The projector permits: (1) dual operation of projectors with sound and picture changeover from one projector to another (applies to AQ-3 projector only); (2) operation of one projector with an external amplifier; and (3) operation of dual projectors with changeover using either internal or external amplifiers (applies to AQ-3 projector only).

Electrical System

The projector electrical system is illustrated by the schematic diagram in figure 11-10. The projector drive motor, ventilating motor, and projection lamp are energized from the ship's 115-volt 60-cycle power through receptacle J3 and the motor-lamp rotary switch S3. The r-f filter FLI, in series with the line to the drive



7.70

Figure 11-10.—Schematic diagram of projector.

Digitized by Google

motor, ventilating motor, and threading lamps minimizes the r-f noise. The threading lamp DS1, and panel lamp DS2 are energized when the threading lamp switch S2 is placed in the ON position.

The projector drive motor B1 is a universal series-wound governor type of motor. It operates at constant speed with changes in voltage from 100 to 130 volts. The motor speed is controlled by a centrifugal governor S6 mounted on the armature shaft. When the motor speed is low, S6 closes and shorts out R5, which increases the current in the circuit. Conversely, when the motor speed is high, S6 opens and inserts R5, which in turn reduces the speed. The capacitor C9, across R5 minimizes the r-f noise. Additional r-f suppression is provided by C7 and C8 connected between the armature and ground. The drive motor is connected to the projector through P5 and J5 to facilitate replacement of the entire motor assembly, if necessary.

The ventilating motor B2 is provided to dissipate the heat generated by the projection lamp and also cools the condenser lens, aperture, and film. The capacitors C4 and C5 are connected between the armature and ground to prevent r-f noise.

When S3 is in the MOTOR position, B2 is energized through contacts 5-6, and B1 is energized through contacts 11-12. The circuit for B1 is from pin 1 of J3, one side of FLI, pin 1 of J5-P5, the right-hand series field coil of B1, pin 2 of P5-J5, contacts 11-12 of S3, the upper blade of S5 in the OFF position, pin 6 of J5-P5, the armature of B1, pin 4 of P5-J5, the lower blade of S5 in the OFF position, pin 8 of J5-P5, R5, the left field coil of B1, pin 7 of P5-J5, the lower side of FLI, returning to pin 3 of J3. When S3 is placed in the LAMP and SOUND position, the projection lamp DS3 is energized through contacts 1-3 and 5-6 in addition to the drive motor and ventilating motor.

Normal operation of the drive motor and the ventilating motor is controlled by the motor-lamp switch S3, when the rewind switch S5 is in the OFF position. When S5 is placed in the REWIND position, terminals 11-12 in the motor-lamp switch S3 are bypassed. The drive motor operates in the reverse (rewind) direction by reversing the armature current with respect to the field. The ventilating motor and projection lamp are deenergized with S3 in the OFF position.

The exciter lamp DS4 is energized from the internal amplifier through receptacle P3, contacts 13-14 of the motor-lamp switch S3, and the closed contacts of S1.

The photocell V1 is a germanium diode, which converts the light variations impinged on its surface to variations in electrical currents. The light source for V1 is the exciter lamp DS4. The sound track on the film interposed between DS4 and V1 causes the light variations imposed on V1. The electrical currents generated by the photocell are fed to the input of the internal amplifier through receptacle P2.

The changeover mechanism is incorporated in each projector when two projectors are used, with one or more amplifiers and loudspeakers to provide uninterrupted sound film programs. The changeover mechanism mounts to the inner surface of the shutter assembly. Sound changeover is effected by breaking the exciter lamp circuit, and picture changeover is effected by a light shield (douser), which drops between the condenser lens assembly and the picture aperture.

The changeover switch S4 controls simultaneously the sound and picture changeover from the outgoing projector to the incoming projector. However, to effect this changeover the hand-set douser switch S1 must be preset once only, at the start of the program, to the OPEN position on the operating (outgoing) projector and to the CLOSED position on the idle (incoming) projector. For single equipment operation, the douser switch S1 must always be set in the OPEN position.

Interconnection of the electromagnetic changeover circuits between projectors is accomplished by connecting the changeover cable into receptacles J2 on each projector (fig. 11-11). The cable connections to J2 parallel the (OPEN) solenoid of projector 1 with the (CLOSE) solenoid of projector 2. Depressing the changeover pushbutton switch S4, simultaneously energizes the (OPEN) solenoid of the desired operative projector and the (CLOSE) solenoid of the other projector. The capacitor C10 (fig. 11-10) is connected across the changeover switch S4, to eliminate the electrical noise resulting from the changeover switching operation.

Internal Amplifier

The internal amplifier (fig. 11-12), which is an integral part of the projector, delivers 7 1 2 watts with a total harmonic distortion not exceeding 2.0 percent at any frequency from 100 cycles to 7,000 cycles. The operating controls

Digitized by Google

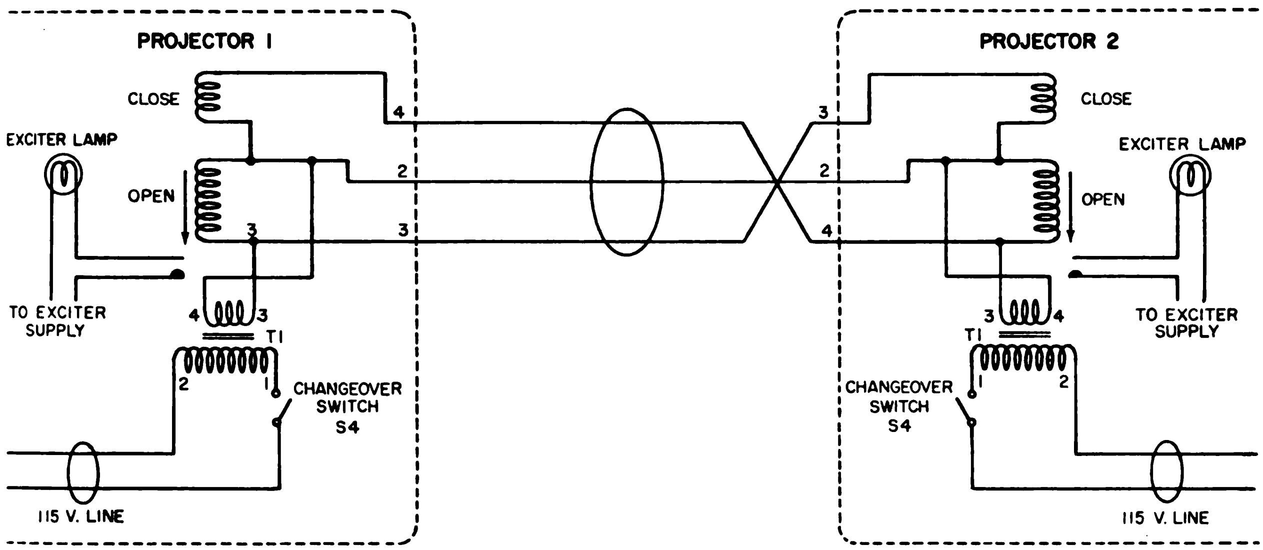


Figure 11-11.—Interconnection of electromagnetic changeover circuits between projectors.

for the amplifier are located at the rear of the case adjacent to the projector controls. These controls include on-off power switch S9; volume control R20; and tone control S8.

The amplifier consists of resistance-capacitance coupled voltage amplifier stages V2A, V2B, and V3A, phase inverter V3B to supply the push-pull grids of the output power amplifier V4 and V5, 180 degrees out-of-phase. The power supply V7 is a full-wave rectifier with pi-section filter to furnish power for all the tubes. The oscillator V6 is a conventional Hartley oscillator in the r-f power supply to produce the power for the exciter lamp.

The voltage generated by the germanium diode V1 (fig. 11-10) in the projector is developed across the load resistor R8 (fig. 11-12) and applied to the grid of V2A. The coupling capacitor C12 blocks the d-c photocell bias from the grid of V2A. The grid load resistor consists of potentiometer R42 and R10 in series with R11. The contact arm of R10, connected through R42 to the grid of V2A, permits adjustment of the input signal to prevent overloading the amplifier and to ensure a 20 db gain reserve. The degenerative feedback network between the plate of V2B and the cathode of V2A consisting of R17 in series with C17 provides increased stability and less distortion. The microphone input jack J7 allows use of the amplifier with an external high-impedance sound device such as a microphone or phonograph.

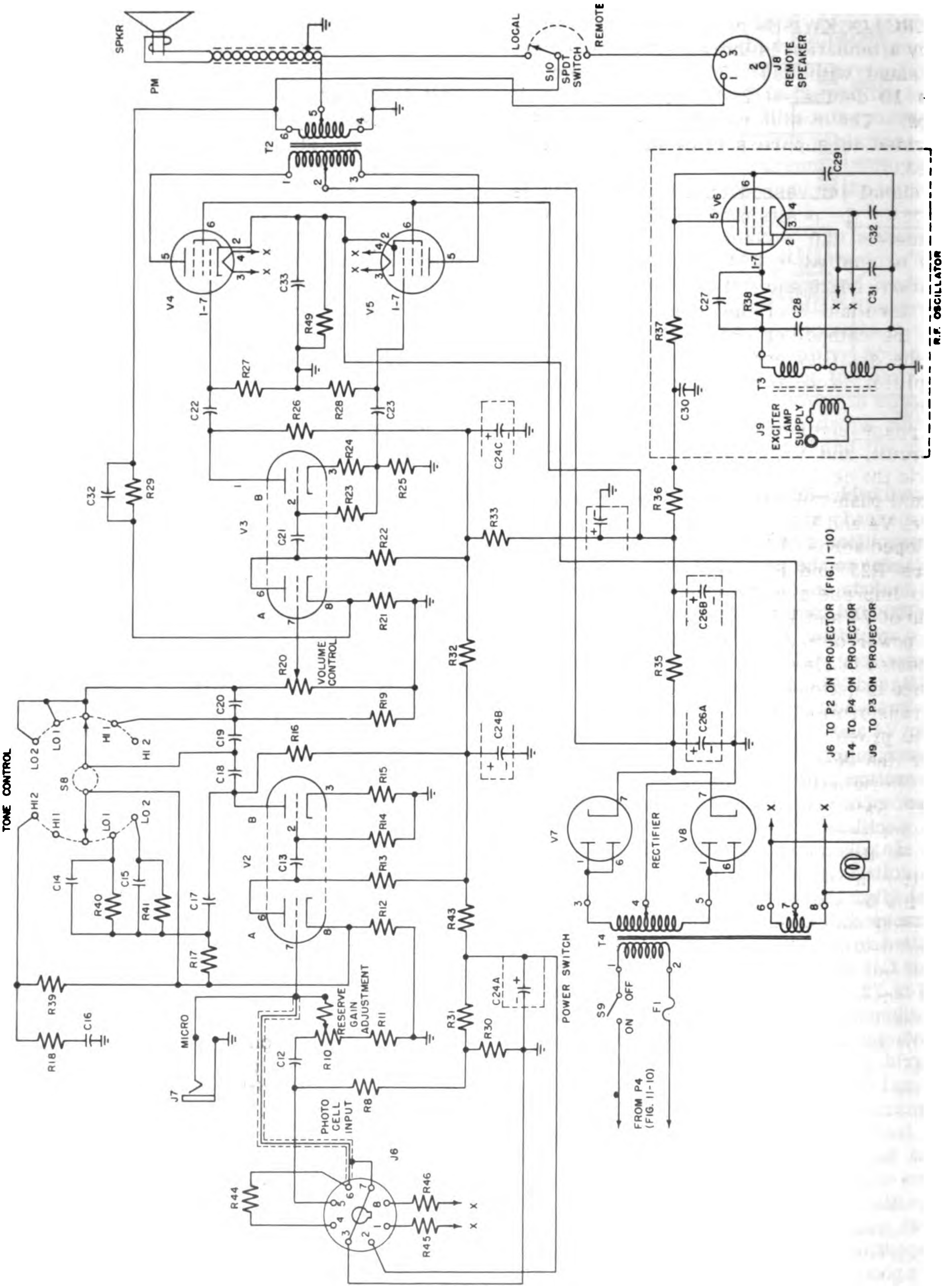
The 2-circuit 5-position rotary switch S8 is provided to control the frequency-response characteristics of the amplifier. The switch section to the left (fig. 11-12) varies the amount of negative feedback applied to V2A. The feedback components are nonlinear with respect to frequency, and thus cause the gain of the stage to vary with frequency. The switch section to the right varies the frequency-response characteristics of the coupling network between V2B and V3A, and thus the signal amplitude as a function of frequency.

When the tone control switch S8 is placed in the FIRST CLOCKWISE position from normal, frequencies below 700 cps are attenuated due to the reduced coupling capacity to the grid of V3A by connecting C20 in series with C18.

When switch S8 is placed in the SECOND CLOCKWISE position, the low-frequency attenuation is increased by connecting C19 in series with C18 and C20. Also, C16 and R18 are shunted across the cathode bias resistor R12 which accentuates frequencies above 700 cps by reducing the cathode degeneration. This switch position provides 12 decibels (±2 db) of attenuation at 100 cps and 6 decibels (±2 db) of attenuation at 3,500 cps.

When switch S8 is placed in the FIRST COUNTERCLOCKWISE position from normal, C14 is connected in parallel with the feedback resistor R17 to increase the negative feedback for frequencies above 700 cps.

Digitized by Google



7.72

Figure 11-12.—Schematic diagram of internal amplifier.

When switch S8 is placed in the SECOND COUNTERCLOCKWISE position, the high-frequency attenuation is increased by connecting C15 in shunt with R17. This switch position provides 10 decibels (+2 db) of attenuation at 5,000 cps. The resistors R39, R40, and R41, are provided to suppress click when switch S8 is rotated.

The signal impressed on the grid of V3A is a function of the position of the volume control potentiometer R20. Negative feedback of 10 decibels is applied to V3A through the parallel combination of R29 and C32, which is connected between terminal 6 of the output transformer T2, and the cathode of V3A. The feedback improves the stability and frequency response of the amplifier, and at the same time reduces distortion.

The phase inverter V3B drives V4 from the plate circuit, and V5 from the cathode circuit to provide the necessary 180 degree phase shift for normal push-pull operation of the power output stage, V4 and V5. The signal for V4 and V5 is developed across R26 and R25, respectively. Resistors R25 and R26 are of equal value in order to impress signals of equal amplitude on the grids of V4 and V5.

The power output stage consists of V4 and V5 connected in class AB push-pull. The output impedance is matched to the loudspeaker by the output transformer T2. The secondary of T2 is tapped to provide an 8-ohm winding (terminals 4-5) for the local loudspeaker and a 16-ohm winding (terminals 4-6) for the remote loudspeaker. Switch S10 is provided to select the desired speaker.

The Hartley oscillator V6 supplies power to the exciter lamp DS4 at a frequency of 112,000 CPS. This frequency is sufficiently high so that the thermal inertia of the lamp prevents the exciting current from modulating the output of the photocell V1. The output voltage of V6 is stepped down through the secondary of T3 to obtain the low-voltage high-current power required by the exciter lamp. The output of T3 is fed to the projector by means of a shielded cable, the outer conductor of which is grounded and connected to one side of the exciter lamp. The inner conductor is connected to terminal 14 on the motor-lamp switch S3 in the projector (fig. 11-10).

The power supply consists of transformer T4, full-wave rectifier V7 and V8, and an R-C pi-section filter (fig. 11-12). The 115-volt a-c power is obtained from the projector electrical system through connector P4 (fig. 11-10). The amplifier power switch S9 (fig. 11-12) is connected in series with one side of the line, which is connected to terminal 3 of the motor-lamp switch S3, in the projector (fig. 11-10).

Full-wave rectification is accomplished by V7 and V8. The plates of each rectifier tube are connected in parallel to safely conduct the current. The a-c components of the resulting d-c voltage are removed by the R-C pi-section filter consisting of C26A, R35, and C26B. The filter composed of R43, R31, R30, and C24A supplies the positive bias voltage for the photocell V1 in the projector.

Internal Loudspeaker

The internal loudspeaker is an integral part of the projector. It is a 5-inch 10-watt permanent magnet moving-coil type having an impedance of 8 ohms.

EXTERNAL AMPLIFIER

The external amplifier (fig. 11-13) delivers an output of 20 watts with a total harmonic distortion not exceeding 2.0 percent at any frequency from 100 cycles to 7,000 cycles. The operating controls are located on the side of the case. These controls include on-off power switch S11; volume control R60; bass and treble controls; and microphone-phonograph-projector switch S12.

The external amplifier consists of voltage amplifier stages V9, V10A, V10B, and V11A, phase inverter V11B, push-pull power output stage V12 and V13, r-f oscillator V15 to supply the exciter lamp, and power supply V14. The amplifier is designed to function from an input signal of 0.006 volt to deliver 20 watts into the loudspeaker load with a 20 decibel reserve of amplification.

The input selector switch S12 provides for rapid switching between projectors to phonograph or microphone. The switch must always be in the PROJ. position when operating the entire equipment with 16-mm sound film.

The input circuit jack (IN), J10, and the multiple connected jack (OUT), J11, permit (1) parallel operation of two amplifiers from the input signal source; (2) use of the amplifier with any external sound device, such as microphones and phonographs, which terminate in a telephone plug; and (3) insertion of auxiliary sound equipment, such as volume compressors

Digitized by Google

7.73

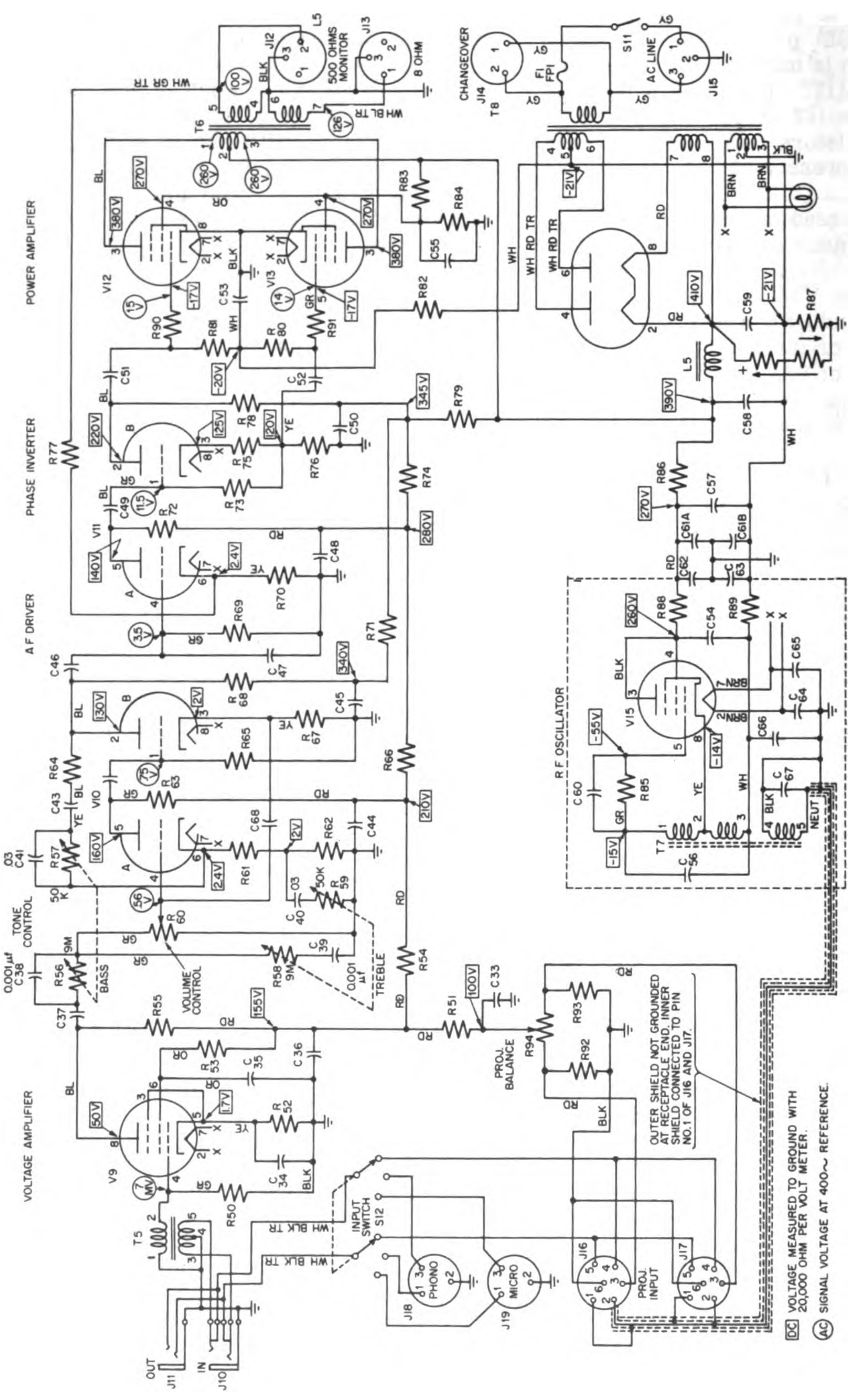


Figure 11-13.—Schematic diagram of external amplifier.

Digitized by Google

and volume expanders, into the input speech circuit. The insertion of a telephone plug in J11 will merely multiply the input sound circuit. The insertion of a telephone plug in J10 will disconnect the input circuit switch S12 from the amplifier input, and transfer the amplifier input to the equipment connected to the telephone plug.

The input signal is applied to the grid of V9 through the audio transformer T5. The gain of the amplifier is varied by the volume control potentiometer R60 and the contact arm of which is connected to the grid of V10A. The basic feedback network between the plate of V10B and the cathode of V10A consists of R64 in series with blocking capacitor C43. A separate tone control is provided at the input of V10A to vary the high-frequency or low-frequency response of the amplifier without affecting any appreciable variation in the sensitivity between 500 cycles and 1,000 cycles.

The low-frequency attenuation network consists of C38 shunted by variable resistor R56. The high-frequency attenuation network consists of variable resistor R58 in series with C39 shunting the volume control potentiometer R60.

The low-frequency accentuation is provided by variable resistor R57 shunting C41 in series with the basic feedback network. The high-frequency accentuation is provided by C40 in series with variable resistor R59 shunting the cathode resistor R62 and V10A.

The variable resistors R56 and R57 for controlling the low-frequency response of the amplifier are ganged and operated by the BASS control, located on the operating panel. Likewise, the variable resistors R58 and R59 for controlling the high-frequency response are ganged and operated by the TREBLE control.

The output of V10 is fed to the grid of V11A, which is a voltage amplifier stage. Capacitor C46 is the coupling capacitor, and R69 is the grid load resistor. Negative feedback of 12 decibels is applied to V11A through R77, which is connected between terminal 5 of the output transformer T6 and the cathode of V11A.

The phase inverter V11B drives V12 from the plate circuit and V13 from the cathode circuit to provide the 180 degree phase shift for push-pull operation of the power output stage V12 and V13. Capacitors C51 and C52 couple V11B to the grids of V12 and V13.

The power output stage consists of V12 and V13 biased for class AB push-pull operation. A fixed negative grid bias is supplied from the rectifier V14 (across R87) through the decoupling resistor R82 terminated in the bypass capacitor C53. Grid series resistors R90 and R91 are used to suppress parasitics. The output impedance of V12 and V13 is matched to the loudspeaker by the output transformer T6, the secondaries 4-5 and 6-7 of which provide impedances of 500 ohms and 8 ohms, respectively. The output receptacle J13 is connected across the 8-ohm winding and the monitor receptacle J12 is connected across the 500-ohm winding.

The Hartley oscillator V15 in conjunction with the stepdown winding 4-5 of T7 supplies power to the exciter lamp at a frequency sufficiently high to be inaudible as modulation of the exciter lamp filament. The plate supply for V15 is supplied from the output of the rectifier V14 through dropping resistor R86. The primary 1-3 of T7 is connected across the plate and grid of V15 and is provided with a cathode tap 2. The grid bias resistor R85 in parallel with bypass capacitor C60 acts as a grid leak. The output voltage of V15 is stepped down through the secondary 4-5 of T7 to obtain the high output current for the exciter lamp.

Capacitor C54 bypasses R-F around the power supply. The decoupling networks, R88, C62, C61A, and R89, C63, C61B are symmetrical with respect to ground. C62 and C63 are feed-through capacitors. The decoupling is such that the reactance of C62 and C61A in parallel is very much smaller than the resistance of R88, permitting negligible amounts of r-f signal to be coupled back into the d-c power supply.

Two symmetrical decoupling networks are required because the d-c power supply has a positive d-c voltage (B+), and a negative d-c voltage, and ground potential is at the junction of C62, C63, C61A, and C61B. C64 and C65 are filament bypass capacitors, and C66 is a bypass capacitor for the negative lead. The output of T7 is fed through a double shielded cable to the projector receptacle. The outer shield terminates in a button plug, which grounds at the chassis, and the inner shield terminates at pin 1 on receptacles J16 and J17.

The full-wave rectifier V14 is supplied from the secondary 4-6 of the power transformer T8. The center tap, terminal 5, is grounded through R87 to provide the negative bias for the power output stage, V12 and V13. The positive polarity filament (pin 2) of V14 is terminated in C59 and L5, both of which comprise the input of a pi-section filter. The power for the oscillator V15

Digitized by Google

is obtained at the junction of L5 and C58, feeding through R86 into C57. The filter decoupling circuit comprising R88, R89, C54, C62, C63, C61A, and C61B prevents the 112,000-cycle signal developed by V15 from feeding back into the power supply and causing r-f interference.

The voltage and decoupling resistor R51 is connected at the junction of R54 and C36, and terminated in decoupling capacitor C33, and the arm of R94. Resistors R92, R93, and R94 comprise a portion of a voltage divider between B+ and ground, the function of which is to supply the positive bias voltage for the photocells in both projectors. The projector balance resistor R94, simultaneously increases the voltage on one projector input and decreases the voltage on the other projector, and thus provides a means of equalizing the audio signal levels from two projectors. Hence, a voltage varying between 50 and 100 volts can be applied to either projector photocell circuit to provide the necessary change in a-c output from the projectors to adequately equalize the volume level. Adaptors for establishing connections between P2 (fig. 11-10), J-16, and J17 (fig. 11-13) are required (not shown in the figs.).

EXTERNAL LOUDSPEAKER

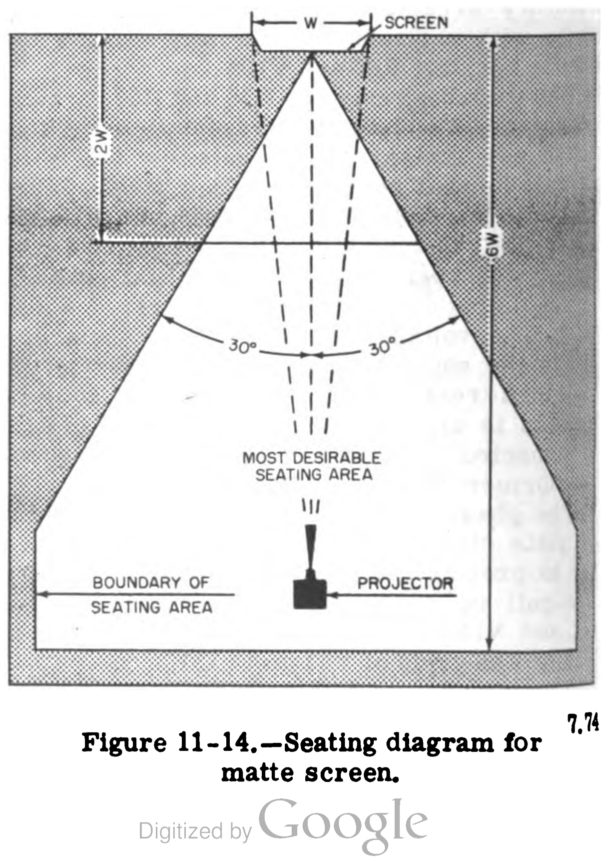
The external loudspeaker is a 25-watt permanent-magnet moving coil loudspeaker contained in a metal case. The unit is equipped with a 75-foot 2-conductor cable, one end of which is permanently connected to the terminals of the loudspeaker, and the other end terminates in a 3-pin male conductor, which plugs into the output receptacle on the amplifier. A receptacle is wired in parallel with the loudspeaker circuit to permit use of a second loudspeaker with the same amplifier.

INSTALLATION

The enjoyment of any film may be dulled by careless or faulty presentation irrespective of the fine quality of the picture and the sound. Most of the success of film programs depends on the preparation prior to the showing. The vital factors involved include the proper selection and placement of the screen, seating arrangement, placement of projection equipment, selection of correct lens, and previewing of the film to be shown.

The efficient use of any screen involves projection that utilizes the entire screen surface. Motion pictures require oblong screens because of the shape of the film image. The types of screens generally used for motion picture projection have white matte or glass beaded screen surfaces. The beaded screens are not recommended for shipboard use because the glass beads fall off in salty atmosphere. The white matte screen is characterized by a wide angle of reflections, affording a more uniform brightness to the entire audience.

The angles of observation are measured from the projection axis, which is a line running from the lens of the projector perpendicular to the center of the screen surface. The best reflection and truest observation of the picture is achieved when the observer views the screen from an angle close to the projection axis. However, all observers cannot be seated close to the projection axis, and it is essential that some latitude of observation angle be provided by screen construction. The preferred angles of observation for the matte screen are approximately 30 degrees on either side of the projection axis (fig. 11-14). To conform with this arrangement, no one should sit outside an angle of 30 degrees from the center line, not closer to the screen than two screen widths, and not farther from the screen than six screen widths.



7.74

Figure 11-14.—Seating diagram for matte screen.

Digitized by Google

The screen should always be placed at right angles to the lens axis and at a convenient height for viewing, with the projector placed high enough to permit the beam of light to pass well above the heads of those sitting in front of the projector. The screen height should be such that the lower edge is at least as high as the heads of those sitting nearest to it. If two projectors are used, the screen should be perpendicular to a line drawn midway between the two projectors and the center point of the screen should be on this line.

The focal length of the lens used in the projector is closely related to the screen because the lens determines the size of the screen image. The 16-mm projector is usually supplied with a lens having a focal length of 2 inches, which meets average projection conditions. However, when it is necessary to depart considerably from average conditions, the focal length of the lens can be readily determined from the equation,

$$F = \frac{3}{8} x \frac{d}{w}$$

where F is the focal length in inches, 3/8 is a constant, d the distance between the lens and screen in feet, and w the width of the screen in feet. For example, if the focal length of a lens for use in a small room where the distance between the lens and screen is 24 feet, and the width of the screen is 6 feet then

$$F = \frac{3}{8} x \frac{24}{6} - 1\ 1/2 \text{ inches}$$

If a lens of the computed focal length is not available, use a lens having the nearest focal length. This computation does not apply for Cinemascope pictures.

Place the projector at least 6 feet behind the last row of seats to eliminate any disturbing influence of the projector and its normal operating noise. Be certain to locate the projector at a sufficient distance from the screen so that the projected pictures will not overrun the screen. The closer the projector is to the screen, the smaller the image. Conversely, the farther the projector is from the screen, the larger the image.

The location and choice of loud speakers to ensure adequate sound intensity in various parts of the sound area requires special considerations. These considerations will vary considerably, depending on whether the projection equipment is installed in a hangar deck or topside. If it is installed in a hangar deck, the problem of echoes and reverberations is introduced, and if it is installed topside, the problem of high-level distraction noises generated by the ship and by the wind passing through and around the super-structure must be considered.

Topside

The topside installation of projection equipment requires special consideration of the location and choice of the loudspeakers because the physical construction of the designated assembly area aboard ship is not designed for entertainment. Therefore, a combination of directional horn loudspeakers and direct radiators is required to cover the audience area with a uniform intensity level of sound.

The direct radiator loudspeaker has a relatively wide angle of sound distribution and is particularly fitted for use in the proximity of the screen. A direct radiator can be expected to cover a distance of 75 to 100 feet, depending on the amount of distracting noise generated by the ship. The horn loudspeaker, on the other hand, has a relatively narrow angle of sound distribution and is well suited to cover areas 75 feet or more away from the screen. The horn loudspeaker should be mounted on the top of the screen frame and directed so that the focal point of the sound output converges at approximately 125 feet from the screen.

The recommended loudspeaker combination, therefore, comprises two direct radiators and two horn loudspeakers. The direct radiators are mounted on the screen frame (one on each side) and tilted to cover the front half of the audience, and the horn loudspeakers are mounted on top of the screen frame (one on each side) and tilted to cover the rear third of the audience. In order to secure uniformity of the sound level over the sound area, each of the two banks of loudspeakers can be adjusted independently of the other.

Dual projection equipments utilizing external amplifiers (fig. 11-15), are required to secure the previously discussed uniform sound distribution and to assure a professional presentation. The amplifiers are designated as the primary amplifier and the secondary amplifier. All input connections are made to the primary amplifier, the output of which is fed to the monitor speaker (not shown) and the direct radiator bank.

The secondary amplifier input signal circuit is connected to the sound input circuit of the

Digitized by Google

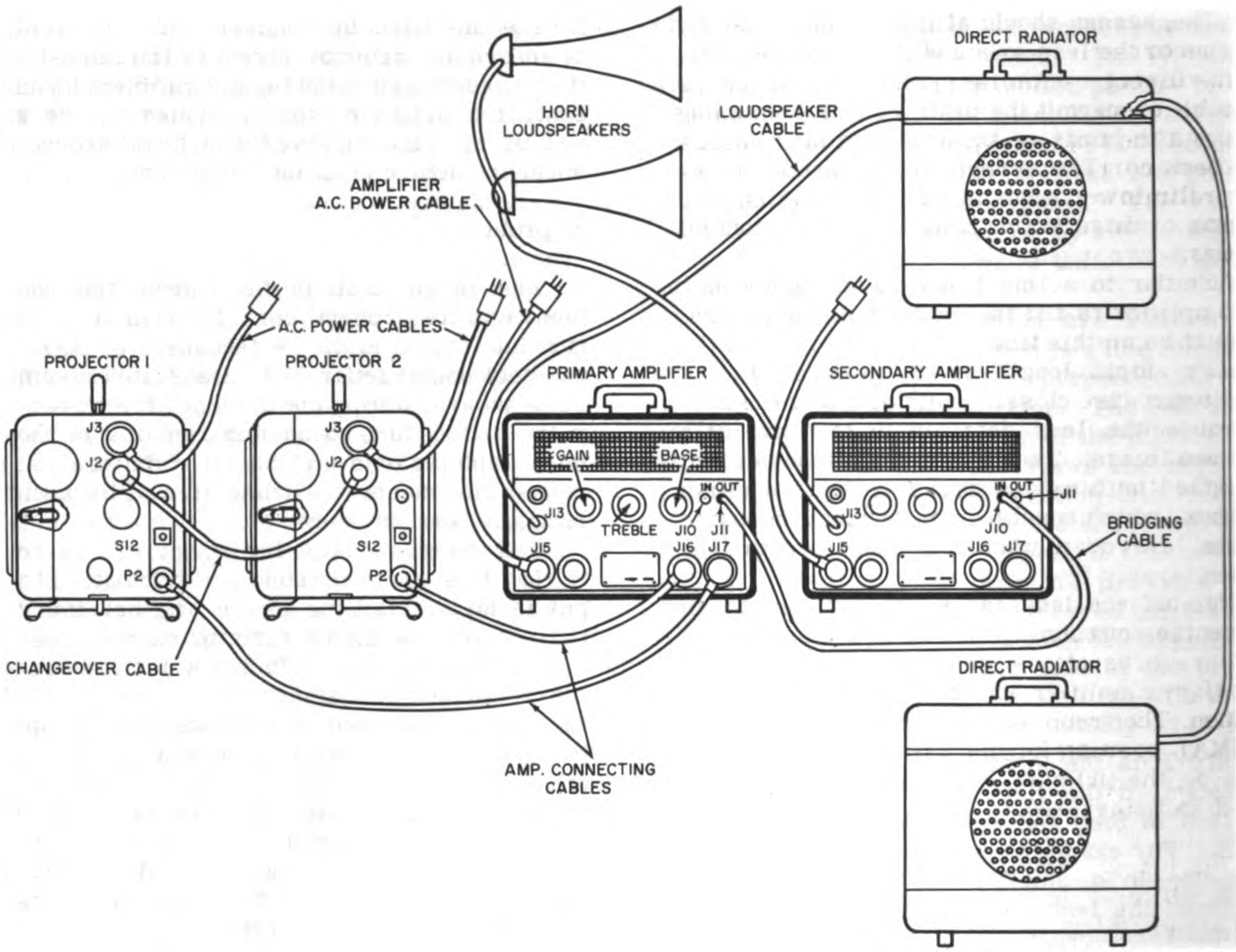


Figure 11-15.—Interconnection of dual projection equipments.

primary amplifier by a bridging cable. The interconnection is between the OUT bridging jack J11 of the primary amplifier and the IN bridging jack J10 of the secondary amplifier. This arrangement disconnects all of the input receptacles on the secondary amplifier, making it a slave to the input circuits of the primary amplifier. The output of the secondary amplifier is connected to the bank of horn loudspeakers.

The direct radiators and horn loudspeakers have a nominal impedance of 16 ohms. When connected in parallel, the joint impedance of the two direct radiators is 8 ohms, which is a matching impedance for the primary amplifier. A similar condition exists for the two horn loudspeakers and the secondary amplifier.

The correct phasing of the loudspeakers is absolutely essential, otherwise dead spots and loss of sound intensity will result. The loudspeakers are all mounted in the same plane at the screen, and thus all of the voice coils must be connected so that they move back and forth identically in the air gaps. If the loudspeaker voice coils are not paralleled correctly, cancellation of the loudspeaker sound output will occur, and distortion with loss of sound will result.

Loudspeaker voice coils are identified by markings, and it is essential that similarly marked terminals be tied together when connecting the loudspeakers in parallel. Check the phasing of the coils in actual operation by temporarily setting the loudspeakers adjacent to each other, then reproduce a sound film as a test, and listen to the sound from the loudspeakers at a distance of 25 feet or more. A temporary reversal of the connections to either loudspeaker will furnish a quick answer as to the

Digitized by Google

orrect phasing of the units. Loss of level, hen incorrectly phased, will be very evident.

The direct radiators and horn loudspeakers ıust be checked separately before combining ıem into the final array. When the loudspeakers ave been correctly phased, perform the follow-ıg preliminary adjustments to establish the ptimum amplifier volume and tone control ettings.

Turn the gain control to zero on the second-ry amplifier that feeds the horn loudspeakers. aise the gain control to position FOUR on the rimary amplifier that feeds the direct radia-ırs. Reproduce a sound film and note the gain ontrol setting necessary to furnish adequate olume at a distance of 50 feet from the screen. nergize the horn loudspeakers and establish ıe gain control setting to secure the same olume level at a distance of 125 feet from the creen.

The horn loudspeakers will not reproduce requencies effectively below 200 cycles, and to void reverberations the bass control on the econdary amplifier should be set at the ATTEN osition. The treble control should be set at the ORMAL position for most films. The tone con-rols on the primary amplifier that feeds the irect radiators should be set at NORMAL, or aried according to the film correction required.

This topside amplifier-loudspeaker combi-ation will provide satisfactory sound coverage ver areas 75 feet by 200 feet with a reserve of ower still available.

langar Deck

The successful installation of projection quipment in a hangar deck involves acoustic roblems not encountered in the comparatively imple case of sound transmission in open air. he bulkheads, overhead, and deck of an en-losed area partly reflect and partly absorb ound originating in the enclosure, and introduce choes and reverberations that may seriously mpair the quality or character of the sound.

When a surface of a room is situated so that reflection from it is outstanding and is heard y a person an appreciable length of time later han the direct sound, it will appear as a distinct cho and will be disturbing. If the surface is oncave, it may have a focusing effect and con-entrate reflected sound energy at one locality. uch a reflection may be several decibels higher n level than the direct sound, and its arrival at later time will be particularly disturbing. In this case the offending surface can be covered with absorbing material to reduce the intensity of the reflected sound; the surface can be changed in contour to send the reflected sound in another direction; or some improvement may be obtained by changing the loudspeaker to a new position. However, the best method of solving any partic-ular problem will depend on local conditions.

The most common acoustic defect encoun-tered in a large room is that of excessive re-verberation. Reverberation is the persistence of sound due to the multiple reflection of sound waves between the several bulkheads of the room. Some of the sound from the distant sources over-laps the succeeding sound and remains in the room as audible delayed images of the original source. The longer the time interval between reflections, and the lower absorbing efficiency of the reflecting surfaces, the longer will be the time that this residual sound will persist. The result is an overlapping of the original sound and its images. This reverberation, if exces-sive, causes a general confusion which is detri-mental to speech intelligibility.

If a single loudspeaker is mounted in a large reverberant area, such as a hangar deck, the intelligibility directly in front of the loudspeaker would be satisfactory. As the distance from the loudspeaker or the angle of the loudspeaker sound axis is increased, the intelligibility de-creases rapidly. This condition is based on the fact that the sound from a loudspeaker in a re-verberant space may be considered as composed of direct sound which reaches the listener di-rectly without having suffered any reflection, and indirect sound which has suffered at least one reflection.

Indirect sound builds up because each of the multiple rays of sound energy leaving the loud-speaker strikes some point on the surface of the room and are then reflected again and again until the energy is completely absorbed. Each point of reflection may be considered as a new source of sound. A large number of these im-age sources will be established so that sound distribution in a room tends to remain substan-tially uniform. The direct sound intensity, on the other hand, decreases inversely as the square of the distance from the source, as it would in open air. Intelligibility under these conditions is related to the ratio of direct to indirect sound, so that as a person moves away from the loudspeaker, the ratio of direct to indirect sound at the listening position decreases and the intelligibility decreases correspondingly.

Digitized by Google

The conclusion is that in a highly reverberant space the intelligibility decreases with distance from the loudspeaker.

The present practice employed in aircraft hangar decks is to mount a number of loudspeakers at frequent intervals on the overhead, facing directly downward. This arrangement decreases the distance from any listening point to the nearest loudspeaker and increases the ratio of direct to indirect sound.

There is a time delay associated with the transmission of sound over any appreciable distance attributable to the finite time required for sound to travel through air. By locating the loudspeakers through the hangar area, a portion of the sound from the distant loudspeakers will be heard along with local loudspeakers, but will be retarded in time phase. The average duration of a single syllable of speech is about 0.2 second. It is obvious then, that one syllable from the distant sources overlaps the succeeding syllable from the nearest source, with resulting confusion and poor intelligibility. This overlapping can be reduced by loudspeaker locations (on the overhead directed downward) which do not favor transmission of sound along the length of the hangar space.

Some sound energy is absorbed at each reflection. If the number of reflections per second is increased, more sound is absorbed per unit time, the reverberant sound dies away faster, and more attenuation occurs along the length of the hangar deck. Because the vertical dimensions of hangar areas are the smallest, and because the loudspeaker sound output characteristic is essentially directional, more reflections will occur per unit time for sound traveling up and down than any other primary mode of sound travel, with a consequent greater sound absorption. This condition also favors the overhead location of the loudspeakers.

Individual switching of the speakers allows disconnection of those not covering the audience. This action reduces needless reverberations and echoes and greatly increases intelligibility.

The most obvious improvement that could be made in hangar decks would be to reduce the reverberations by the use of sound-absorbing materials. The most practical location for such material would be on the overhead where the absorption would be most effective for the vertical mode of sound travel established by overhead loudspeaker mountings. In all new construction carriers beginning with CVA-59, this acoustical treatment for hangar decks has been incorporated.

Excessive volume in the enclosure provided by the hangar deck area will result in a marked increase in reverberations or echoes. The correct volume level is that which provides adequate loudness without excessive reverberation. It is important to remember that the intelligibility of the program suffers decidedly at the very slightest overload of the amplifier. However, the 20 watts of power provided by the overhead type of loudspeaker supplied to carriers is adequate for the largest carrier. A power reserve of 20 watts may be obtained by parallel operation of the external amplifiers.

The tone control setting is best which results in the highest degree of intelligibility. In general, it is best to attenuate the low frequencies because reverberation is now pronounced at the low frequencies, which do not contribute to the intelligibility. Therefore, the control (BASS) should be set in the maximum attenuate position. Conversely, the TREBLE control should be set in the maximum accentuate position depending on the condition of the film with respect to film noise.

The noise level aboard a carrier is of such a high amplitude and character that compression of the sound is essential in order to make low sound level sequences intelligible. In other words, the operator must constantly control the volume, otherwise, low level sound will not be heard, or high level sound will overload the amplifier.

OPERATION

Only qualified personnel are authorized to maintain and operate motion picture projection equipment. To connect the projection equipment for single equipment operation, turn the motor-lamp switch S3 (fig. 11-10), and the external amplifier on-off switch S11 (fig. 11-13), to the OFF position. Turn the gain control (fig. 11-15) and the tone control on the external amplifier to the NORMAL position. After determining that the equipment is properly grounded plug the a-c power cable from receptacle J3 on the projector into the ship's 115-volt 60-cycle power supply. Place the loudspeaker selector switch S12 on the projector in the LOCAL or REMOTE position, depending on whether the internal loudspeaker or an external, 16-ohm loudspeaker is to be used. Be certain that the douser switch S1 (fig. 11-10), is in the OPEN position, the rewind switch S5 is in the OFF position, and the rewind knob on the feed reel

Digitized by Google

·m (not shown) is in the OUT position and ·operly engaged in the short slot.

To operate single projector equipment, turn e motor-lamp switch S3 to the MOTOR posi- on. When showing training films, as soon as e end of the film leader passes the picture erture, turn S3 to the LAMP position, and at e same time, increase the amplifier volume ntrol to the required setting for proper sound lume. When showing 16-mm entertainment ms, numbers starting at 12 and ending at 3 t regular intervals) are on the film following e end of the film leader. When the last num- r passes the picture aperture, turn S3 to the AMP position.

To operate dual projector equipment (fig. -15), place projector 1 in operation as ex- ained for a single projector. While the film is nning through (outgoing) projector 1, mount e second reel of film to the feed reel arm, and empty reel to the takeup arm of (incoming) ·ojector 2. Thread projector 2 and set the user switch S1 in the CLOSED position (fig. -10). As projector 1 nears the end of the reel, atch for the opaque dot which appears for an stant in the upper right-hand corner of the reen. When the dot appears, turn S3 on (in- ming) projector 2 to the LAMP position. nother opaque dot will appear in the same sition on the screen approximately 6 seconds ter the first one. When this dot appears, de- ess the changeover pushbutton S4 on (incoming) ojector 2 and turn off (outgoing) projector 1 placing S3 in the OFF position. The change- er button S4 when depressed on projector 2, ens the douser S1 of (incoming) projector 2 d the picture is projected on the screen ac- mpanied by sound. The picture and the sound e cut out from (outgoing) projector 1.

To stop the projector equipment, place S3 the MOTOR position and turn the volume con- ol to the extreme counterclockwise position soon as the sound or end title on the end of e reel has faded out. Allow the remaining m to run through the projector and then turn to the OFF position.

AINTENANCE

The corrective maintenance of sound motion cture projection equipment is divided into the tegories of emergency repair service, which performed aboard ship or in the field, and ajor overhaul and repair which is performed a repair ship or shore activity. Only emergency repairs which are accomplished aboard ship or in the field are discussed here.

Projector

The projector equipment is set up for sound operation with the sound film properly threaded in the projector, the on-off amplifier toggle switch in the ON position, the loudspeaker selector switch in the LOCAL position (if external speaker is not used), the volume control in the MID position, and the motor-lamp switch in the LAMP position.

If no sound is present under these conditions, check the projector sound system consisting of the exciter lamp, photocell, and associated light path elements (fig. 11-10). The motor-lamp switch, when placed in the LAMP position, should light the exciter lamp. If the lamp does not operate, replace it with one that is known to be good. If the new lamp does not operate, replace the exciter lamp oscillator tube V6 in the internal amplifier (fig. 11-12).

If sound is not present after replacing the oscillator V6 insert a piece of cardboard or heavy paper between the sound drum and sound lens (fig. 11-8) to obstruct the optical light path with no film in the projector and with the volume control at the MID position. This action should produce a "plop" in the speaker. If no "plop" is heard, it may be the result of a bad photocell, an open or shorted photocell cable, misalignment of the light path, or an obstruction such as oil, dirt, or a piece of broken film. Do not attempt to remove or adjust the lens of the sound optical system because this requires special training and equipment. If sound is obtained after the foregoing checks, the trouble is in the internal amplifier or loudspeaker.

Internal Amplifier

If the amplifier pilot lamp (fig. 11-12) does not operate, the lamp is defective or no filament power is present. If the tubes do not heat after allowing approximately 1 minute to warm up, no a-c power is being delivered to the amplifier. Check the fuse and replace if necessary. If the pilot lamp and tube filaments are operating normally but no sound is forthcoming, move the output tube V5 in and out of the socket with no film in the projector, with the motor-lamp switch in the MOTOR position, and with the volume control in the extreme clockwise position. If noise is heard from the loudspeaker as the tube pins

Digitized by Google

make and break contact with the socket, it indicates that the output tube V5 and the loudspeaker are operating. Repeat this test with the output tube V4. Noise from the loudspeaker indicates that V4 is good.

If no noise is heard when either V4 or V5 is moved, check the loudspeaker connections and speaker selector switch. If the connections are intact and the selector switch is in the proper position, replace the rectifier tubes V7 and V8 (fig. 11-12).

If noise was heard when checking the output tubes V4 and V5 move the driver tube V3 in and out of the socket. A similar noise of greater intensity should be heard. Failure to produce noise at this point indicates a bad driver tube V3. Repeat the same procedure for the input tube V2.

The performance of the internal amplifier, with respect to the audio signal, cannot be determined without a steady amplitude input signal. A 400-cycle test film can be used to supply the audio frequency signal for all amplifier emergency audio frequency measurements. If desired, the film can be used in the form of a loop about 3 feet in length.

The a-c signal voltages must be measured with a high-impedance vacuum-tube voltmeter, otherwise the readings will be in error. The amplifier should be terminated in a 16-ohm load resistor instead of the external loudspeaker, when taking output power measurements. The a-c signal voltages are indicated by the voltage enclosed in a circle with an arrow pointing to the exact point of measurement (fig. 11-13).

The d-c voltages for normal conditions are designated by the voltage value enclosed in a rectangular block with adjoining arrow to indicate the point of voltage measurement (fig. 11-13). A 20,000 ohm-per-volt type of meter must be used for taking the d-c measurements.

Internal Loudspeaker

The internal loudspeaker is an integral part of the 16-mm projector. It is a 5-inch dynamic loudspeaker containing a permanent magnet and moving voice coil. To gain access to the loudspeaker, remove the speaker mounting panel from the projector case and place it on a bench. Check the loudspeaker cone for holes or cracks. Apply equal pressure to all sides of the cone and gently push the cone with the fingers to be certain that the voice coil is not rubbing in the air gap. Be careful not to damage the loudspeaker when making this inspection. Unsolder the connection from the terminals of the loudspeaker and check the d-c resistance of the voice coil with an ohmmeter. The d-c resistance should be approximately 8 ohms.

The procedures used to localize troubles and effect emergency repairs to the internal amplifier and loudspeaker are also followed when performing similar maintenance on the external amplifier and loudspeaker. The scope of this training course does not permit a complete coverage of the operation, care, and maintenance of the sound motion picture projection equipment. More detailed information is contained in chapter 9850 of the Bureau of Ships Technical Manual and the Manufacturer's Technical Manual furnished with the equipment in use aboard your ship.

A recent experimental modification to the 16-mm motion picture projector permits the use of a Xenon arc-lamp light source instead of the incandescent type of lamp. Although additional components are used including the power supply and controls required to operate the lamp and portions of the projector have been extensively modified, the operation and construction are essentially the same as that for the equipment utilizing an incandescent lamp. This type projector is still undergoing tests and is not standard equipment.

Digitized by Google

CHAPTER 12

GYROCOMPASSES, PART I

The gyrocompass system provides a means f indicating own ship's course at various staions throughout the ship. Gyrocompasses are dentified by the Mark-Mod system. The mark Mk) number designates a major development f a compass, the modification (Mod) number ndicates a change to the major development.

The two principle suppliers of gyrocomasses for the U.S. Navy are the Sperry Rand 'orporation and the American Bosch Arma Cororation. There are various Mks and Mods of oth Sperry and Arma gyrocompasses, and new nes are being developed.

All gyrocompasses installed in U.S. Navy hips, except the Sperry Mk 19, provide only wn ship's course information. The Sperry Mk 9 (discussed in IC Electrician 1 & C, NavPers 0557-B), provides own ship's course, roll, and itch information. Arma compasses are used rincipally on fleet type submarines, however the .rma Mk 8 is still installed in some cruisers nd aircraft carriers. All references to the .rma compass in this chapter applies to the .rma Mk 8 and the Arma compasses installed n the fleet type submarines. A new type of Arma ompass, the Mk 26, is discussed in the next hapter of this training course.

Basically all gyrocompasses depend upon the roperties of the gyroscope and the rotation of ıe earth for their operation. This chapter disusses the free gyroscope and shows how it is onverted into a gyrocompass. The major comonents of the Sperry Mk 11 Mod 6 gyrocompass ystem are discussed along with compass opera.on.

THE FREE GYROSCOPE

The gyroscope is a heavy wheel, or rotor, uspended so that its axle is free to turn in any irection. The rotor axle is supported by two earings S, S' in a ring, as illustrated in figure 12-1. 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 non-existent.

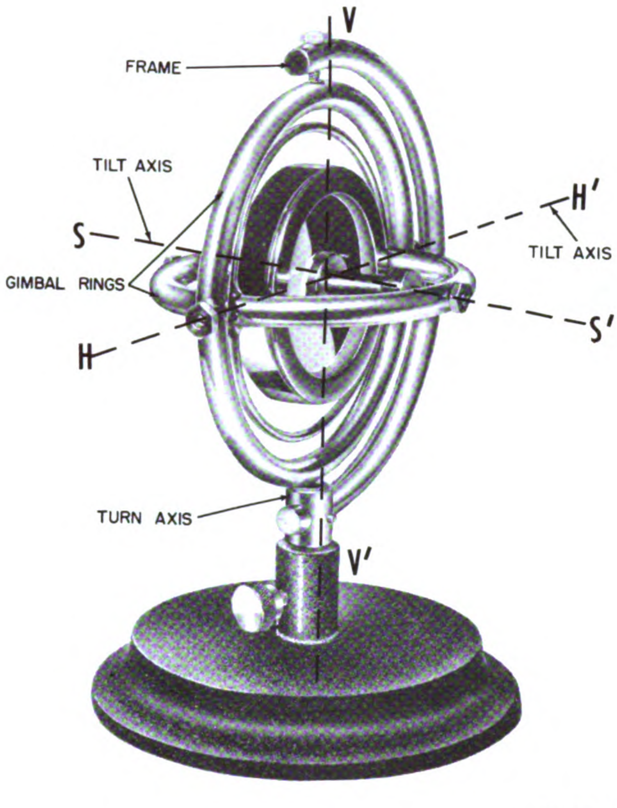
THREE DEGREES OF FREEDOM

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. 12-1). 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.

Digitized by Google

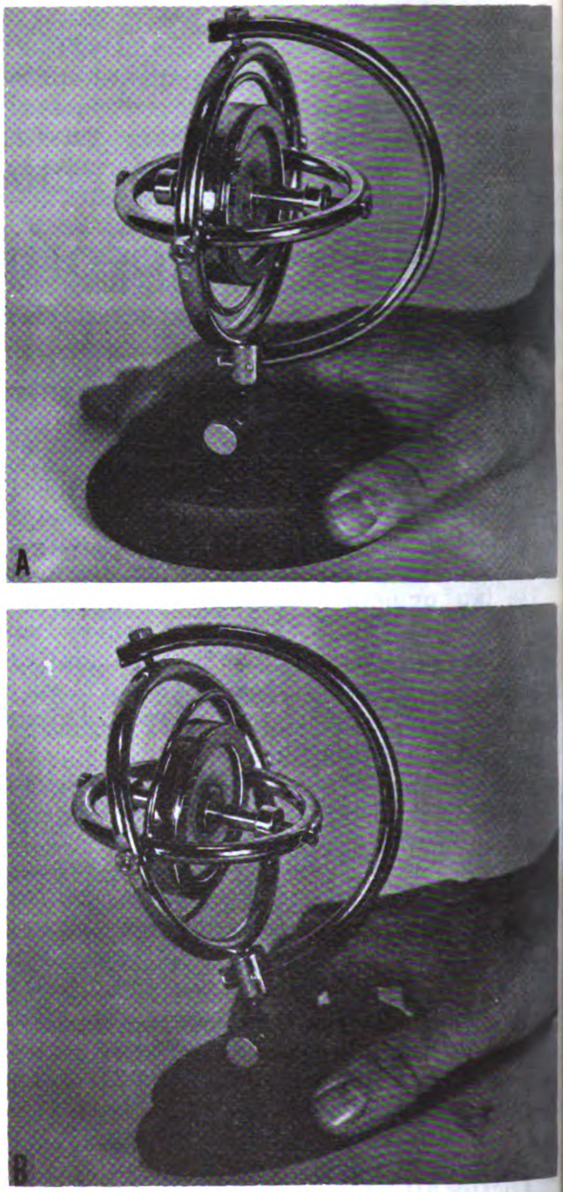


77.194
Figure 12-1.—The gyroscope.

Rigidity of Plane

When the rotor of a gyroscope is set spinning with its axle pointed in one direction (fig. 12-2A) the rotor continues to spin with its axle pointing in the same direction, no matter how the frame of the gyroscope is tilted or turned (fig. 12-2B). 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 can be explained by Newton's first law of motion which states that a body in motion will continue to move at a constant speed in a straight line unless acted upon by an outside force.

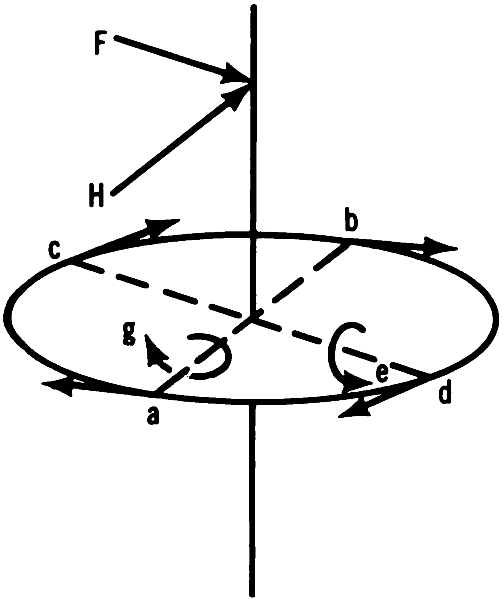
Any point on a spinning wheel is moving in a circular path. Because of inertia (Newton's first law), such a point will tend to move in a straight line tangent to its circular path. Molecular attraction within the wheel, however, confines all the particles in the wheel to circular paths. (However, any wheel will fly apart if it is rotated fast enough.) Although each particle is confined to a circular path, the entire wheel is free to change its plane; but because each particle tends to stay in a straight line the inertia of every particle causes it to resist leaving that plane.



27.12
Figure 12-2.—Rigidity of plane of spinning gyroscope.

Consider the particles in the rotor at points a, b, c, and d (fig. 12-3). 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

Digitized by Google



77.195

Figure 12-3.—Spinning rotor with a vertical axle.

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.

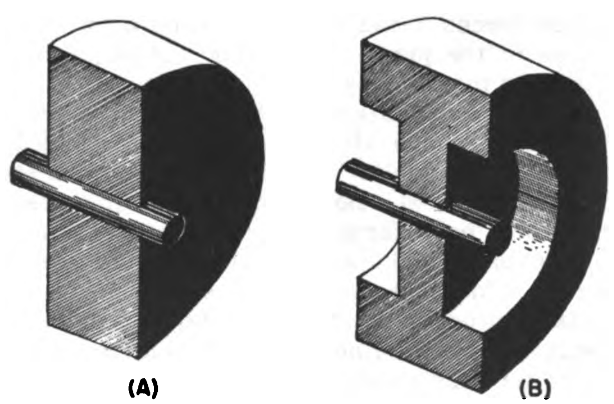
A gyroscope can be made more rigid by (1) making the rotor heavier, (2) causing the rotor to spin faster, and (3) concentrating most of the rotor weight near the circumference. If two rotors with cross sections like those shown in figure 12-4 are of equal weight and rotate at the same speed, the rotor in figure 12-4B is more rigid than the rotor in figure 12-4A. This condition exists because the weight of the rotor in figure 12-4B is concentrated near the circumference. Both gyroscope and gyrocompass rotors are shaped like the rotor shown in figure 12-4B.

Precession

Because of gyroscopic inertia it has been shown 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 (F) on one end of the axle (fig. 12-3) produces a turning effect which attempts to tilt the gyroscope about the axis ab. 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 in the direction of arrow e. Conversely a force attempting to turn the gyroscope about the axis cd is similarly resisted and results in a tilt about the axis ab. If the force is applied in direction H, rotation will occur in the direction of arrow g. This rotation of a gyroscope about an axis perpendicular to the axis about which a force is exerted is called precession. Precession takes place whenever any force tends to tilt the axle of a spinning gyroscope rotor. The precession caused by the applied force is always about an axis at right angles to the axis about which the force is applied.

A simple way to determine the direction of precession is illustrated in figure 12-5. 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 displaced 90° in the direction of rotation moves in the direction of the applied force. This is the direction of precession.

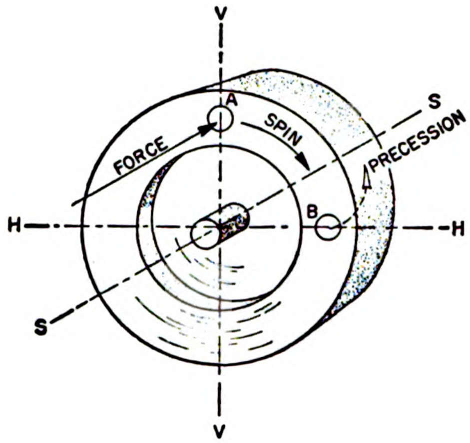
Any force that tends to change the plane of rotation causes a gyroscope to precess. Precession continues as long as there is a component of force acting to change the plane of rotation and precession ceases immediately when the force is removed. If the plane through which the force is acting remains unchanged, the gyroscope precesses until the plane of the rotor is



77.196

Figure 12-4.—Weight distribution in rotors.

Digitized by Google

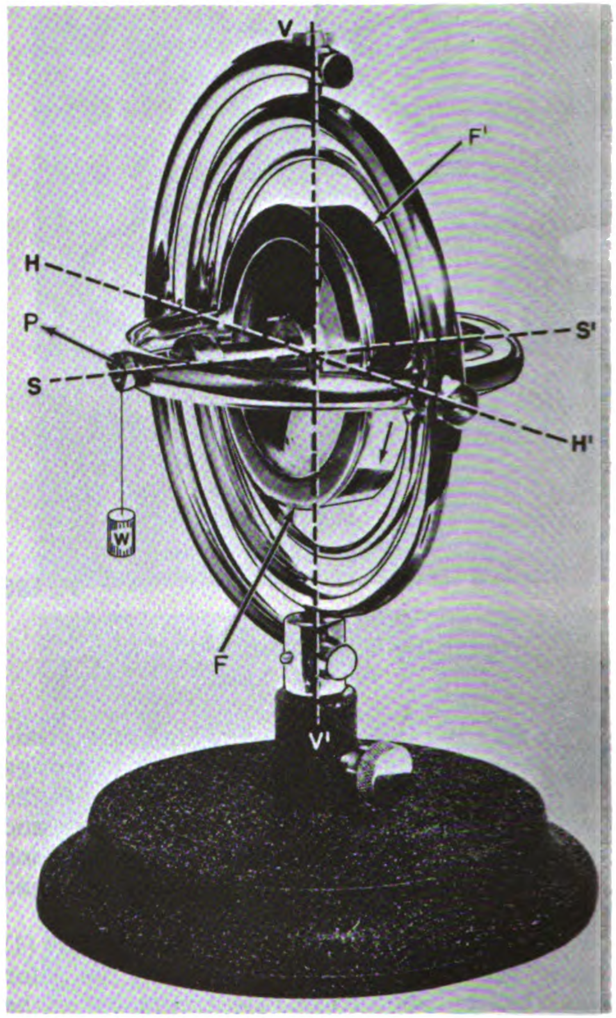


27.131
Figure 12-5.—Direction of precession.

in the plane of the force. When this position is reached, the force 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. This is illustrated by figure 12-6, in which the force attempting to change the plane of rotation is provided by a weight W suspended from the end of the horizontal axle. Although the weight is exerting a downward force, it must be remembered that the force it produces against the particles in the spinning wheel is horizontal. This force is imparted to the particles in the wheel as exemplified by arrows F and F'. If the wheel rotates clockwise as seen from the weighted end, precession will occur in the direction of arrow P. As the gyroscope precesses it carries the weight around with it so that forces F and F' continuously act at right angles to the plane of rotation and precession continues indefinitely.

A valid explanation of why precession occurs requires the use of vector representations of torques and angular motions and is beyond the scope of this text. However, the concept of torque should be understood since that term is used extensively in the discussion of gyrocompasses. Torque is defined as the product of a force which tends to produce rotation and the perpendicular distance from the line in which that force is acting to the axis about which the rotation tends to occur. Whereas force acts in a straight line at or on a point, torque occurs in a plane, and is referred to as being applied about an axis. A force acting on the axle of a gyroscope produces



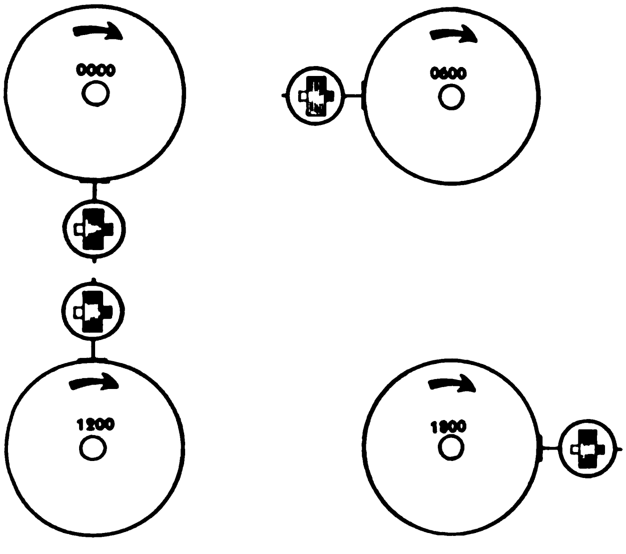
77.197
Figure 12-6.—Continuous precession.

a torque about either or both of the gyro's other two axes. For a given amount of force, the greater its distance from the axis of rotation, the greater the torque. If the force is acting on the axis of rotation, the torque is zero ($F \times 0 = 0$).

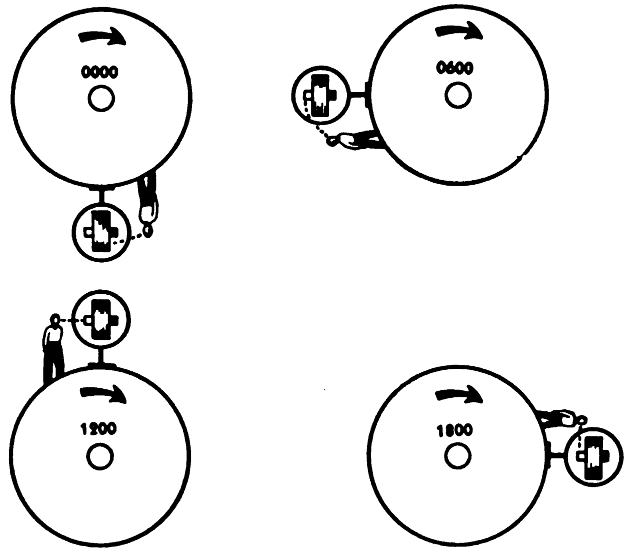
Force of Translation

Any 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

Digitized by Google



12.144
Figure 12-7.—Free gyroscope at the equator viewed from space.



12.144
Figure 12-8.—Free gyroscope at the equator viewed from the earth's surface.

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. It produces no torque on the gyro rotor.

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 12-7 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° while the gyroscope retains its original position. At 0000 the earth has rotated 360° and the gyroscope is back in its original position.

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 12-8 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 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

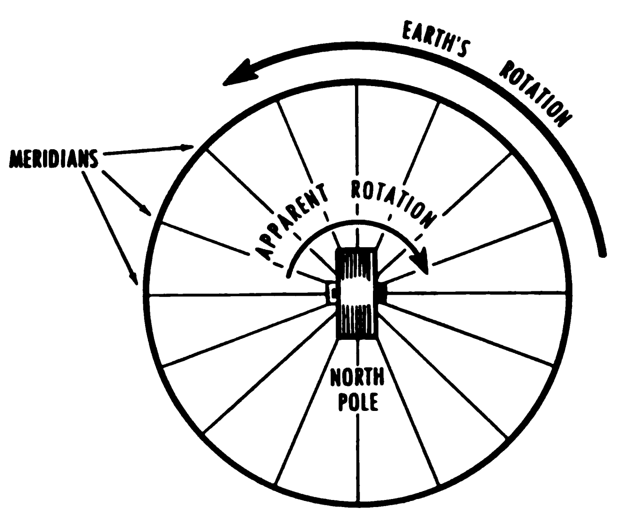
Digitized by Google

by rigidity of plane which tends to maintain the plane of the gyroscope wheel parallel to its original position in space. This apparent rotation or tilt of the gyro horizontal axis is referred to as horizontal earth rate effect. This effect varies with the cosine of the latitude, and is maximum at the equator and zero at the poles.

Now assume that the spinning gyroscope, with its spinning axis horizontal, is moved to the North Pole (fig. 12-9). 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. This apparent rotation about the vertical axis is referred to as vertical earth rate effect, and varies with the sine of the latitude. It is maximum at the poles and zero at the equator.

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 horizontal earth rate and vertical earth rate.

Apparent rotation is illustrated by placing a spinning gyroscope with its axle on the meridian (aligned north-south) and parallel to the earth's surface at 45 north latitude and



77.198

Figure 12-9.—Apparent rotation of a gyroscope at the north pole.

0° longitude, as shown in figure 12-10. 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 12-10 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 & D of fig. 12-10) is due to the rotation of the earth. The gyroscope axle has moved from alignment with the meridian to a position 45° east of the meridian, and the axle apparently has tilted 45° from the horizontal. At 1200 (E & F of fig. 12-10) 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 & H of fig. 12-10) 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 & B of fig. 12-10). The action of any free gyrsocope 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.

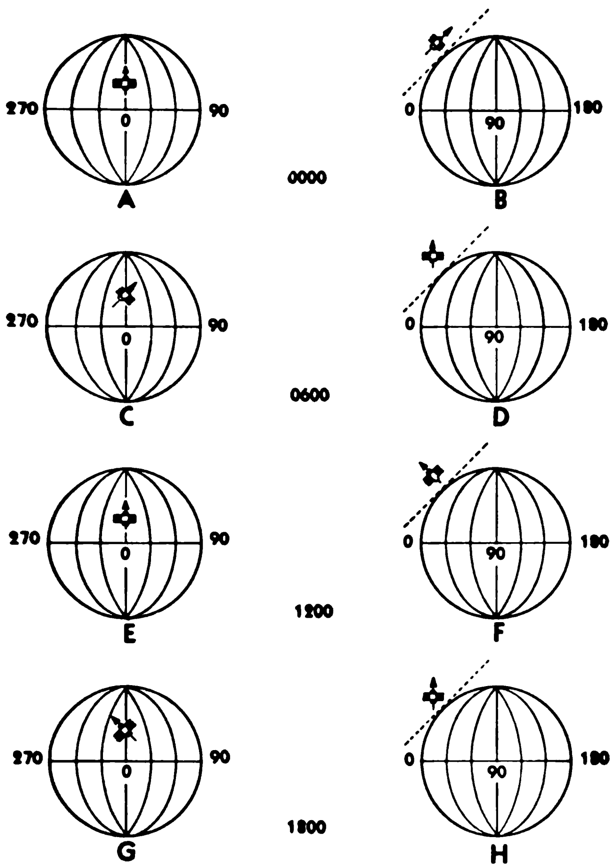
A gyroscope, if set on any part of the earth's surface with the spinning axle not parallel to the earth's polar axis, appears to rotate, over a 24-hour period, about a line passing through the center of the gyroscope and parallel to the earth's axis. This apparent rotation is in a counterclockwise direction 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. 12-11).

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.

CONVERTING THE GYROSCOPE INTO A 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

Digitized by Google



77.199

Figure 12-10.—Apparent rotation of a gyroscope at 45° N latitude.

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.

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 gyroscope must be nearly level when parallel to the meridian, and a means must be provided to prevent it from oscillating across the meridian.

The principles employed by the Arma and Sperry manufacturers in converting the gyroscope into a gyrocompass are discussed below.

SPERRY PRINCIPLES

Sperry gyrocompasses (with the exception of the Mk 19 and 23) employ a mercury ballistic, or liquid ballistic in the case of the Mk 22, which provides necessary torques to make the compass continuously seek the meridian (true north). The Mk 19 and 23 Sperry compasses use an electronic control system to make the compass north-seeking.

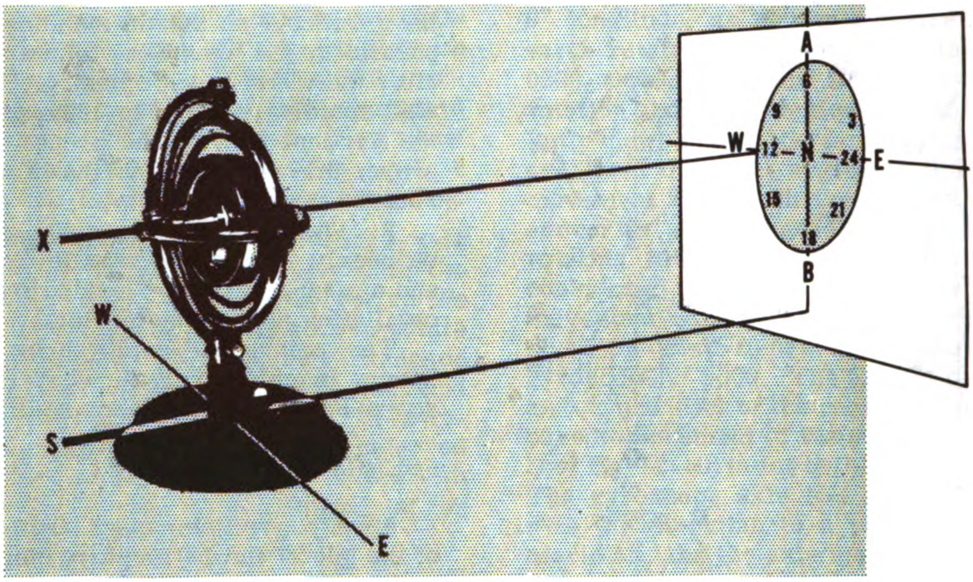
Mercury Ballistic

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 12-12.

When the axle is level (fig. 12-12A), 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. 12-12B), 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 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

Digitized by Google



77.200

Figure 12-11.—Path of the spinning axle of a free gyroscope.

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.

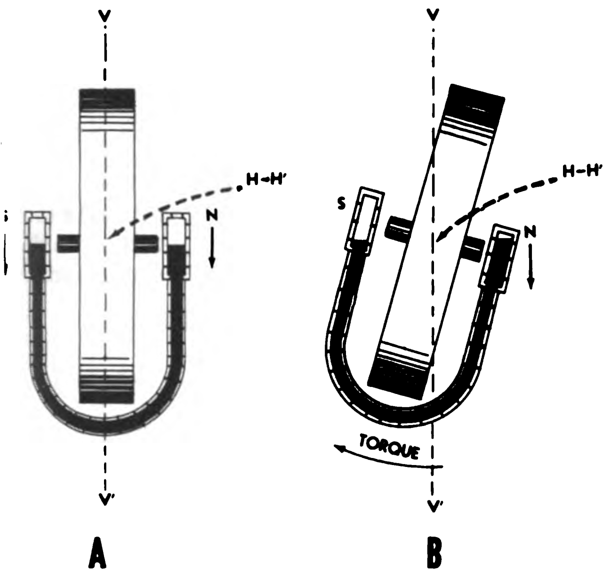
As you have learned, when the north end of the rotor axle is east of the meridian, the earth's rotation causes it to rise. When a mercury ballistic is added to the gyroscope, the elevation of the north axle produces a torque about the horizontal axis that causes counterclockwise, or westerly, precession. 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 (fig. 12-13A) 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 (fig. 12-13B). 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 (fig. 12-13 C&D). This upward tilting continues until the gyroscope axle is on the meridian (fig. 12-13E). 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, and 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

Digitized by Google



77.201
Figure 12-12.—Action of a mercury ballistic.

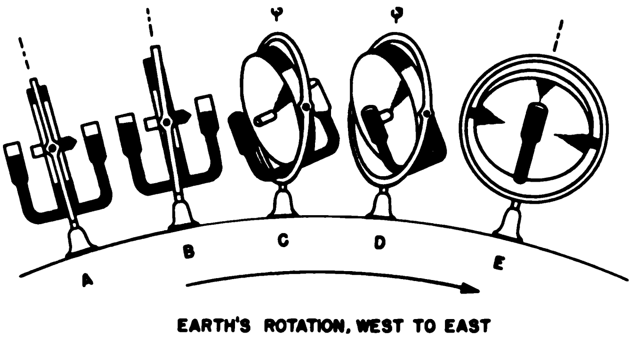
starts the north end of the gyroscope axle tilting upward. As this action occurs the torque about the north axle gradually diminishes to zero and the precessional motion around the vertical axis slows down until the gyroscope axle is once more horizontal and precession ceases. When the gyroscope axle becomes horizontal, the axle points in its original starting position. Figure 12-14 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.

Electronic Control System

The electronic control system utilized by the MK 19 and Mk 23 gyrocompasses consists of a special type electrolytic bubble level, electronic amplifiers, electromagnetic torquers, and associated circuitry. The electrolytic level generates a signal voltage that is proportional to the tilt of the gyro axle. This signal is amplified, then fed to the torquers which provide the necessary torques to make the compass seek and settle on the true meridian. This system is discussed further in chapter 13 of this training course.

ARMA PRINCIPLE

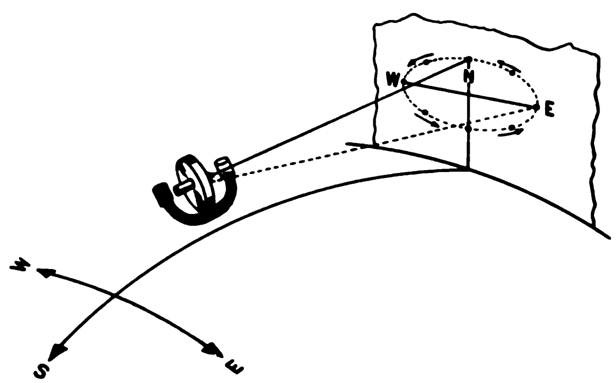
The Arma compass is north-seeking because it is given a force of precession by a pendulous



77.202
Figure 12-13.—Elementary Sperry gyrocompass at the equator.

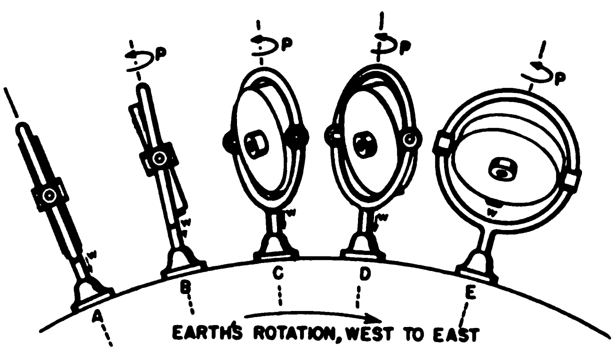
weight. To understand how this compass operates, assume again that the gyroscope is on the equator and that its spinning axis is horizontal and points to the east of the meridian. Instead of having a mercury ballistic, the gyroscope has a weight, W, at the bottom of the rotor case, as shown in figure 12-15. 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 12-15. This pull of gravity has the same effect as a torque about the horizontal axis.

The mercury ballistic of the Sperry compass as shown in B of figure 12-13 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



77.203
Figure 12-14.—Undamped period of the Sperry compass at the equator.

Digitized by Google



77.204

Figure 2-15.—Elementary Arma compass at the equator.

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. 12-13), 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.

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.

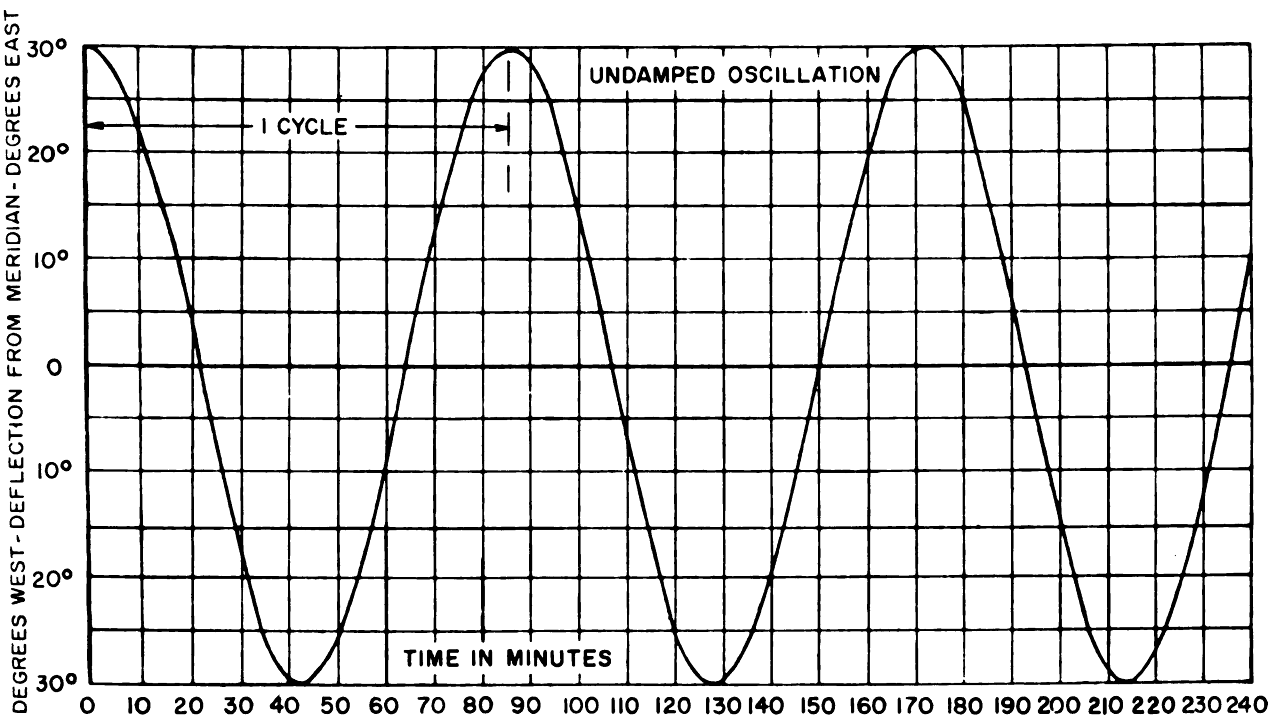
The period of a north-seeking gyroscope is determined by the (1) size and shape of the rotor, (2) rotor speed, (3) torque developed by the mercury or liquid ballistic, or torquers (Sperry compasses), or the pendulous weight (Arma compasses), and (4) latitude. If a short period of oscillation is used, the gyrocompass is disturbed too greatly by ship motions such as speed and course changes, roll and pitch. Lengthening the period reduces the effect of these forces. Too long a period however, causes the compass to take an excessive amount of time to settle on the meridian after starting and after a disturbance.

Both Arma and the ballistic type Sperry gyrocompasses are built with an undamped period of 85 minutes at 40.7° north (New York) latitude. An undamped period of 85 minutes is long enough to prevent excessive disturbances of the compasses from the motions of the ship.

A graph representing the oscillations of a north-seeking gyroscope with a period of 85 minutes is shown in figure 12-16. 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

Digitized by Google



77.205

Figure 12-16.—Oscillation curve of an undamped compass.

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.

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 is about 4 hours for Arma and ballistic type Sperry compasses. The Sperry Mk 19 and 23 gyrocompasses are provided with fast settling systems which greatly reduce the time required for damping during starting.

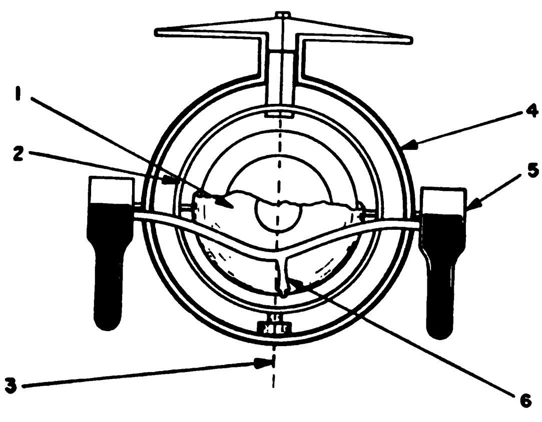
Digitized by Google

Sperry Methods

Oscillations are damped in the Sperry gyrocompasses utilizing the mercury ballistic 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 ballistics, 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. 12-17). The rotor case corresponds to the inner ring of a gyroscope and holds the bearings on which the axle turns.

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. 12-17), the force exerted by the mercury



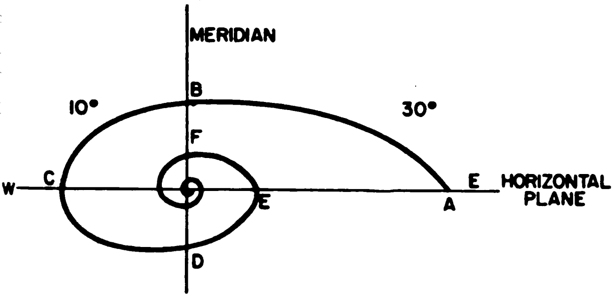
77.206

Figure 12-17.—Elements of the Sperry compass.

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 30° E of the meridian and level (point A, fig. 12-18), 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, fig. 12-18), because at this time it has its maximum tilt and therefore maximum rate of precession about the vertical axis. As the gyro precesses past the meridian, the direction of apparent rotation about the horizontal axis and the direction of precession about the horizontal axis are now both downward. This action causes the gyro to become level (point C, fig. 12-18). When the axle becomes level, precession ceases as there are no torques being applied by the mercury ballistic. If the proper (correct) torques have been applied, the compass would be only 10° W of the meridian, reducing the oscillation by 66 2/3 percent. However, as the earth continues to rotate, the compass will not remain level. Apparent rotation about the horizontal axis causes the north axle to tilt downward. This action causes a transfer of mercury to the north tank. Gravity action on this excess of mercury in the north tank will produce torques about both the horizontal and vertical axes. The torque about the horizontal axis will cause precession about the vertical axis, the north end moving toward the east. The torque about the vertical axis will cause precession about the horizontal axis, the north end moving upward, again opposing apparent rotation about the horizontal axis. The precession about the vertical axis will cause the gyro to precess to

Digitized by Google



77.207
Figure 12-18.—Path followed by the north axle of a damped Sperry compass.

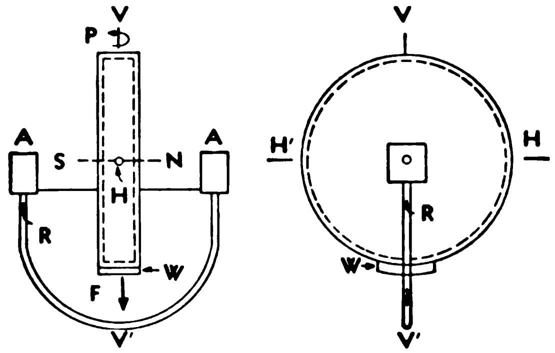
the meridian (point D, fig. 12-18). However, it cannot remain in the meridian because at this time it has maximum tilt, therefore maximum, rate of precession, causing the gyro to precess past the meridian. Now that the north axle is again east of the meridian, the apparent rotation about the horizontal axis and the direction of precession about the horizontal axis both cause the north axle to become level (point E, fig. 12-18) more quickly. At this time the compass would be approximately 3 1/3° east of the meridian. This damping action would continue for approximately 2 1/2 oscillations, and the compass would then settle on the meridian.

The Sperry Mk 22 gyrocompass utilizes a fraction of the weight of the followup pickoff armature to provide the torques for damping. Damping is accomplished for the Mk 19 and 23 gyrocompasses by the electronic control system mentioned previously.

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 12-19. 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



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

77.208
Figure 12-19.—Damping arrangements of the Arma compass.

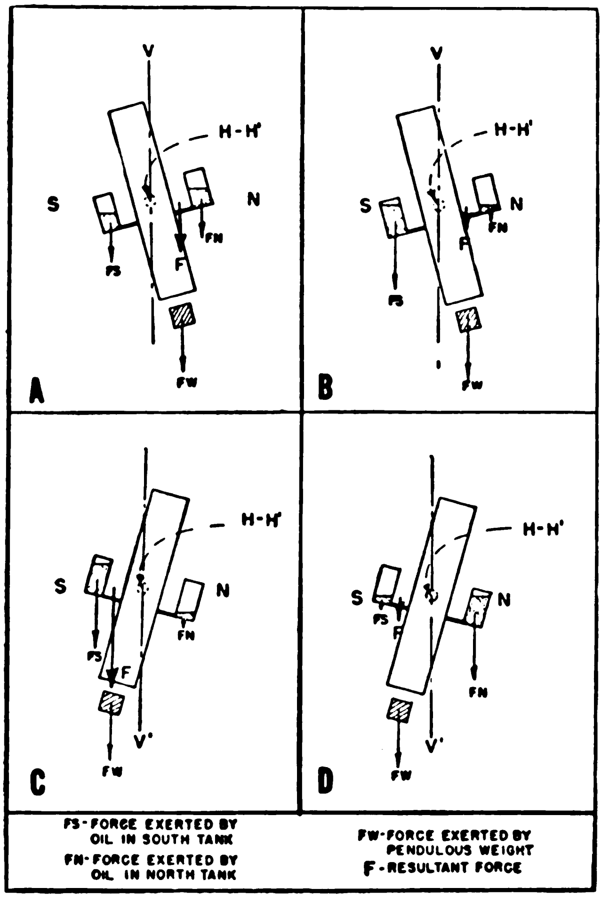
opening in the tube. The effect of this damping lags behind that of the pendulous weight.

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.

In A of figure 12-20, 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 12-20 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

Digitized by Google

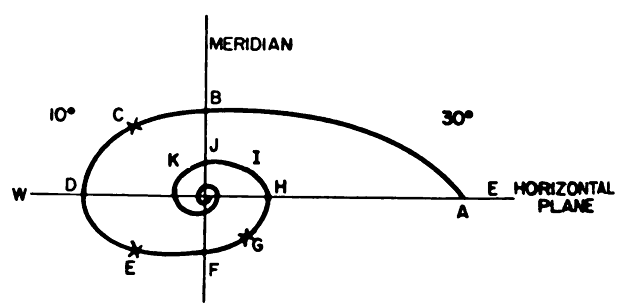


77.209

Figure 12-20.—Action of Arma damping tanks.

12-20 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 12-20 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.

Starting with the compass displaced 30° to the east of the meridian and level (point A, fig. 12-21) 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, fig. 12-21). 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, fig. 12-21). 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 precession to the east even though the axle has not yet become level. As the north axle becomes level (point D, fig. 12-21) there is still an excess of oil in the south tank due to the restriction in the oil line. This excess of oil in the south tank causes it to



77.210

Figure 12-21.—Path followed by the north axle of a damped Arma compass.

Digitized by Google

continue to precess to the east. However, the north axle continues to fall due to the rotation of the earth, elevating the south axle. The pendulous weight now produces a torque about the horizontal axis that also causes precession to the east. At this time the oil ballistic and pendulous weight are exerting torques that are aiding each other. However, as the south axle is now elevated, oil will be transferring to the north tank until a point is reached where there is equal oil in both tanks (point E, fig. 12-21). However, precession continues to the east because of the torque produced by the pendulous weight. The south axle being elevated causes oil to continue to transfer to the north tank. This action produces an excess of oil in the north tank, causing a torque about the horizontal axis opposing that torque produced by the pendulous weight. However, as long as the north axle remains west of the meridian, it will continue to fall, producing enough torque to cause it to reach the meridian (point F, fig. 12-21). At this time there is maximum tilt and maximum rate of precession, therefore, it cannot remain on the meridian. The north axle of the compass is now east of the meridian and will rise due to the earth's rotation further reducing the effect of the pendulous weight. As oil has been accumulating in the north tank during this time, a point is soon reached at which the torque produced by the oil ballistic is exactly equal and opposite to that produced by the pendulous weight. The net torque about the horizontal axis is now zero and precession to the east ceases (point G, fig. 12-21). The north axle continues to rise due to the earth's rotation further reducing the effect of the pendulous weight. The oil ballistic is now producing a greater torque than the pendulous weight and causes precession to the west even though the north axle is not yet level. When the north axle becomes level (point H, fig. 12-21), there is still an excess of oil in the north tank because of the restrictor in the connecting line which causes the compass to continue to precess to the west. As the north axle becomes elevated due to the earth's rotation, it raises the pendulous weight to the north which produces a torque about the horizontal axis that also causes precession to the west. The torques 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, fig. 12-21). 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, fig. 12-21). This action continues for about 2 1/2 oscillations at which time the compass has settled and is on the meridian.

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 12-22. 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.

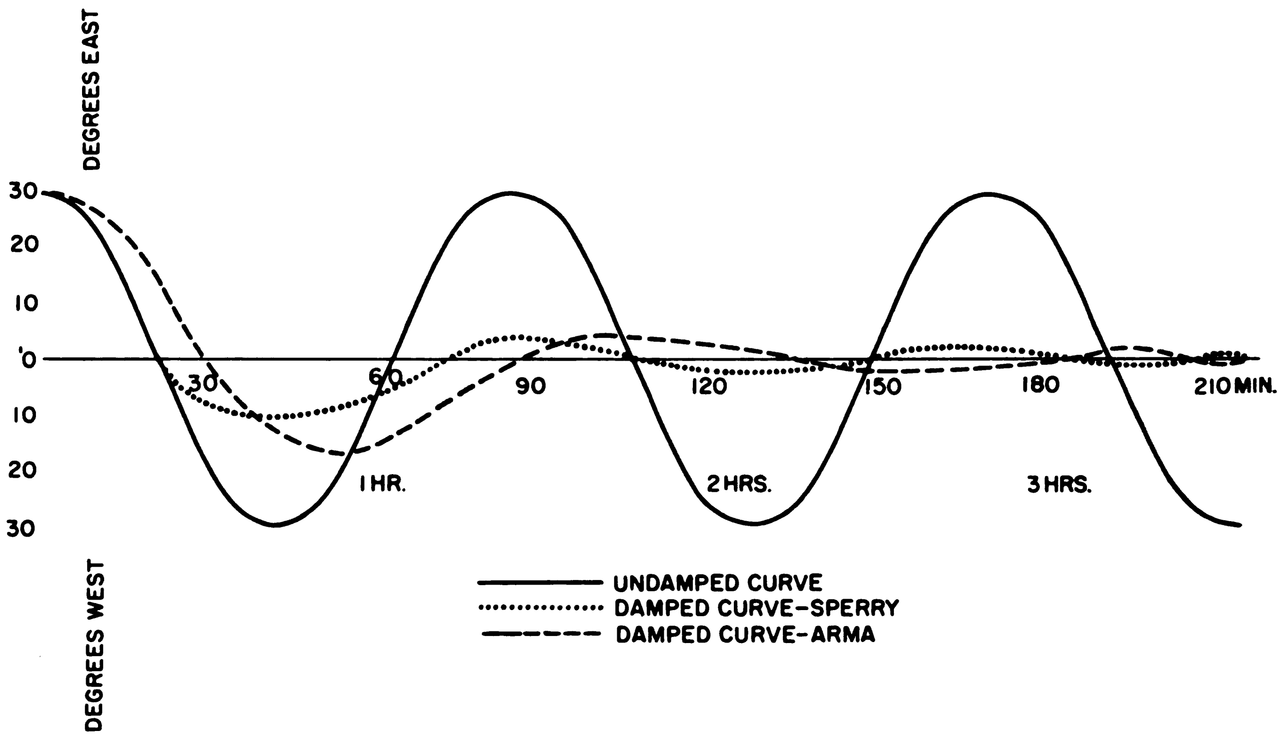
The amount by which each successive swing past the meridian is reduced by the damping device is not the same for all swings. In the Arma compass it is less on the first swing than on the following swings. In the Sperry compass it is greater on the first swing than on succeeding swings. The average amount by which successive oscillations are reduced is called the percentage of damping or the damping factor. It is about 70 percent for Arma and ballistic type Sperry compasses.

The normal damping factor for Sperry Mks 19 and 23 compasses is 65 percent. This factor may be increased during starting as mentioned previously.

ERRORS

A gyrocompass installed aboard ship is subjected to many disturbing forces caused by the ship's linear speed, changes in course and speed, and roll and pitch. These forces, if not compensated for, would produce errors in the gyrocompass. Some errors are eliminated by the design of the compass, others are eliminated by calculating the amount of the error and correcting the compass either manually or automatically to the correct reading. Gyrocompass errors and the methods of correcting them differ

Digitized by Google



77.211

Figure 12-22.—Oscillation curves of damped and undamped compasses.

depending upon the type and mark of gyrocompass concerned.

SPERRY MK 11 MOD 6 GYROCOMPASS

The Sperry Mk 11 Mod 6 gyrocompass is used principally on destroyers. The complete system consists of the master compass, the control system, alarm system, followup system, and the transmission system. The master compass includes five major components: (1) Sensitive element, (2) Mercury ballistic, (3) Phantom element, (4) Spider, and (5) Binnacle and gimbal rings. The binnacle and gimbal rings enclose and support the other four major components (fig. 12-23).

SENSITIVE ELEMENT

The sensitive element (fig. 12-24) is the north-seeking element of the master compass. It consists of the gyro unit, vertical ring, compensator weights, followup indicator, and suspension.

Gyro Unit

The gyro unit provides the directive force for the sensitive element that makes the compass north-seeking. The unit consists of the rotor and case (fig. 12-25). The gyro rotor (fig. 12-25B) is 10 inches in diameter, 4 1/2 inches wide, and weighs approximately 72 pounds. It is machined and balanced to rotate on special ball bearings at a normal speed of 11,000 rpm.

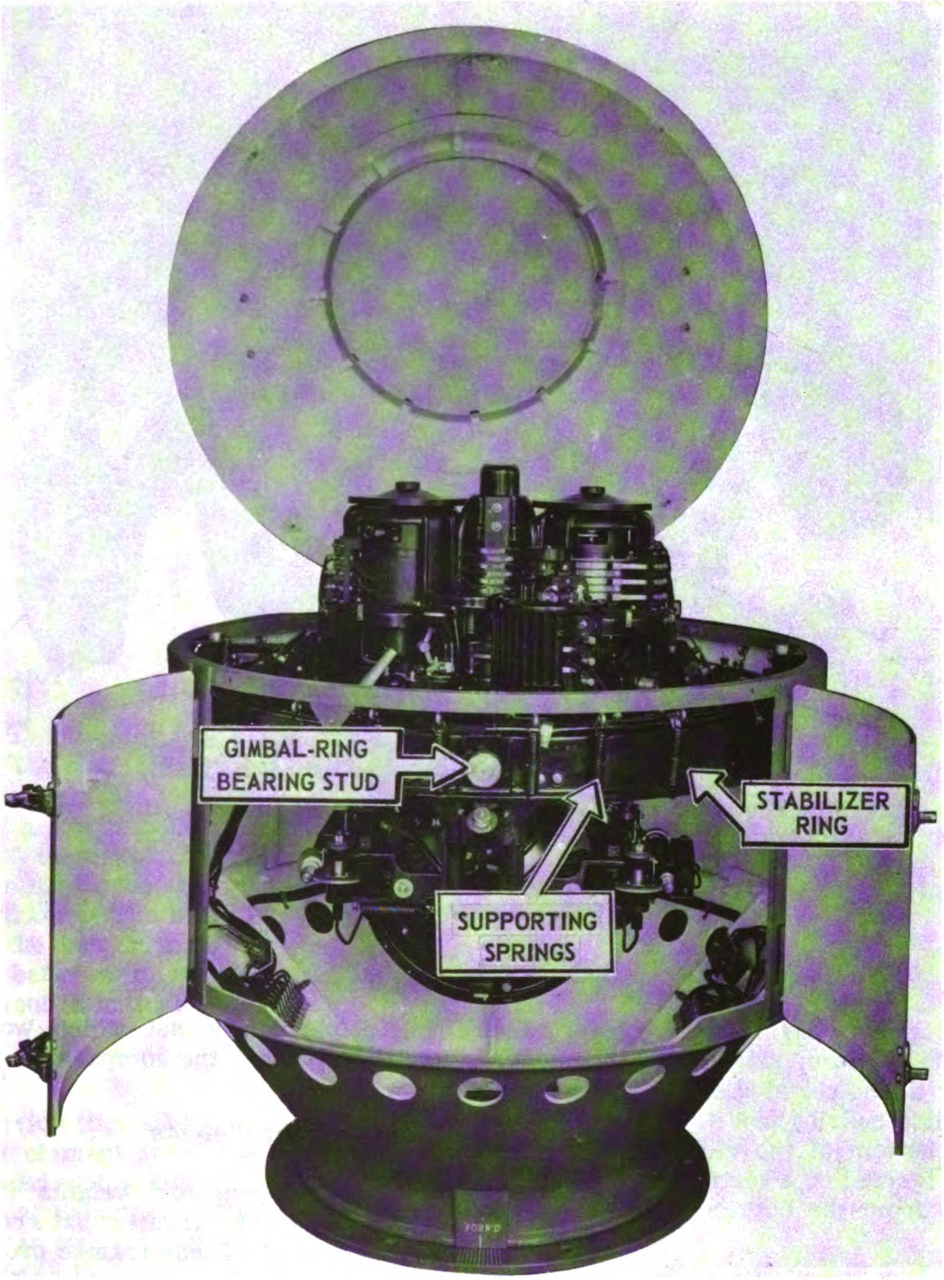
The gyro case (fig. 12-25 A & C) includes a 3-phase, double-stator winding, one stator being mounted in each half of the case.

The case is made airtight and the rotor operates in a vacuum (26 to 30 inches of mercury) to reduce the friction caused by air resistance. A vacuum gage (not shown) is mounted near the top of the north half of the case to indicate the degree of vacuum.

A spirit level (gyro case level in fig. 12-24) is mounted on the lower part of the north side of the case to indicate the tilt of the rotor.

A small window (not shown) is provided in the south half of the case through which the spinning rotor can be observed during starting.

Digitized by Google



40.35

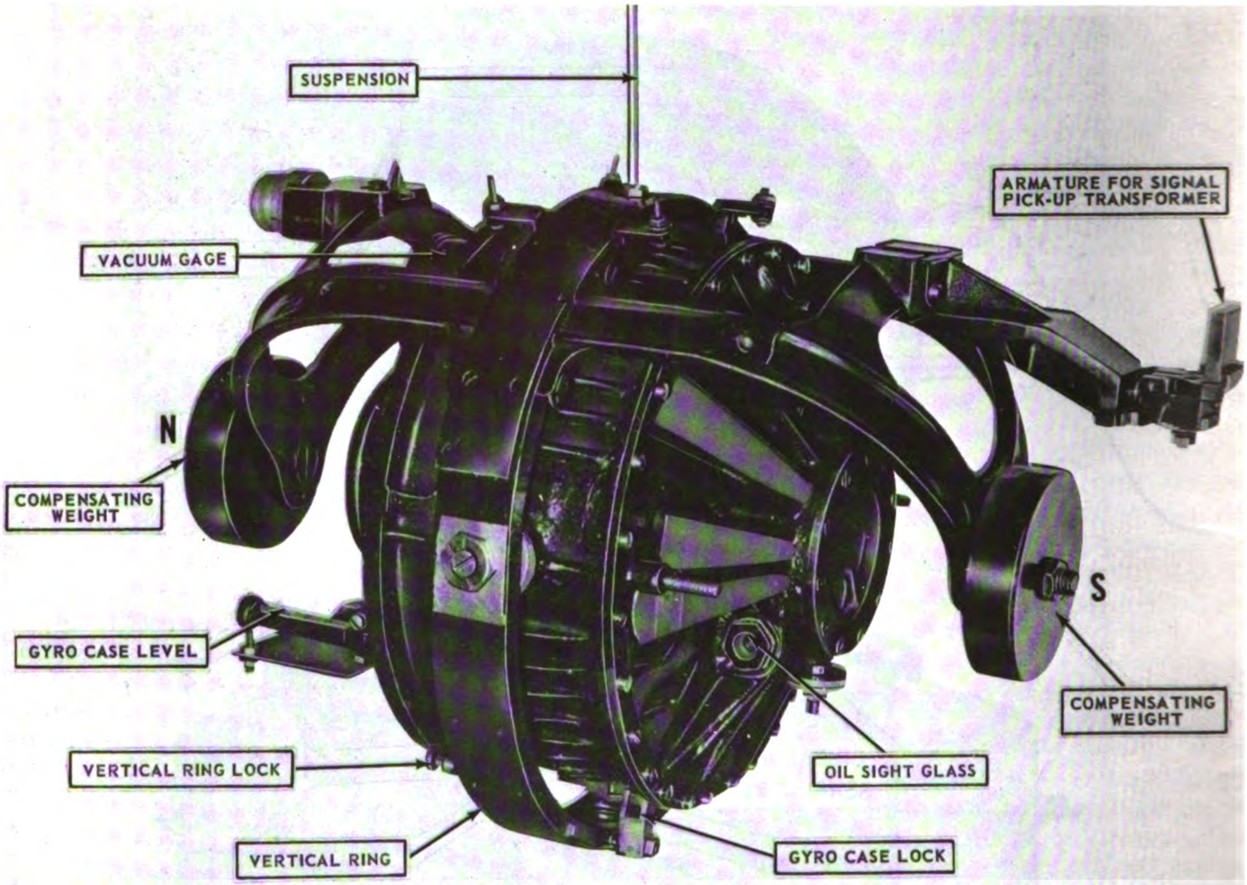
Figure 12-23.—Sperry Mk 11 Mod 6 gyrocompass showing binnacle and gimbal rings.

Vertical Ring

The vertical ring (fig. 12-24) is attached to a wire suspension from the head of the phantom element. The phantom ring is concentric with the vertical ring and surrounds the entire sensitive element. It is kept in alignment with the vertical ring, while the compass is in operation, by the action of the followup system, discussed later.

An upper and a lower guide bearing prevent the vertical ring from moving laterally within the phantom ring.

Digitized by Google



40.30

Figure 12-24.—Sperry Mk 11 Mod 6 sensitive element.

The upper guide bearing has its outer race secured in the phantom ring. The inner race is formed by the lower stud of the suspension. The lower guide bearing has its outer race secured in the bottom of the vertical ring. The inner race is formed by a vertical stud that projects upward from the bottom of the phantom ring.

A gyro case lock (fig. 12-24) is provided to prevent the gyro case from tilting about its horizontal axis when the compass is not operating. This latch should be disengaged only when the rotor is running at normal speed. It is located on the lower part of the south side of the vertical ring.

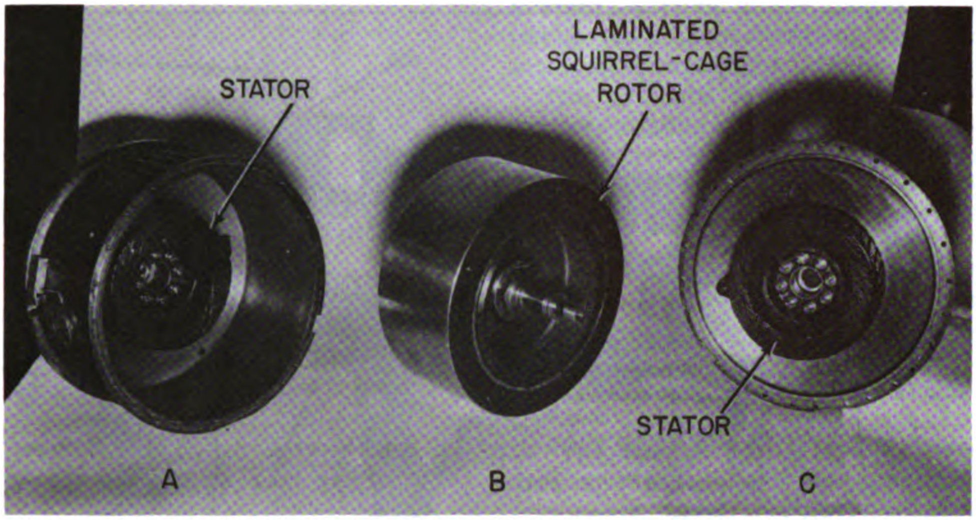
A vertical ring lock (fig. 12-24) is provided to keep the vertical ring in line with the phantom ring when the compass is not operating. This lock prevents the wire suspension from acquiring a permanent set which would affect the settling point of the compass.

Compensator Weights

The compensator weights (fig. 12-24) are supported by two frames that are attached to the vertical ring. These frames project out beyond each end of the rotor axle. The weights are mounted concentrically on their studs, and their positions can be adjusted in the direction of the axis of the gyro rotor. The function of the weights is to provide an even distribution of the weight of the gyrocompass about the vertical axis.

The armature of the signal pickoff or follow-up transformer is attached to an arm that protrudes horizontally from the upper part of the south compensator-weight frame (fig. 12-24).

Digitized by Google



40.31

Figure 12-25.—Sperry Mk 11 Mod 6 gyro unit. B, rotor; A and C, case.

Followup Indicator

The followup indicator (not shown) indicates the position of the phantom element with relation to the sensitive element. This indicator consists of a scale and a pointer. The scale is attached to the phantom element below the spider table and the pointer is attached to the north compensator weight frame. The scale is calibrated in degrees with the center marked "0". Thus, a misalignment between the phantom element and sensitive element is indicated in degrees.

Suspension

The suspension (fig. 12-24) suspends the entire sensitive element from the phantom element. It consists of a number of small steel wires secured at the upper end to a support stud and at the lower end to a guide stud. A nut and check nut secures the support stud to the phantom element, and provides a means to adjust the sensitive element vertically. The guide stud passes through a hole in the upper part of the vertical ring and is clamped to the ring by a nut. This stud also serves as the inner race of the upper guide bearing of the ring.

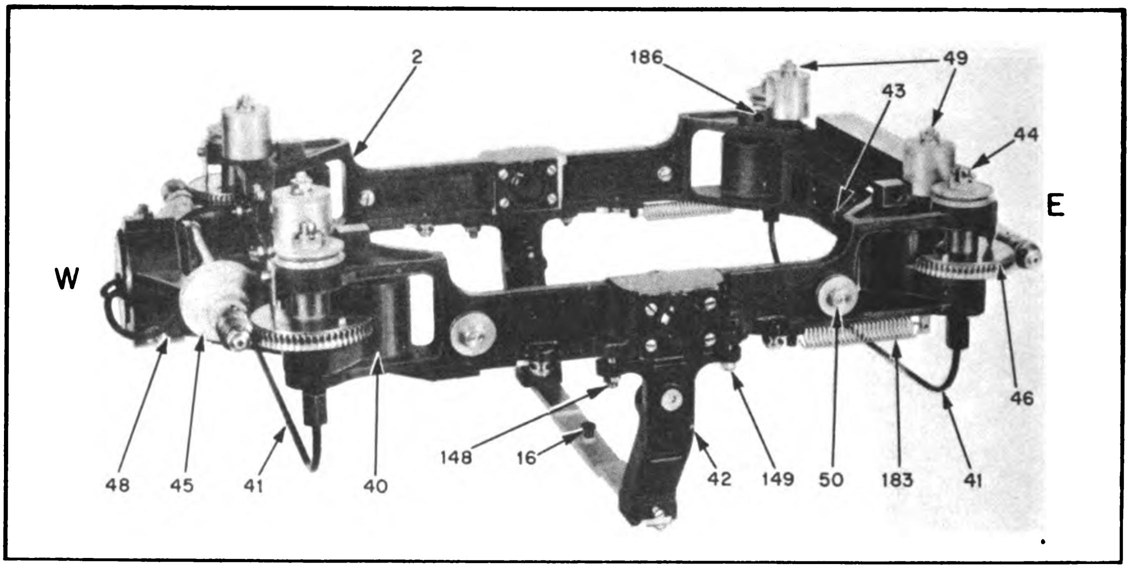
MERCURY BALLISTIC

The mercury ballistic (fig. 12-26) is that group of parts which applies the gravity controlling force to the gyro unit and makes it north-seeking. It consists of a rigid frame supported on bearings in the phantom ring. These bearings are in line with the horizontal case bearings in the vertical ring so that the mercury ballistic is free to tilt about the east-west axis of the sensitive element.

The frame supports a mercury reservoir in each of its four corners. The N and S reservoirs on the east side of the compass are connected by a U-shaped tube and the N and S reservoirs on the west side are similarly connected. The gravity controlling force of the mercury ballistic is applied to the bottom of the gyro case through and adjustable offset bearing stud mounted on the ballistic connection arm.

The connection bearing is offset to the east from the vertical axis by a short distance to provide the damping adjustment. When it is desired to eliminate damping, a solenoid (damping eliminator magnet) is energized by an automatic damping eliminator switch (discussed later) that attracts a plunger which moves the pivoted connection arm until the connection bearing is in line with the vertical axis of the gyro. In addition, each mercury reservoir is offset from its supporting stem so that each can be rotated around its stem through an arc of about 110° in order to vary the lever arm of each tank. Thus the period of an undamped oscillation of the gyrocompass is maintained constant in all latitudes by adjustment of the mercury reservoirs. This

Digitized by Google



2 MERCURY BALLISTIC FRAME	46 LATITUDE SCALE
16 OFFSET CONNECTION BEARING STUD	48 DAMPING ELIMINATOR MAGNET
40 MERCURY RESERVOIRS	49 NON-PENDULOUS BALANCING WEIGHTS
41 MERCURY TUBE	50 HORIZONTAL BALANCING WEIGHTS
42 CONNECTION ARM	148 NO-DAMPING ADJUSTMENT SCREW
43 MERCURY BALLISTIC SUPPORT STUD	149 DAMPING ADJUSTMENT
44 MERCURY RESERVOIR SUPPORT STEM	183 MAGNET LINK SPRING
45 LATITUDE SETTING THUMB WHEEL	186 LEVELING SCREW HOLES

40.32

Figure 12-26.—Sperry Mk 11 Mod 6 mercury ballistic.

adjustment is referred to as the ballistic latitude adjustment.

PHANTOM ELEMENT

The phantom element (fig. 12-27) is a group of parts that acts to support the sensitive element. It consists essentially of a hollow cylindrical stem that projects radially from the phantom ring, which is mounted in the spider and extends below the central hub of the spider table.

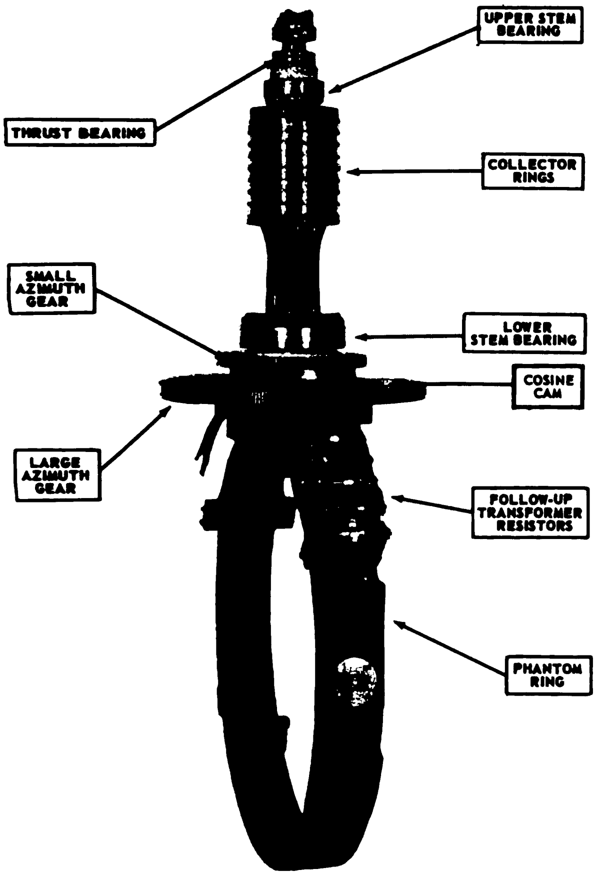
The phantom element supports the sensitive element by means of the suspension. The phantom element has no north-seeking properties of its own, however it does continuously indicate north, because it is made to follow all movements of the sensitive element by the action of the followup system.

A thrust bearing on the top of the stem (fig. 12-27) rests in the hub of the spider table and supports the weight of the phantom and sensitive elements. The upper and lower stem bearings keep the stem in alignment with the vertical axis of the spider but permit the phantom element to rotate about its own vertical axis.

The phantom ring also carries bearings that support the mercury ballistic. The axis of these bearings coincides with the axis of the horizontal bearings of the gyro case. Collector rings are mounted on the phantom stem below the upper stem bearing to connect the various electrical circuits from the fixed to the moving parts of the compass. The large and small azimuth gears are included in the azimuth followup mechanism (to be discussed later).

An eccentric groove called the cosine cam is cut into the upper surface of the large azimuth gear. The cosine cam is associated with the speed and latitude corrector mechanism.

Digitized by Google



40.33
Figure 12-27.—Sperry Mk 11 Mod 6 phantom element.

SPIDER

The spider (fig. 12-28) is a circular table of cast aluminum alloy that supports the entire inner, or moving, member of the compass by means of the hub on which the thrust bearing that supports the phantom element rests. The spider is supported in the inner, or cardan, ring of the two rings that comprise the gimbal system. A boss in the center of the table supports the thrust bearing and the upper and lower stem bearings.

The azimuth followup motor and the automatic damping eliminator switch are mounted on the forward side of the spider table. The speed and latitude correction mechanism and the auxiliary latitude corrector are mounted on the after side of the table. The 36-speed synchro transmitter is located on the port side and the single-speed synchro transmitter is located on the starboard side of the table.

CONTROL AND ALARM SYSTEM

The Sperry Mk 11 Mod 6 gyrocompass control and alarm system consists of a motor-generator, speed regulator, control panel, battery throwover panel, and bridge alarm indicator, with the necessary apparatus for the operation and control of the master compass. The principal components of the system are illustrated in figure 12-29.

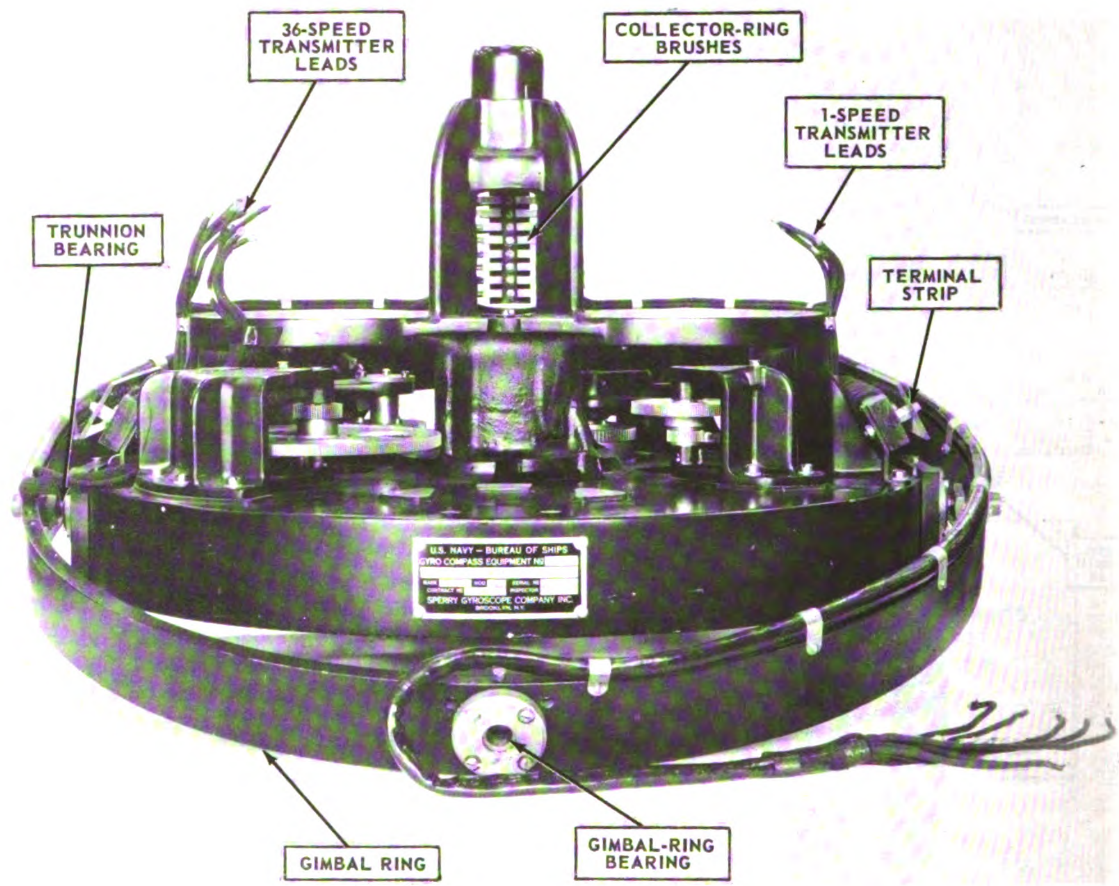
The gyrocompass drive system consists of the primary and emergency sources of power. The primary power source is the ship's 3-phase, 120-volt, 60-cycle supply, and the emergency power source is the 24-volt battery supply.

Motor-Generator

Two separate motor-generator sets are provided with each complete Sperry gyrocompass equipment. Each set consists of an induction motor, a d-c emergency motor, an a-c generator, and a d-c generator (fig. 12-29). The induction motor and the d-c emergency motor are mounted on a common shaft in a single frame. The a-c generator and the d-c generator are also mounted on a common shaft in a single frame. The shafts of these two units are directly coupled together. Each motor-generator set is assembled as a complete unit and mounted on a single bedplate.

The induction motor is a 3-phase, 120-volt, 60-cycle, wound-rotor motor with slip rings. Under normal operating conditions, the induction motor drives the d-c motor, the a-c generator, and the d-c generator. It operates at a constant speed of 1460 rpm (necessary for the a-c generator to deliver a constant 3-phase output of 55 volts at 195 cycles), which is maintained constant by means of a speed regulator that compensates for a maximum

Digitized by Google



40.34

Figure 12-28.—Sperry Mk 11 Mod 6 spider.

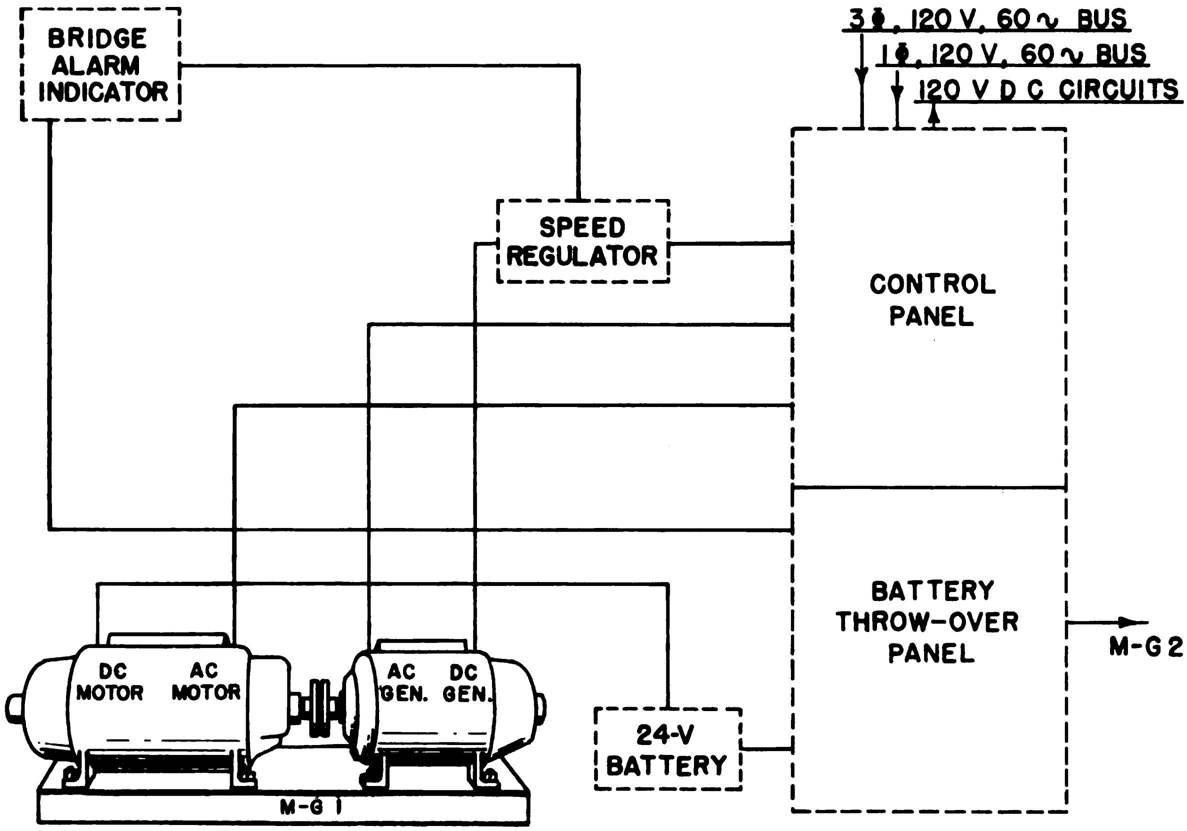
of ± 10% variations in the ship's primary power supply frequency.

The d-c motor is a shunt-wound machine. Under normal conditions of induction motor drive, the d-c motor operates as a self-exicited d-c generator for charging the battery with a continuous-duty rating of 27 volts at 7 amperes.

Under emergency operating conditions because of failure in the ship's 3-phase supply to the induction motor, the d-c motor operates from the battery supply to drive the a-c and d-c generators. As a d-c motor, it has an intermittent-duty rating of 22.5 volts at 70 amperes.

The a-c generator is a 3-phase, 60-volt, 195-cycle, inductor type generator having 16 polar projections. Both the field and the armature are stationary. The 16 polar projections (inductors) rotate continuously at approximately 1,460 rpm, thereby varying the magnetic field flux through the armature windings and generating a-c voltages at a frequency of 195 cps. The armature consists of a wye-connected, 3-phase winding, and the field consists of a single d-c winding. Slip rings are not required with this type of generator. The machine supplies power to drive the gyro rotor and to energize the amplifier and the followup system.

Digitized by Google



40.36

Figure 12-29.—Sperry Mk 11 Mod 6 gyrocompass control and alarm system.

The d-c generator is a 120-volt, compound wound, interpole, self-excited generator. This machine supplies excitation for its own fields, the a-c generator field, and the azimuth-motor field. It also supplies d-c power for the damping eliminator, the azimuth-motor cutout relay, the dead reckoning equipment, and the voltage coil of the speed regulator.

Speed Regulator

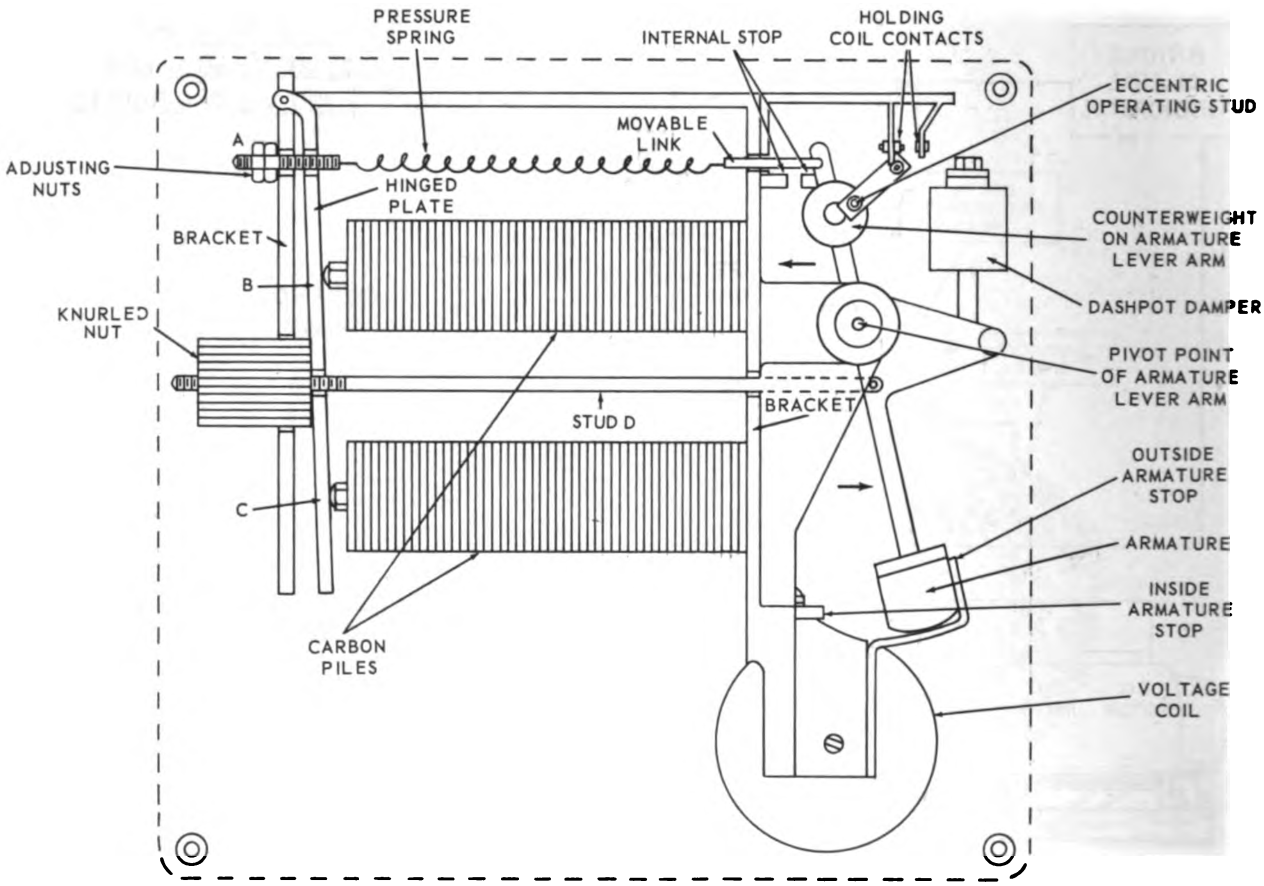
The speed regulator (fig. 12-30) is a separate unit located adjacent to the motor-generator sets. It compensates for variations in the ship's supply voltage or frequency to maintain the speed of the induction motor constant and thereby causes the a-c generator to deliver a constant output to drive the gyro motor. The same speed regulator is used for each of the two motor-generator sets because they are not operated simultaneously.

The speed regulator consists of a wye-connected, carbon-pile voltage requlator connected in the form-wound rotor circuit of the 3-phase induction motor by means of slip rings.

The actuating coil of the speed regulator is connected in a shunt circuit across the output terminals of the d-c generator. It therefore responds to changes in d-c output voltage occasioned by any changes in speed of the motor generator. The voltage coil attracts a spring-loaded pressure arm that varies the pressure on the carbon piles in accordance with any change in voltage across the coil.

If the ship's supply voltage or frequency increases, the induction motor-rotor currents increases. This action causes a slight increase in the speed of the motor-generator. The consequent slight increase in d-c generator voltage causes the voltage coil of the speed regulator to attract the spring-loaded arm. This action decreases the pressure on the carbon

Digitized by Google



40.38

Figure 12-30. —Speed regulator schematic.

piles. The accompany increase in rotor-circuit resistance restores the rotor currents to their normal value and checks the rise in speed and d-c generator output voltage.

A dashpot damper is connected in the pressure arm to prevent hunting when rapid changes occur in the voltage or frequency.

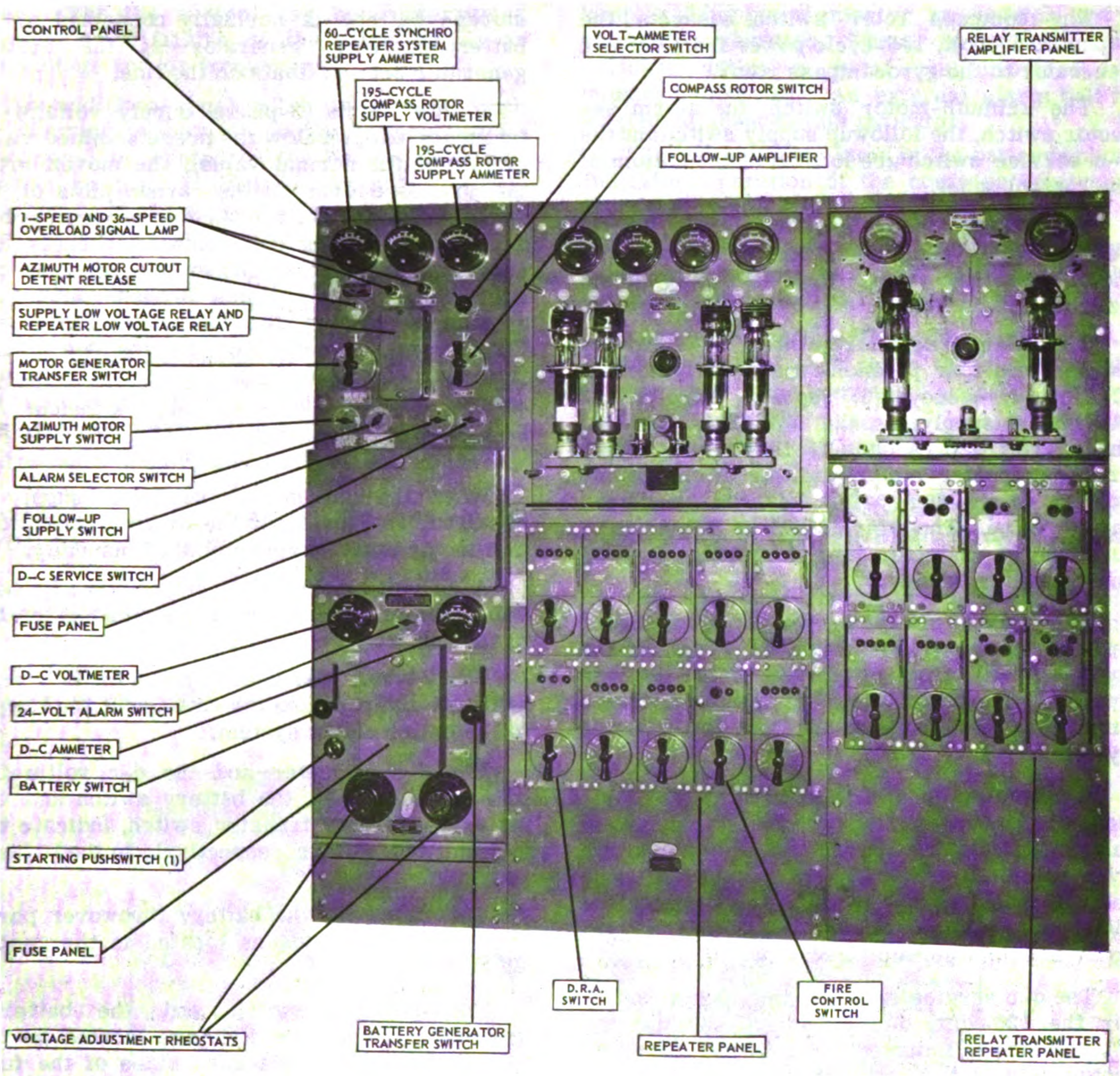
Compass control Panel

The compass control panel is located at the upper left-hand section of the gyrocompass switchboard (fig. 12-31). The control panel is used to control and indicate the operating conditions of the master compass. The ship's 3-phase, 120-volt, 60-cycle power supply and the ship's signal-phase, 120-volt, 60-cycle power supply are connected directly to terminals on the back of the compass control panel. The 3-phase, 120-volt, 60-cycle power supply is fed from these terminals on the control panel through the battery throwover relay on the battery throwover panel to the motor-generator transfer switch on the compass control panel. The switches and fuses necessary for these power supplies are included on the IC switchboards but are not provided on the gyrocompass switchboard.

The a-c ammeters and an a-c voltmeter are mounted at the top of the control panel to indicate the operating conditions of the master compass. One ammeter indicates the 60-cycle alternating current supplied to the synchro repeater system by the master compass transmitter, and the other ammeter and the voltmeter indicate the 195-cycle current and voltage respectively, supplied by the 3-phase, a-c generator to the gyro-compass rotor.

The azimuth-motor cutout detent release, the single and 36-speed overload signal lamps, and the volt-ammeter selector switch are

Digitized by Google



40.39

Figure 12-31.—Sperry Mk 11 Mod 6 gyrocompass switchboard.

mounted just below the two ammeters and the voltmeter.

The azimuth motor cutout detent release is provided to reset the cutout after a fault has been cleared on the followup system.

The volt-ammeter selector switch is a 3-position rotary switch. The three switch positions provide for shifting the ammeter and voltmeter to any one of the three phases of the a-c gyro rotor supply to obtain current and voltage readings of the selected phase.

The motor-generator transfer switch and the compass rotor switch are mounted on the third row from the top.

The motor-generator transfer switch is a double-throw rotary switch provided for

Digitized by Google

selecting either one or the other of the two motor-generators.

The compass rotor switch connects the 3-phase, 55-volt, 195-cycle power from the a-c generator to the gyrocompass rotor.

The azimuth-motor switch, the alarm selector switch, the followup supply switch and the d-c service switch are located at the bottom of the control panel.

The azimuth-motor switch controls the (1) rectified a-c supply circuit to the azimuth motor armature and (2) the d-c supply to the azimuth-motor field.

The alarm selector switch is a rotary switch with four positions marked (1) normal (2) low frequency, (3) repeater supply, and (4) ship's supply. In the NORMAL position, the alarm bell sounds if the ship's supply or the repeater supply fail or if the supply voltage or frequency fall below a predetermined value. The alarm bell is silenced by turning the selector switch to the position indicating the trouble.

The followup supply switch is an on-off switch. In the ON position it energizes the followup panel from one phase of the 3-phase gyro supply, and heats the filaments of the amplifiers and rectifier tubes in the followup system.

If the followup switch is in the OFF position, the compass supply ammeter and voltmeter indicate the current and voltage to the gyro rotor only; whereas, if this switch is in the ON position, the meters will indicate the 195-cycle current voltage to both the gyro rotor and the followup panel.

The d-c service switch is the master switch for the 120-volt, d-c circuit. It supplies the (1) damping eliminator circuits, (2) azimuth-motor field, and (3) azimuth-motor cutout relay coil.

The fuses for the compass control panel are within an enclosure located at the bottom of this panel.

Battery Throwover Panel

The battery throwover panel is located directly below the compass control panel (fig. 12-31). It is used to transfer automatically the gyrocompass circuits from the ship's 3-phase supply to the battery supply in the event of failure of the ship's supply. The 24-volt storage battery is normally connected to the battery-charging generator of the motor-generator set and floats on the line.

If the ship's 3-phase supply voltage or frequency drops below the predetermined value (± 10% of the normal value), the movement of the pressure arm on the carbon piles of the speed regulator will open the battery throwover relay holding coil contacts, thereby deenergizing this relay. When this relay is deenergized, the (1) ship's 3-phase supply is disconnected from the motor-generator set, (2) battery is connected to the d-c motor (charging generator) as a primary power source so that the d-c motor becomes the prime mover for the motor-generator set, and (3) alarm bell rings.

When the ship's 3-phase power supply is restored, retransfer of the drive to the induction motor must be accomplished manually.

A 24-volt alarm supply switch and a battery voltmeter and ammeter are mounted at the top of the battery throwover panel.

The 24-volt alarm supply switch is a separate switch provided for cutting out the supply to the entire alarm system.

The d-c ammeter and the d-c voltmeter connected between the battery switch and the battery-generator transfer switch, indicate the current and voltage respectively in the battery line.

The fuses for the battery throwover panel are within an enclosure located in the center of the panel.

The battery switch and the battery-generator transfer switch are located on the left-hand and the right-hand sides of the fuse enclosure, respectively.

The battery switch is a DPST lever-switch that connects the 24-volt battery supply to the battery throwover panel.

The battery-generator transfer switch is a DPDT lever-switch that connects the battery to one or the other of the two battery generators.

The starting pushswitch is mounted below the battery switch. It is used to start the motor-generator and also to restore the circuit

Digitized by Google

to the holding coil of the battery throwover relay after the system has been interrupted because of a failure of the ship's supply or low voltage and/or frequency.

An additional pushswitch in parallel with the starting pushswitch on the battery throwover panel is located on the bridge alarm indicator so that, if desired, the ship's power supply can be restored to the compass equipment from this station.

Two voltage adjustment rheostats, one for each of the battery generators, are mounted at the bottom of the panel. These rheostats are used to adjust the generator-field resistance to control the charging rate of the battery when the machine operates as a generator. The rheostats are cut out when the machine operates as a motor, and the resistance that is cut into the field by the battery throwover relay automatically increases the speed to the proper value.

Bridge Alarm Indicator

The bridge alarm indicator (fig. 12-32) is located in the pilot house. The indicator includes a red, a blue, and a green indicator lamp, a damping-eliminator pushswitch and a starting pushswitch. These components are enclosed within a metal case provided for bulkhead mounting. An external alarm bell is located adjacent to this indicator.

The red indicator lamp in the battery supply indicates operation of the compass equipment from the 24-volt battery supply.

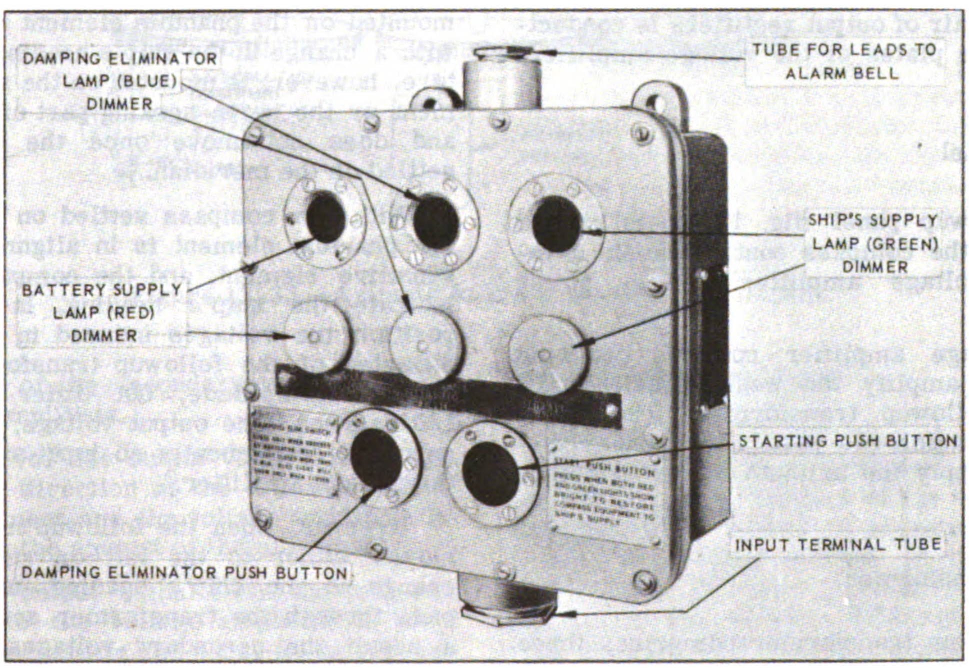
The blue indicator lamp is in the damping-eliminator circuit as a warning whenever the damping-eliminator coil is energized.

The green indicator lamp in the ship's a-c supply is lighted as long as the ship's supply is connected to the compass equipment.

Each indicator lamp is provided with a series variable resistor to control the intensity of illumination.

The starting pushswitch is in parallel with the pushswitch on the ballistic throwover panel as mentioned previously.

The damping-eliminator pushswitch is in parallel with the automatic damping-eliminator switch on the master compass and may be manually operated to energize the damping-eliminator coil and thus remove damping.



77.212

Figure 12-32.—Bridge alarm indicator.

Digitized by Google

FOLLOWUP SYSTEM

The followup system includes the followup mechanism, the followup transformer, the azimuth motor, and the followup panel. The system functions to detect any misalignment between the phantom and sensitive elements and to drive the phantom element in the proper direction to restore alignment. Any misalignment between the phantom and sensitive elements results in a signal voltage output from the followup transformer. The amount of misalignment determines the magnitude of this signal voltage and the direction of misalignment determines its phase. The signal output from the followup transformer is amplified by a voltage amplifier and used to control the output of a power amplifier which operates the azimuth motor. The azimuth motor in driving the phantom element back into alignment with the sensitive element also drives the single and 36-speed synchro transmitters, and a lost motion device through the azimuth followup gearing mechanism (fig. 12-33).

The azimuth motor is a d-c motor having its field excited from the 120-volt d-c output from the motor generator. Its armature is connected in either one or the other of the two output rectifier circuits of the power amplifier. The direction of rotation depends upon which pair of output rectifiers is conducting when the plates of the voltage amplifiers are positive.

Followup Panel

The followup panel (fig. 12-31) is located adjacent to the compass control panel. It includes a voltage amplifier and a power amplifier.

The voltage amplifier contains two twin triodes that amplify the weak signal voltage from the followup transformer. The power amplifier contains two pair of thyratron rectifiers that supply the azimuth motor armature current.

Followup Transformer

The followup transformer comprises three coils wound on an E-shaped laminated core (fig. 12-34). The primary coil (P) mounted on the center leg, is connected to the 3-phase 195 cycle compass rotor supply. One primary lead is connected to one phase through resistor R1 which limits the primary current to a few ma. The other primary lead ties to the common connection of phasing resistors R2 and R3 across the other two phases. This provides the proper phase relation between the followup signal voltage and the followup amplifier bias and plate voltages.

An armature carried on the sensitive element serves as a closing link in the double magnetic circuit of the followup transformer. The armature is positioned so that a small air gap is maintained between the armature and the transformer.

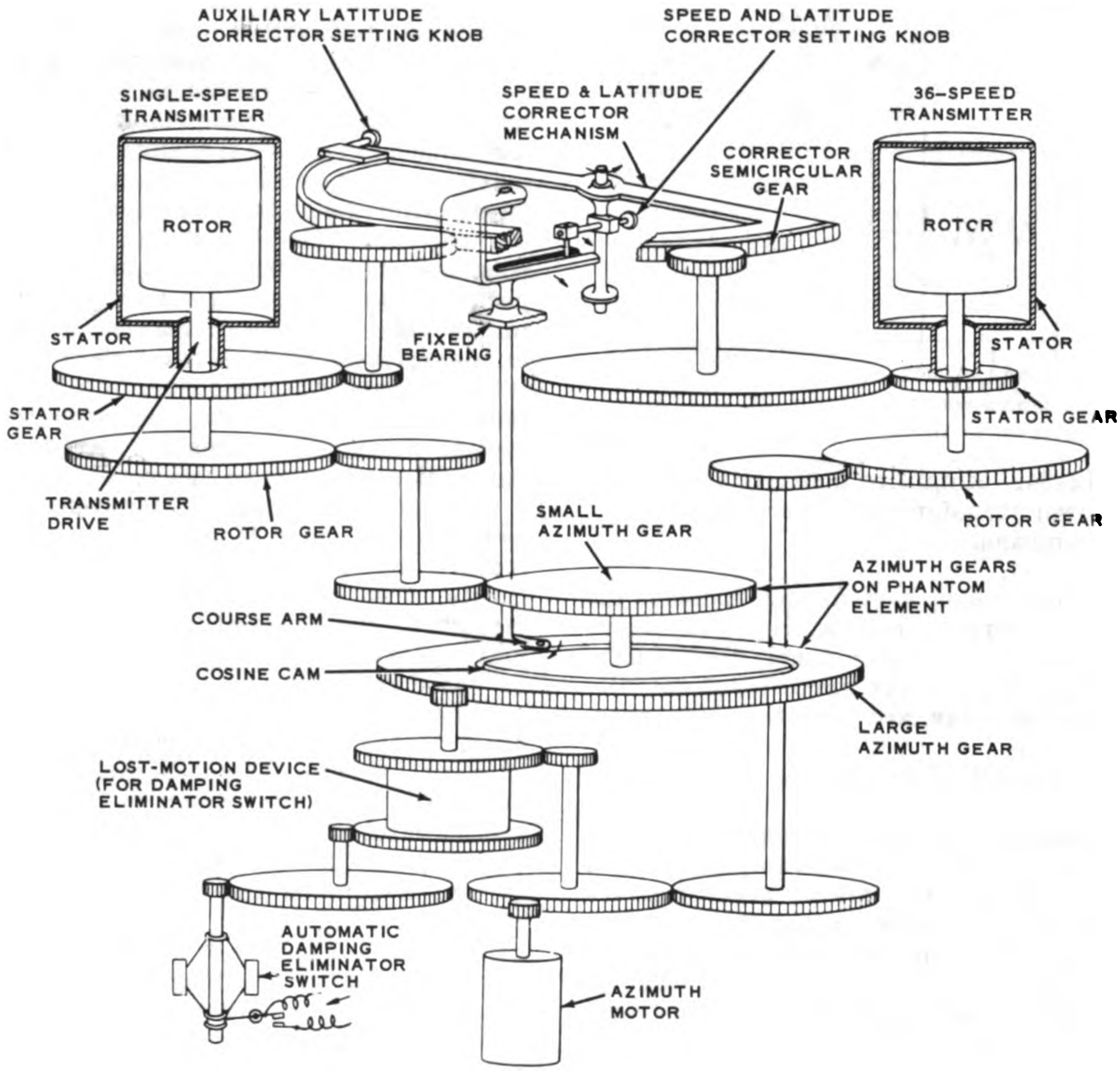
Secondary coils A and B on the outside legs of the transformer are connected in such a manner that the induced voltage in one leg is 180° out of phase with the induced voltage in the other leg. Small capacitors C connected across the secondary coils, are in parallel resonance with the coils at 195 cycles in order to obtain the maximum voltage across the coils at that frequency. To balance the voltage output of the secondary coils when the armature is centrally located, two fixed resistors (not shown) are connected across the capacitors.

The E-shaped followup transformer is mounted on the phantom element and will move with a change in the ship's heading. The armature, however, is mounted on the sensitive element or the north-seeking part of the compass and does not move once the compass has settled on the meridian.

With the compass settled on the meridian the phantom element is in alignment with the sensitive element, and the compass card will indicate the ship's heading. In this neutral position the voltages induced in the two secondaries of the followup transformer will be equal in amplitude, but differ in phase by 180 degrees. The output voltage, therefore, is zero and consequently no input signal is fed to the voltage amplifier.

However, when the followup transformer is moved either to the left or right, due to a change in the ship's heading, unequal fluxes pass through the transformer secondaries. As a result the secondary voltages become unbalanced. The resultant output voltage will be the vector sum of the two voltages and the phase of the output voltage will be the same

Digitized by Google



40.40

Figure 12-33.—Azimuth followup mechanism gearing.

as the phase of the secondary voltage having the greatest amplitude.

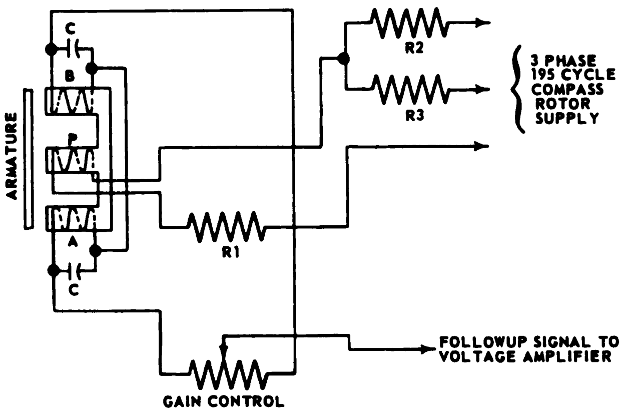
The phase of the output voltage is determined by the direction of the followup transformer movement and the voltage amplitude is determined by the amount of the movement.

Thus, the output signal from the followup transformer to the voltage amplifier is proportional in magnitude and phase to the amount and direction of the armature displacement or ship's movement.

TRANSMISSION SYSTEM

The Sperry Mk 11 Mod 6 gyrocompass transmission system provides a means of transmitting the readings of the master gyrocompass to a number of repeater compasses located at various stations in the ship. The single and 36-speed synchro transmitters (driven by the azimuth followup motor) control the movement of the repeater compasses that indicate the readings of the master compass at the remote stations.

Digitized by Google



77.213

Figure 12-34.—Simplified schematic diagram of followup transformer, Sperry Mk 11 Mod 6 gyrocompass.

The transmission system also includes the transmitter overload relays, repeater panel, relay transmitter repeater panel, relay transmitter, relay transmitter amplifier panel, differential alarm relay, and repeater compasses.

Transmitter overload relays

Two similar transmitter overload relays, mounted on the back of the compass control panel, provide a visual alarm when an overload occurs in the transmitter circuits. One relay is connected in the single-speed transmitter circuit, and the other relay is connected in the 36-speed transmitter circuits. The relay consists of three legs with a coil on each leg. Each coil is connected in series with a transmitter stator lead. An increase in the current through any or all of the coils above a critical value attracts the relay armature, causing it to move. This action closes a contact that lights a red signal lamp on the panel front, indicating trouble in the transmitter circuit. A stepdown transformer (115 volts to 7 volts) on the panel supplies the indicator lamp circuits.

Repeater Panel

The repeater panel (fig. 12-31) is located below the followup panel. It comprises an assembly of rotary switches, and auxiliary equipment. Each switch with its associated fuses and overload indicating devices is assembled as a unit and can be withdrawn from the front of the panel for inspection and repair.

Each compass repeater switch is arranged to connect the circuits of two repeater compasses so that either one, or both, may be driven by the master compass transmitters.

Each repeater circuit is provided with an overload indicator, comprising a transformer and a neon lamp. The transformer has two primaries, which are connected in series respectively with two of the three secondary leads to the repeater. The transformer secondary is connected across the neon lamp. When the repeater is approximately alined with the transmitter, the very small current in the transformer primaries does not generate sufficient voltage across the secondary to illuminate the lamp. However, excessive current in the transformer primaries causes the lamp to glow and thus indicate trouble in this repeater circuit.

Associated with each of the repeater circuit switches are four fuses, access to which is through the hinged door just above the switch handle. Two of the fuses are in the primary circuit to the 1-speed repeater, and the remaining two are in the primary circuit to the 36-speed repeater.

The rotary type switch designated on the panel as the fire control switch is not provided with an overload alarm because connections are made from this switch to the fire control switchboard, which has an alarm for each circuit leaving the board. However, at the fire control switch on the repeater panel the two indicators are (1) a pilot lamp, connected across the a-c supply to this switch and therefore illuminated as long as this supply is available, and (2) a transformer and neon lamp arranged to indicate when one or both of the a-c supply fuses blow.

The rotary type switch designated on the panel as the dead reckoning analyzer switch is provided to operate the DRA from the underwater log transmitter and the 1-speed transmitter on the master compass. This switch also supplies single-phase, 120-volt, a-c power and 120-volt, d-c power necessary for the operation of the DRA. Each of these circuits is provided with two fuses. A neon lamp across each fuse in the d-c circuit is lighted when a fuse blows.

Relay Transmitter Repeater Panel

The relay transmitter repeater panel (fig. 12-31) is located adjacent to the repeater panel. This panel and the repeater panel are

Digitized by Google

arranged so that the repeater compasses can be connected to either the master-compass transmitter or to the relay transmitter.

The relay transmitter repeater panel includes eight rotary switches. These include a checking repeater switch, a fire control switch, a relay transmitter supply switch, an emergency navigation transfer switch, two compass repeater switches, and two radar mast (special) switches.

The checking repeater switch connects the gyrocompass-room checking repeater to either the master compass or to the relay transmitter. Two fuses are connected in series with the primary leads on the load side of the switch. Two transformer and neon-lamp overload indicators (one for each circuit) are connected in the transmitter secondary circuits to indicate an overload in these circuits.

Relay Transmitter

In order to actuate a number of repeater compasses without imposing this load directly on the compass transmitters, an intermediate instrument known as a relay transmitter is used. The relay transmitter (fig. 12-35) consists of a single-speed and a 36-speed synchro control transformer (CT), a commutator transmitter, a followup motor, and a reactor. These components are enclosed within a metal case provided for bulkhead mounting (fig. 12-35A).

The relay transmitter is synchronized with the master compass by means of the synchro control transformer followup motor, and relay-transmitter amplifier (fig. 12-35B). The controlling signal voltage from the master compass energizes the primaries of the control transformers. The output of the control transformers is fed to the amplifier, the output of which controls the followup motor. The followup motor drives a commutator-type transmitter, the output of which energizes the repeaters, causing them to follow the master compass. The followup motor also drives the secondaries of the control transformers to the zero-voltage position, thereby synchronizing the relay transmitter with the master compass.

Relay Transmitter Amplifier Panel

The relay transmitter amplifier panel (fig. 12-31) is located adjacent to the followup panel. It consists of a voltage amplifier and a power amplifier. The voltage amplifier receives the signal from the control transformers, and the output is fed to the power amplifier. The power amplifier provides the controlled power necessary to operate the followup motor in response to the signals from the voltage amplifier.

Differential Alarm Relay

The differential alarm relay (fig. 12-36) is a device for sounding an alarm whenever the relay transmitter loses synchronism with the master compass. The amount by which the transmitter is allowed to diverge, before the alarm is sounded, is adjustable from 0° to 2.5°.

The device comprises a synchro differential receiver. The stator receives its signal from the 36-speed output of the relay transmitter; the rotor circuit receives its signal from the 36-speed transmitter at the master compass. As long as the two outputs are in agreement, the rotor remains at the neutral position. Failure of the relay transmitter to keep in synchronism causes the rotor to move from the neutral position to that amount corresponding to the divergence from synchronism.

A bakelite disk that has a metallic segment is mounted on the shaft of the differential receiver (fig. 12-36A). Two trolleys bear on the periphery of the disk. These trolleys are arranged so that rotation of the disk causes one trolley to contact the metallic segment. This action closes the 120-volt, a-c circuit to a relay (fig. 12-36B), which in turn, closes the 120-volt, a-c supply to the alarm bells located in the pilot house.

An 8-pole switch on the relay transmitter repeater panel is provided for disconnecting the differential synchro receiver and the alarm circuit (fig. 12-36B). The toggle switch disconnects only the alarm circuit.

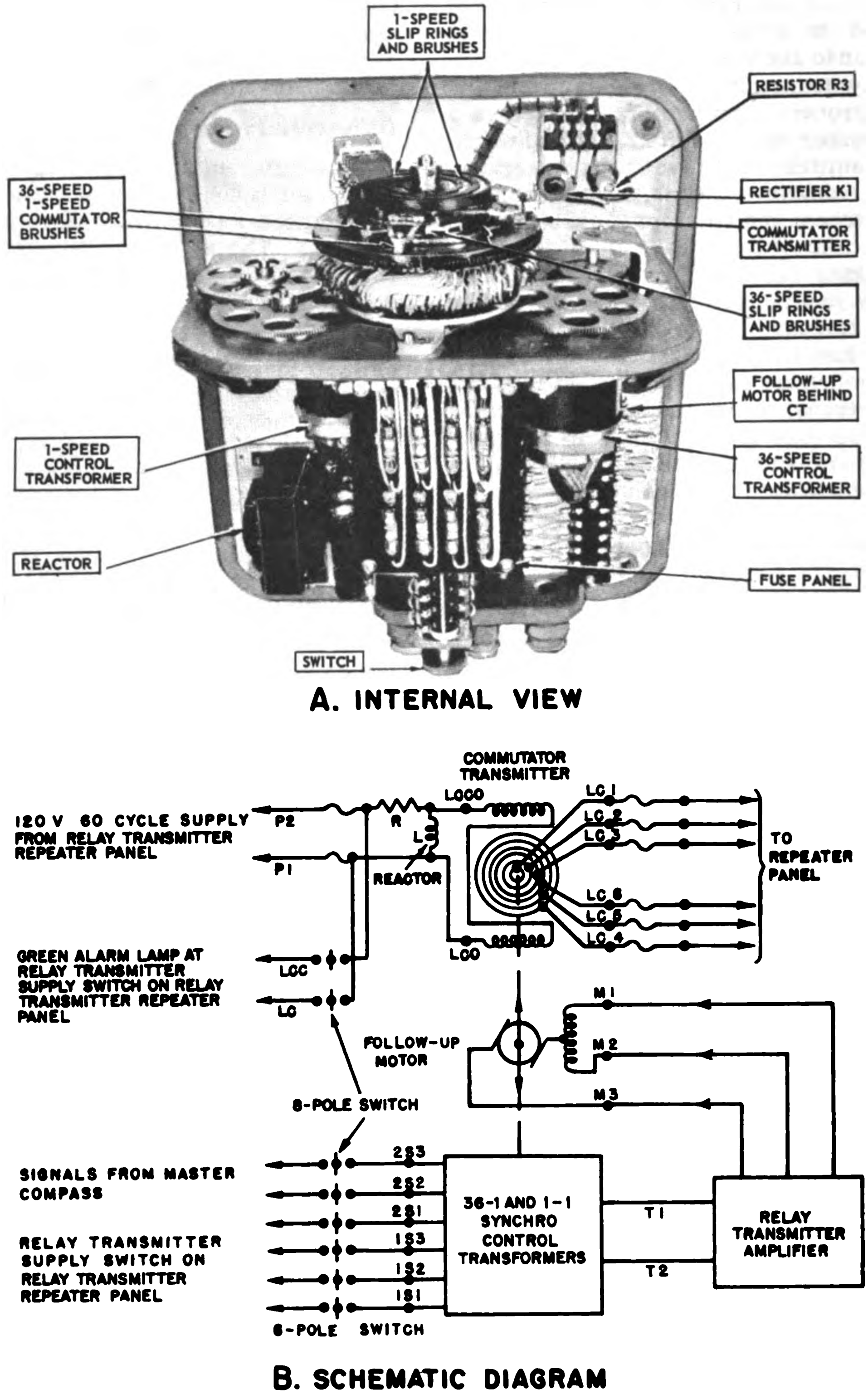
AUTOMATIC CORRECTION DEVICES

The Sperry Mk 11 Mod 6 gyrocompass is provided with two automatic devices associated with error correction. They are (1) an automatic speed corrector associated with speed course, latitude error correction, and (2) an automatic damping eliminator which prevents the introduction of ballistic damping errors during rapid changes in ship's speed or course.

Automatic Speed Corrector

The Sperry automatic speed corrector (fig. 12-37) automatically transmits corrections for

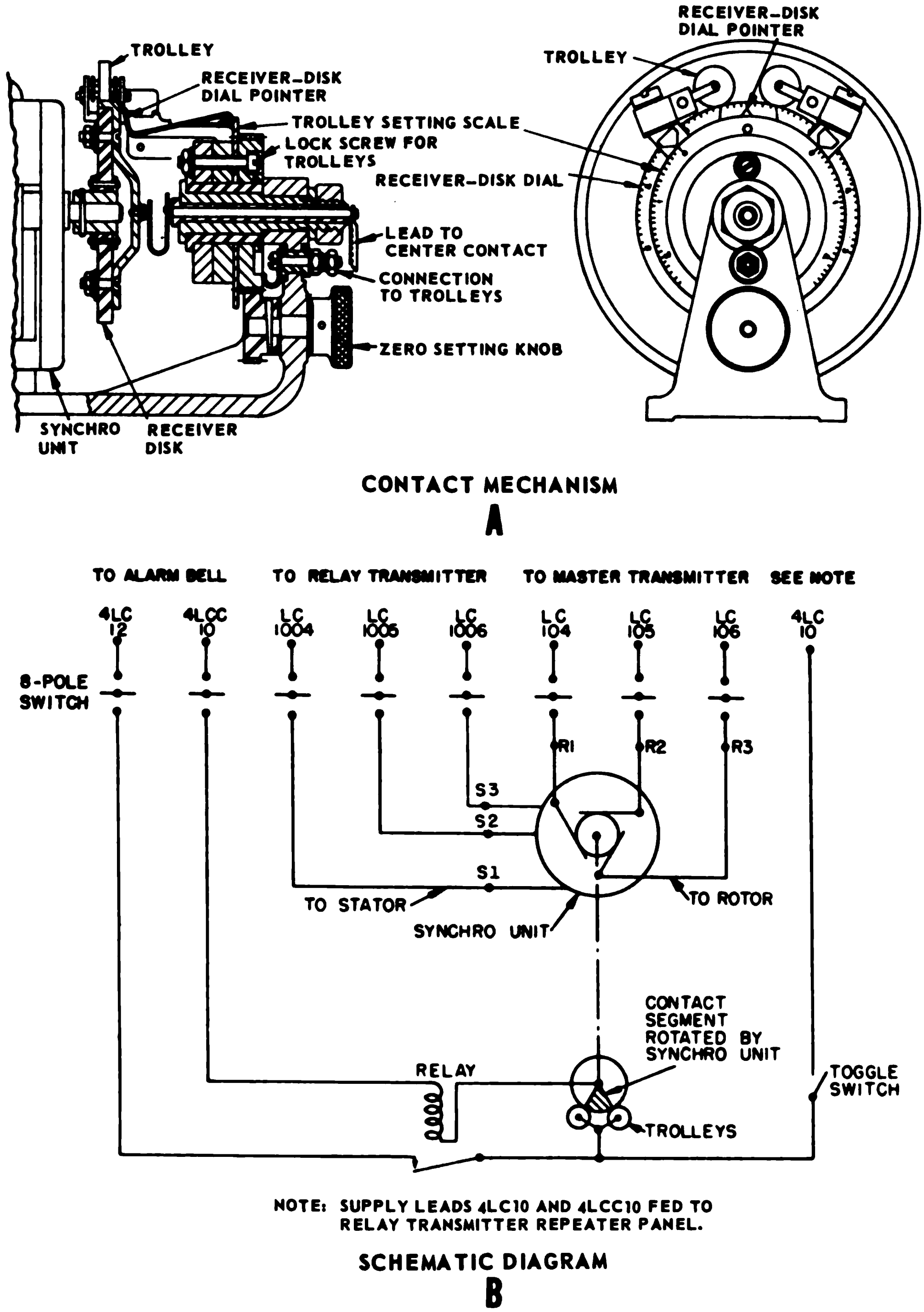
Digitized by Google



40.45

Figure 12-35. —Sperry Mk 11 Mod 6 relay transmitter.

Digitized by Google

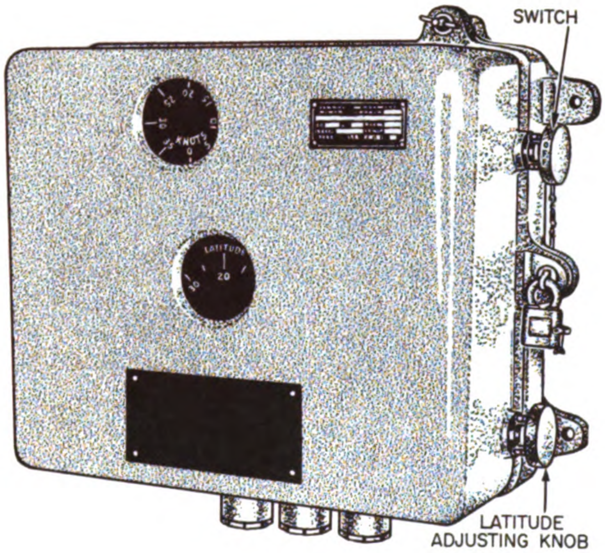


40.47

Figure 12-36.—Sperry Mk 11 Mod 6 gyrocompass differential alarm relay.

the ship's speed to the speed correction mechanism on the master compass. The step-by-step motor geared to the corrector spindle on the speed correction mechanism (fig. 12-38) is remotely controlled by a step-by-step transmitter in the automatic speed corrector. A switch is

Digitized by Google



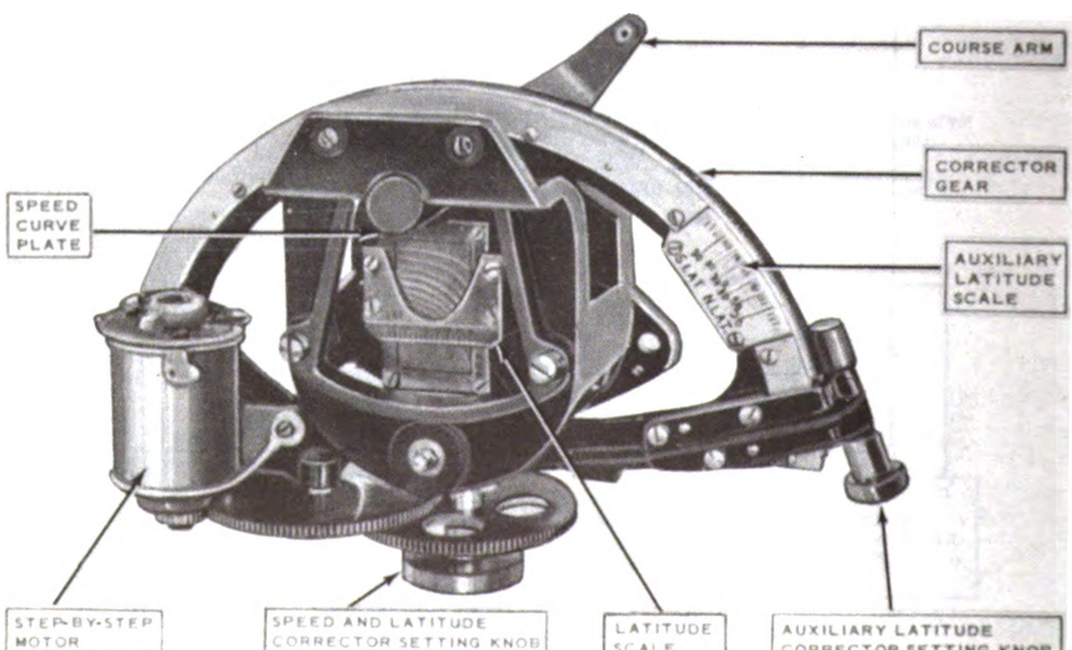
40.48
Figure 12-37.—Sperry automatic speed corrector.

mounted on the compass for opening the motor circuit when setting the correction device by hand.

The automatic speed corrector is contained in a metal box, mounted on the bulkhead in the vicinity of the master compass.

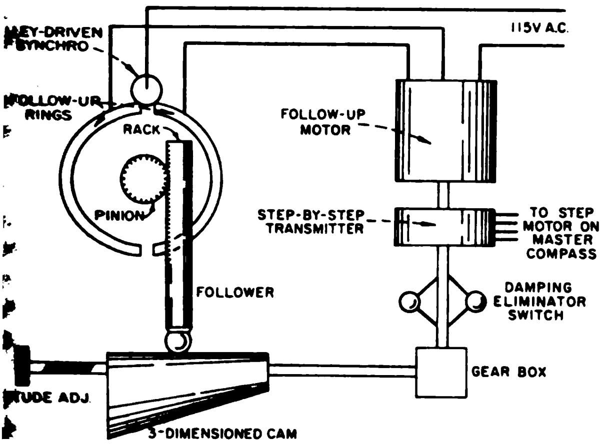
The ship's speed is introduced into the automatic speed corrector by a synchro motor controlled by the underwater log. In operation, the rotor of the synchro motor takes a position representing the ship's speed and correspondingly locates a pair of trolleys bearing on a follow-up ring assembly (fig. 12-39).

When the position of the trolleys is not on the gap in the followup contact rings, the followup motor is energized. The motor drives a three-dimensioned cam, which, by means of a follower and gears, drives the followup contact rings into synchronism with the trolleys. The cam is designed so that when it is correctly positioned lengthwise for the local latitude, the amount it must turn to synchronize the trolleys and rings is proportional to the speed correction that must

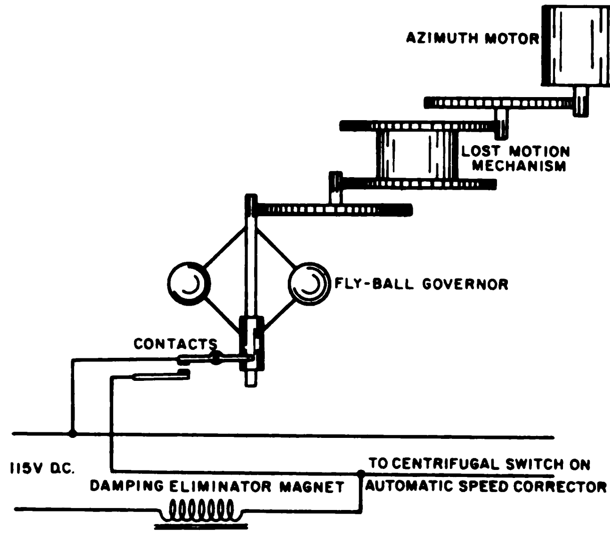


40.49
Figure 12-38.—Speed correction mechanism.

Digitized by Google



40.50
Figure 12-39.—Schematic diagram of Sperry automatic speed corrector.



40.51
Figure 12-40.—Schematic diagram of Sperry automatic damping eliminator.

e set into the compass. This correction is ransmitted to the step-by-step motor on the ompass by a step-by-step transmitter driven y the followup motor that rotates the cam. The ollowup motor also drives a centrifugal type amping-eliminator switch to eliminate damping uring rapid changes in speed.

The instrument (fig. 12-37) is provided with dial to indicate the ship's speed, graduated n knots, and visible through a window in the over. The latitude adjustment, which deternines the lengthwise position of the threeimensioned cam, is shown on another dial, lso visible through a window in the cover.

utomatic Damping Eliminator

The automatic damping eliminator used with he Sperry Mk 11 Mod 6 compass (fig. 12-40) onsists of two centrifugal switches, one geared o the azimuth motor, and one to the followup notor of the automatic speed corrector; and an electromagnet that moves the mercury ballistic onnecting arm from its offset position to a rue vertical position.

The switch geared to the azimuth motor akes care of changes in course where no change in speed is involved. This switch consists of a flyball governor driven through a gear train which speeds the governor shaft to about 4300 revolutions to one revolution of the phantom. To eliminate constant starting and stopping of the governor when the ship is yawing, a lostmotion mechanism and a helical driving spring are inserted between the switch driving gear in the azimuth motor train and the first gear in the train to the governor shaft. As the ship yaws, the lost-motion mechanism comes into play. This mechanism prevents transmission of motion to the governor shaft.

If the ship turns more than 15 degrees, the helical spring is wound in one direction or the other until there is sufficient tension in the spring to set the governor in motion. As the governor spins, the balls fly up, raising a sliding collar on the governor shaft which engages an arm operating the magnet circuit contact, thus closing the 115-volt d-c supply circuit to the damping eliminator magnet.

A friction brake on the governor, and a spring disk friction clutch in the gear train, prevent the governor from spinning too fast. The contacts are adjusted so that the circuit is closed when the ship turns at a rate of more than 40 degrees per minute.

The gearing arrangement from the azimuth motor through the lost motion device to the flyball governor is also shown in figure 12-33.

The damping-eliminator switch (fig. 12-39) driven by the followup motor in the automatic speed corrector operates in a similar manner to eliminate damping during rapid changes in ship's speed.

Digitized by Google

OPERATION

Operating the compass consists of starting, stopping, adjusting correction devices, and making checks for any indications of abnormal operating conditions.

Starting The Compass

If possible the compass should be started at least four hours before it is needed for service. Before starting make sure that all switches on the compass and repeater switchboards are off. Ensure that the gyro case lock and vertical ring lock (fig. 12-24) are in the locked position, and that the vacuum gage (not shown) indicates approximately 28 inches. Take hold of both sides of the phantom and vertical rings and turn slowly until the compass card indicates the approximate heading of the ship. Never turn the compass by exerting pressure on the compensating weights or mercury ballistic. Check the oil sight glass to ensure that the rotor bearings will be supplied with oil. Set the auxiliary latitude corrector, the speed and latitude corrector, and the ballistic latitude adjustment to the proper settings (discussed later). After completing the above checks, proceed to start the compass as follows:

1. After closing the necessary supply switches on the IC switchboard, turn the motor-generator transfer switch on the control panel (fig. 13-31) to the motor-generator set desired.
2. Press the starting push-button, turn the compass rotor switch to the motor-generator set in use, then close the d-c service switch.
3. When the gyro rotor has been running for about 30 minutes, close the followup supply switch, then wait approximately 15 minutes for the gyro rotor to come up to normal speed. Normal speed will be indicated by a reading of approximately 60 volts of the compass rotor supply voltmeter (fig. 12-31), and from 2 to 3 amperes on the compass rotor supply ammeter when the voltammeter selector switch is in the number 1 phase position.
4. Release the vertical ring lock (fig. 12-24), then release the gyro case lock. Be sure to release the vertical ring lock first.
5. Turn the azimuth motor supply switch on the control panel (fig. 12-31) to ON, and note whether the azimuth motor starts operating. It may be necessary to press the azimuth motor cutout detent release (fig. 12-31) to complete the circuit to the azimuth motor.
6. Turn the battery generator transfer switch on the battery throw-over panel to the motor-generator set in use, close the battery switch, and adjust the battery charging rate with the voltage adjusting rheostat.
7. Level the rotor case, then precess the compass to the approximate heading of the ship. To level the rotor case, apply a slight pressure on one side of a rotor case bearing housing as if to turn the compass in azimuth. If the rotor case starts to tilt in the wrong direction, apply the pressure to the other side of the housing. To precess the compass in azimuth, apply a slight downward pressure from the top of the rotor case bearing housing. If the compass starts to precess in the wrong direction, apply the pressure upward from the bottom of the housing.
8. Close the repeater supply switch on the IC switchboard (not shown), the 24 volt alarm switch on the battery throwover panel, (fig. 12-31), and the rotary switches for the relay transmitter supply and differential alarm relay on the relay transmitter repeater panel, (not shown).
9. Close the switch on the relay transmitter (fig. 12-35A).
10. Close the followup switch on the relay transmitter amplifier panel (fig. 12-31) wait about one minute for the tube filaments to heat up, then close the azimuth motor switch. The relay transmitter should synchronize immediately to the same heading as the master compass.
11. Close the toggle switch on the differential alarm relay (fig. 12-36B), and turn on all repeaters.

Setting Correction Devices

The gyrocompass operator must ensure that all error correction devices are properly set before starting the compass. While the ship is underway; he is further concerned with adjusting these devices. For the Sperry Mk 11 Mod 6 gyrocompass system, these devices include the Speed and Latitude Corrector, the Automatic Speed Corrector, the Auxiliary Latitude Corrector, and the Ballistic Latitude Adjustment.

SPEED AND LATITUDE CORRECTOR.—To set the speed and latitude corrector (fig. 12-38) without utilizing the automatic speed corrector, turn the knurled knob at the upper center of the corrector until the point on the latitude scale corresponding to the local latitude intersects the speed curve corresponding to the ship's

Digitized by Google

speed. For maximum accuracy the corrector should be kept within 2 degrees of the local latitude and within 2 knots of the ship's speed. It is impractical, however, to attempt to keep the speed settings within these limits without utilizing the automatic speed corrector.

To put the automatic speed corrector in operation, set the speed and latitude corrector (fig. 12-38) at zero, and turn the corrector step-by-step motor switch to ON. After the ship is underway and the underwater log is in operation, turn the switch on the upper right side of the automatic speed corrector (fig. 12-37), to ON. Set the corrector (fig. 12-37) to the local latitude with the latitude adjusting knob. Adjust the latitude setting when the ship's latitude changes as much as two degrees or as ordered by the ship's navigator.

AUXILIARY LATITUDE CORRECTOR.—To set the auxiliary latitude corrector, turn the smaller knurled knob on the right side of the corrector (fig. 12-38) until the line engraved on the large gear segment coincides with the point on the latitude scale corresponding to the local latitude. Change this asjustment for changes in ship's latitude of 2 degrees, or as ordered by the ship's navigator.

BALLISTIC LATITUDE ADJUSTMENT.—To make the ballistic latitude adjustment, turn the knurled latitude setting thumbwheel (fig. 12-26) until the pointer on the ballistic frame points to the local latitude on the latitude scale located on top of the mercury reservoir. Make the same adjustment on the opposite side of the ballistic. Make these adjustments for changes in latitude of 10 degrees, or as ordered by the ship's navigator.

Stopping the Compass

To stop the Sperry Mk 11 Mod 6 gyrocompass, proceed as follows:

1. Turn the switch on the automatic speed corrector, and the step-by-step speed corrector motor switch on the master compass to OFF.
2. On the battery throwover panel (fig. 12-31) open the 24-volt alarm switch, the battery switch, and the battery generator transfer switch.
3. Open the toggle switch on the differential alarm unit, then open the azimuth motor switch and the followup switch on the relay transmitter amplifier panel.
4. Open all repeater switches, and the rotary switch for the differential alarm unit.
5. Open the azimuth motor supply switch on the control panel, then lock the gyro case, and vertical ring locks (fig. 12-24). Be sure to lock the gyro case lock first.
6. On the control panel (fig. 12-31), open the followup supply switch, the d-c service switch, the compass rotor switch, and the motor generator transfer switch.
7. Open the repeater supply, and control panel supply switches on the IC switchboard, (not shown).

Indications of Normal Operations

Normal operating conditions for the compass system are indicated by the various electrical meters and overload indicators on the gyrocompass switchboard (fig. 12-31). Normal readings for the electrical meters are listed in the manufacturer's technical manual, NavShips 324-0020. As these readings may vary slightly for different installations, the average meter readings during actual normal operation should be recorded and used as the normal readings.

Normal operating conditions are also indicated by the gyro case level and vacuum gauge on the sensitive element, and the presence of the blue flame in the compass followup and relay transmitter power amplifier thyratrons.

Study the gyrocompass installation on your ship and become familiar with all indications of normal operation. This will enable you to recognize any abnormal condition immediately.

Digitized by Google

CHAPTER 13

GYROCOMPASSES, PART II

This chapter continues the discussion of gyrocompasses using the Sperry Mk 23 Mod 0, and the Arma Mk 26 Mod 2 as representative gyrocompasses.

SPERRY MK 23 MOD 0 GYROCOMPASS

The Sperry Mk 23 Mod 0 gyrocompass incorporates some major changes in gyrocompass design. In addition to the electronic control system mentioned previously, the Mk 23 is provided with oil suspension (flotation) of the sensitive element.

The compass was designed to provide a small compass capable of withstanding the severe operating conditions encountered in amphibious craft and submarines without sacrificing its primary function of furnishing accurate heading data. It is also used as an auxiliary gyrocompass aboard larger combatant ships. The force of gravity, instead of acting directly to control the compass, merely acts on a special type of electrolytic bubble level (gravity reference) which generates a signal proportional to the tilt of the gyro axle. This signal, after amplification, is used to apply torque electromagnetically about the vertical and/or horizontal axes to give the compass the desired period and damping. The gyro unit is enclosed in a sphere called a gyrosphere, and is suspended in oil.

The compass is compensated for speed error, latitude error, unbalance, and supply voltage fluctuations. In addition to the normal opoperating range of latitudes, the compass incorporates controls which make it suitable for accurate operation in high latitudes, and as a directional gyro near the poles.

An electronic followup system is provided which furnishes accurate transmission of 1- and 36-speed heading data.

The system consists of the master unit, control cabinet, speed units, alarm control, and the alarm bell, and compass failure annunciator as shown in figure 13-1.

MASTER UNIT

The master unit (fig 13-1) consists of a shock mounted oil filled binnacle and the gyrocompass element. The unit is designed for deck mounting and the compass element is gimbaled in the binnacle so as to have a freedom of ± 45 degrees about the roll and pitch axes. The sensitive element has a freedom of ± 70 degrees about its horizontal axis. Heaters in the binnacle keep the oil bath at a temperature of 100° F, and drain plugs are provided in the lower bowl for draining the oil. The complete master unit weighs approximately 100 pounds.

Gyrocompass Element

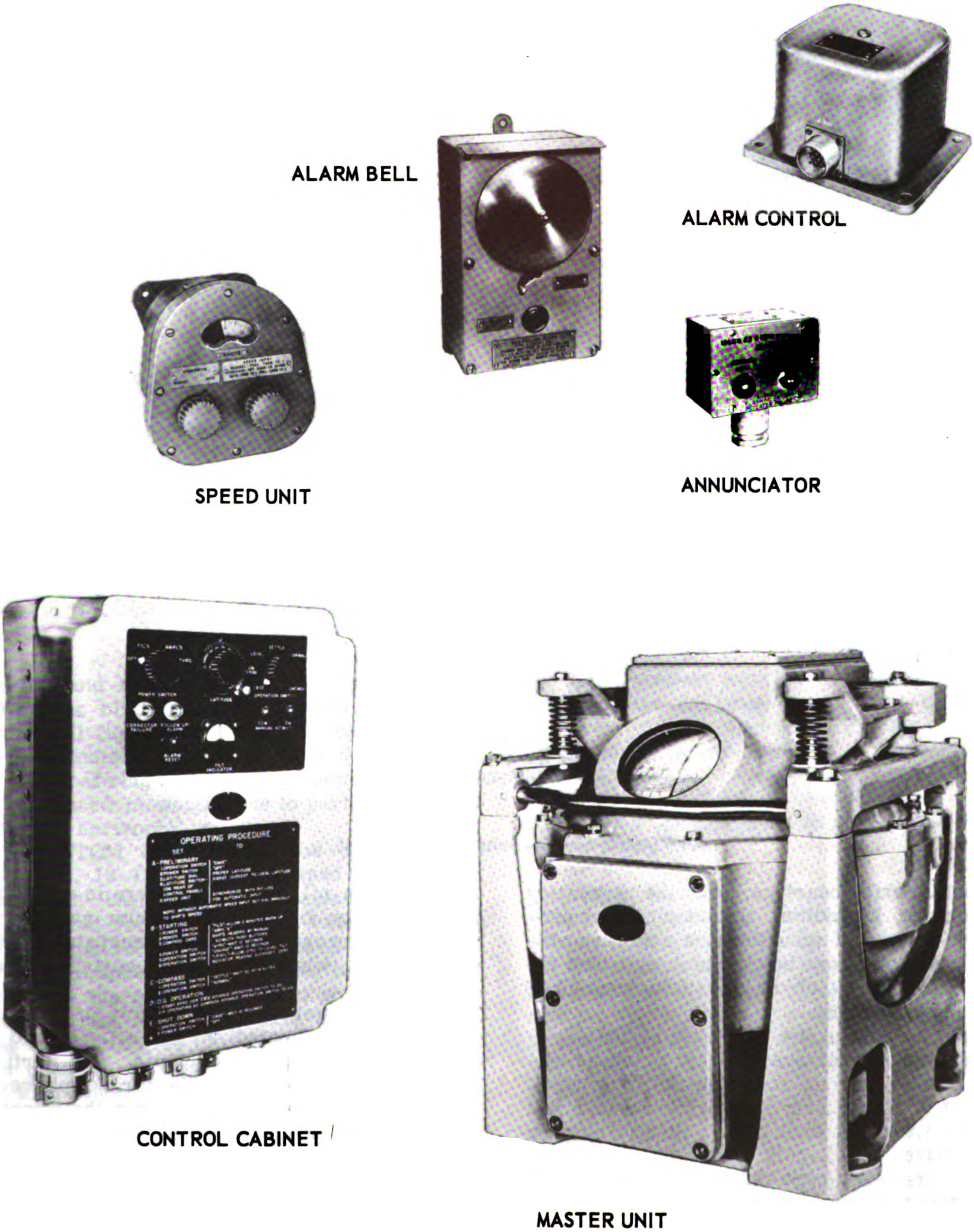
The gyrocompass element is the principle unit of the compass system and consists of three basic elements: the sensitive element, phantom element, and the spider element.

THE SENSITIVE ELEMENT.—The sensitive element (fig. 13-2) consists of the vertical ring, adapter ring, and gyrosphere.

The gyrosphere is pivoted about the vertical axis within the vertical ring. The vertical ring, in turn, is pivoted about the horizontal axis in the adapter ring. At right angles to the vertical ring is a horizontal ring, carrying the pivots about which the vertical ring and gyrosphere rotate. The horizontal ring also provides surfaces for mounting the electrolytic level (gravity reference), followup pickoff, and leveling torquer.

The adapter ring provides mounting surfaces for the azimuth control torquers, the

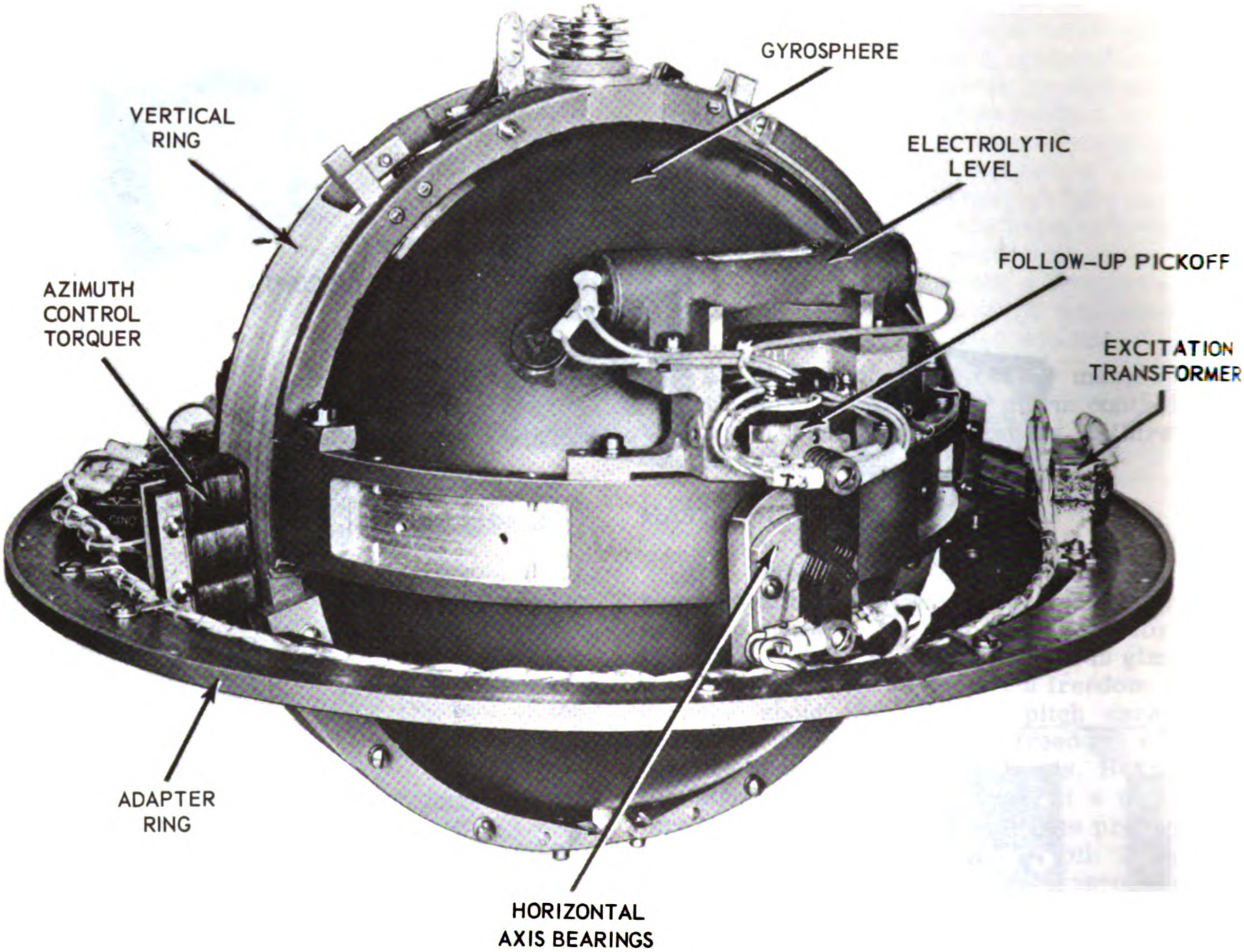
Digitized by Google



7.167

Figure 13-1.—Mark 23 Mod 0 gyrocompass equipment.

Digitized by Google



7.175

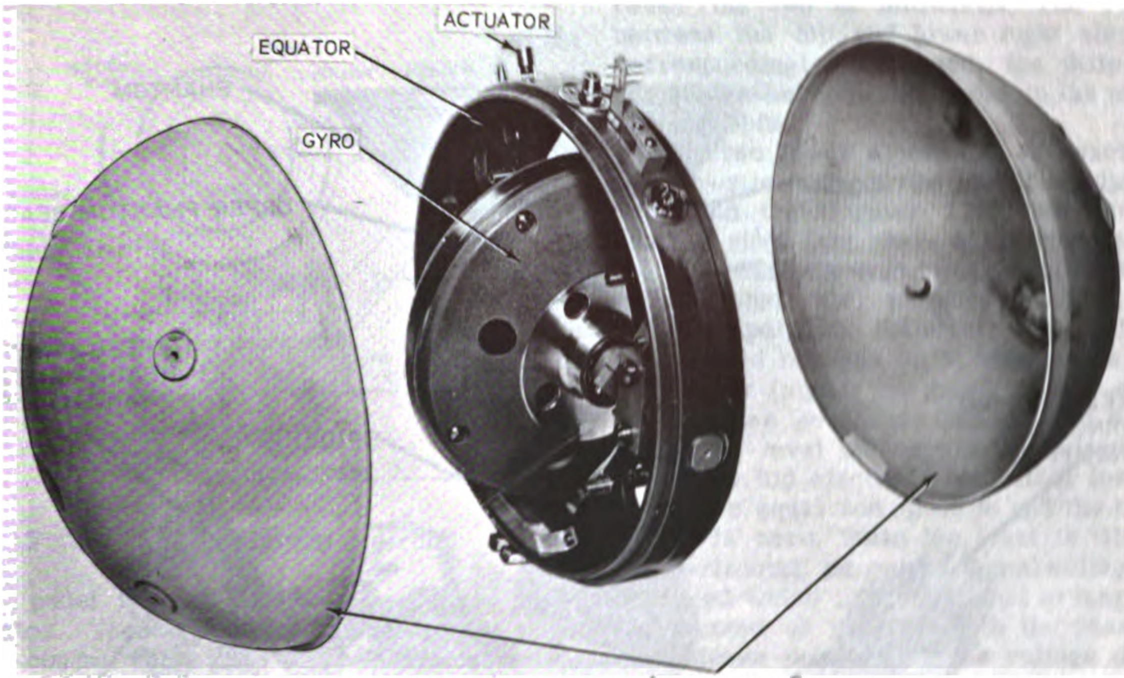
Figure 13-2.—Sensitive element.

horizontal axis bearings, and the excitation transformer. In additon, the adapter ring provides a method of mounting the sensitive element to the phantom bowl, which provides for ready replacement of the sensitive element if the need should arise.

The gyrosphere is the heart of the whole system, as it encloses the gyro and is the north-seeking part of the compass. It is composed of a center ring called the equator and two hemispherical shells (fig. 13-3). The gyro unit is driven by a 2-pole, 115-volt, 400-cycle, 3-phase squirrel cage induction motor. The rotor speed is approximately 23,600 rpm and the direction is clockwise when viewed from the south end. The gyro is hermetically sealed within the sphere and the complete unit is suspended in oil. The gyrosphere is evacuated and partially filled with helium gas, which serves to transfer the heat generated by the gyro motor windings to the surface of the sphere.

When the weight and buoyancy of the gyro are properly adjusted in the oil, no load is placed on the vertical pivots, the vertical bearings serving only as guides for the sphere. This liquid suspension eliminates the effect of shifts of the center of mass of the sensitive element with respect to the suspension axis. Liquid suspension also serves to protect the gyro from destructive shocks which are absorbed by the oil-filled compass enclosure, and the acceleration effects on the sensitive element are minimized because the center of

Digitized by Google



7,173

Figure 13-3.—Exploded view of gyrosphere.

gravity and center of buoyancy coincide. In addition to eliminating the load on the vertical pivots, oil flotation greatly reduces the load on the horizontal axis pivots. Only the weight of the vertical ring and its components, which are also reduced in weight due to partial flotation, loads the horizontal bearings.

PHANTOM ELEMENT.—The phantom element (fig. 13-4), is a bowl-shaped casting supported on ball bearings, located within the spider, and rotates about the vertical axis of the gyrosphere. As the ship turns with respect to the gyrosphere, the phantom is servomotor driven by the followup system so as to always maintain the horizontal axis of the vertical ring at right angles to the gyro axle (fig. 13-5). The phantom element mounts the azimuth gear and slip rings.

SPIDER ELEMENT.—The spider element (figs. 13-4 & 13-5) is a cast member having two ribbed arms carrying pivots which fit in bearings on the gimbal ring. The lower section carries the bearings supporting the phantom and caging mechanism. The cager is solenoid operated, and fits up into the hollow shaft of the phantom. Mounted on the spider are the 1- and 36-speed synchro heading data transmitters, the followup motor, and the speed resolver. The spider supports the phantom, gyrosphere, and vertical ring assembly. The spider, in turn, is supported by the gimbal ring and the complete gyrocompass element (fig. 13-6) is gimbaled in the binnacle by a gimbaling system.

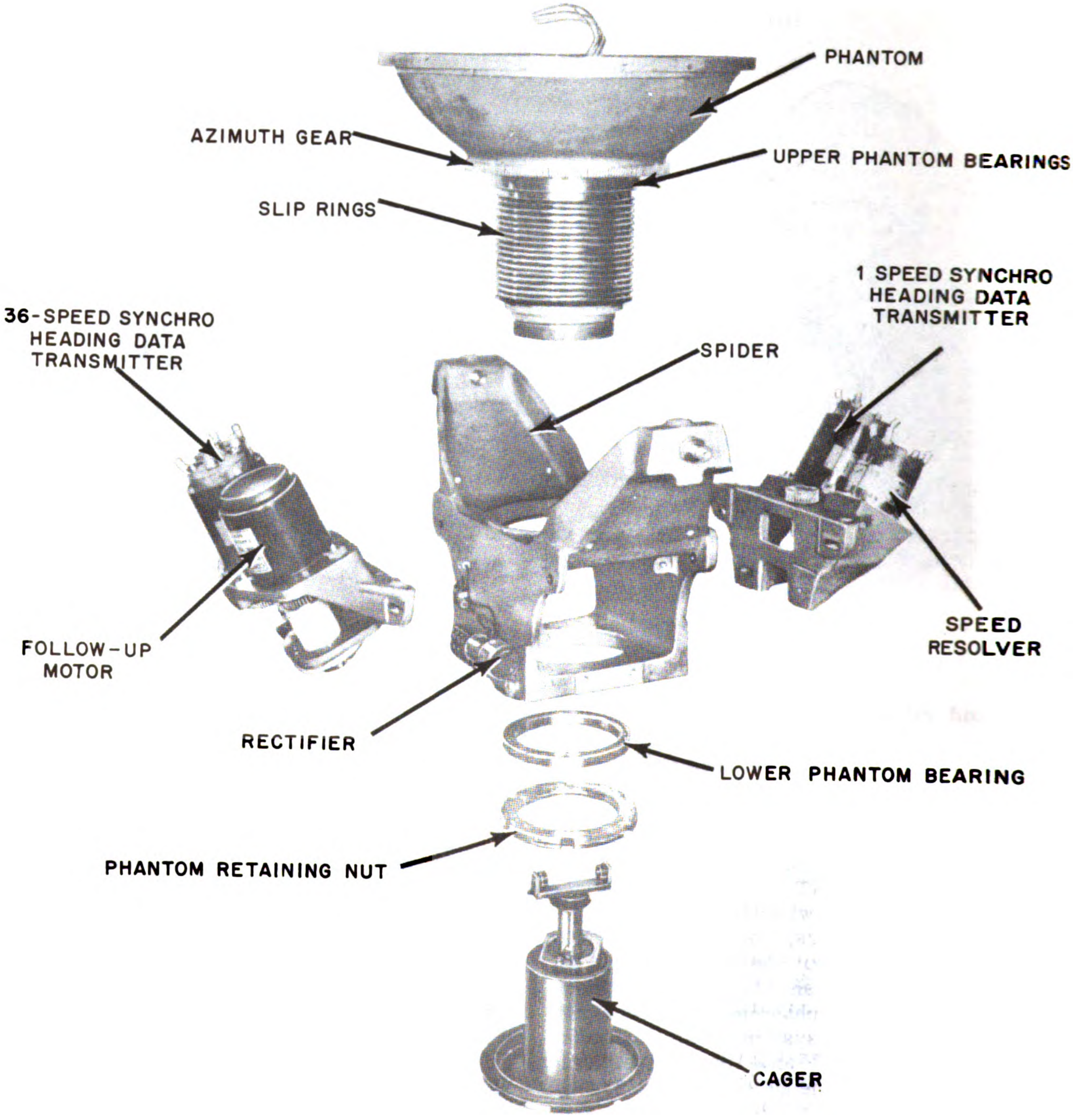
CONTROL CABINET

The control cabinet (fig. 13-1) contains all the equipment required for operating and indicating the condition of the master compass except the compass failure annunciator and alarm bell. It houses the control panel, control amplifier, followup amplifier, and power supply.

SPEED UNIT

The speed unit (fig. 13-1) contains the necessary components to produce an electrical signal proportional to the ship's speed, as will be discussed later. Speed data is received from the ship's underwater log

Digitized by Google



27.159

Figure 13-4.—Exploded view of phantom, spider, and cager.

equipment, or set in manually. Speed range of the unit is 0 to 40 knots.

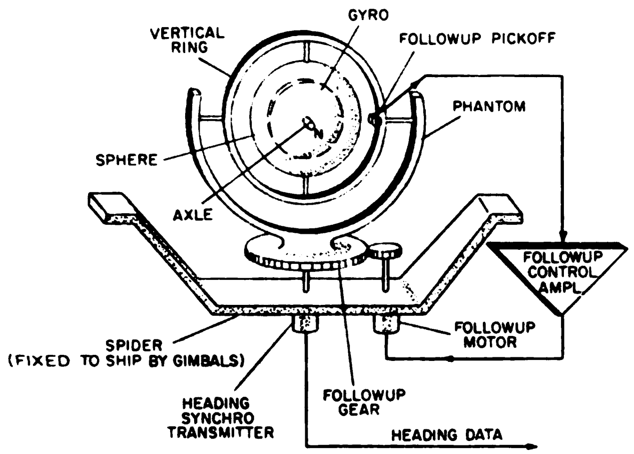
ALARM CONTROL

The alarm control (fig. 13-1) contains the necessary relays and components to actuate a flashing light or bell alarm when certain portions of the system become inoperative.

ALARM BELL AND ANNUNICIATOR

The alarm bell (fig. 13-1) is a standard Navy B-10 bell. A Navy type B-51 or B-52

Digitized by Google



7.174

Figure 13-5.—Followup controls.

alarm panel may be used in place of the annunciator. The alarms are actuated by the alarm control and either the bell or annunciator, or both, may be used to indicate system failure.

MK 23 GYROCOMPASS CONTROLS

All controls for the Mk 23 gyrocompass system (fig. 13-7) may be divided into two systems, the compass control system and the followup system. The compass control system may be further divided into three separate systems: the gravity reference system, the azimuth control system, and the leveling control system.

GRAVITY REFERENCE SYSTEM

The gravity reference system consists of the electrolytic bubble level, excitation transformer, and tilt signal amplifier.

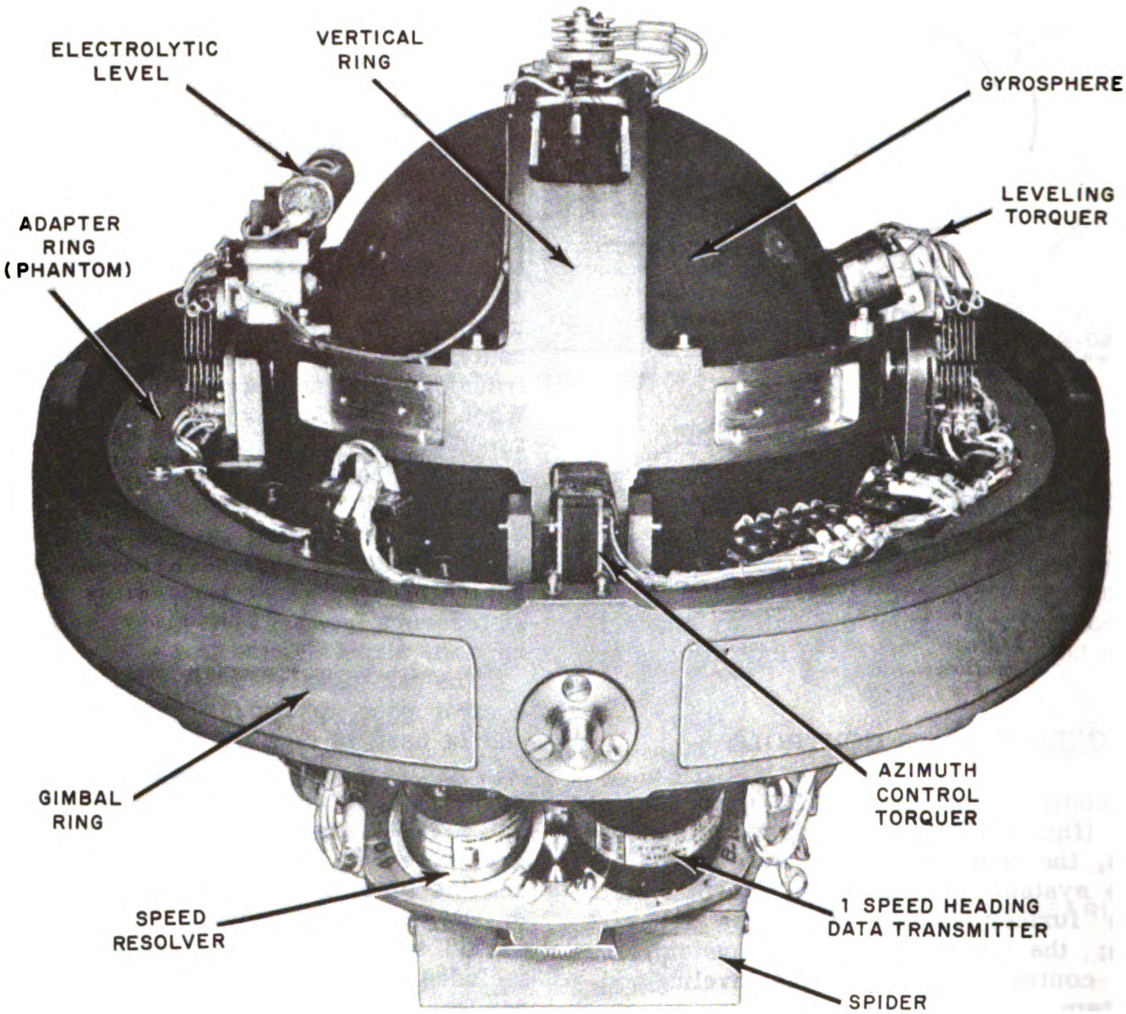
The electrolytic bubble level (fig. 13-2) is mounted on the horizontal pivots, so that it is parallel to the gyro axle. It is a cylindrical glass vial containing three platinum electrodes, the vial being nearly filled with an electrolyte so that a bubble is formed at the top of the vial (fig. 13-8). When the vial is horizontal, the bubble is centered, and the resistance between the top electrode and either lower electrode is equal. If the vial tilts so that the bubble moves to the left, there is less electrolyte between the top electrode and the lower left electrode and consequently the resistance between the two is increased. The resistance between the top and lower right electrode is correspondingly decreased, the difference in resistance being proportional to the movement of the bubble.

The two lower electrodes are excited from the opposite ends of the output winding of the excitation transformer T102 mounted on the adapter ring. One phase of the 400-cycle, 115-volt, 3-phase power supply excites the excitation transformer primary winding. The tilt signal output from the electrolytic bubble level is obtained between an accurately determined center-tap (signal common) of the excitation transformer secondary and the top electrode. When the level is horizontal, the voltage between the top electrode and either lower electrode are equal and opposite and the tilt signal output is zero. When the level is tilted from the horizontal, an output signal voltage will be produced which is proportional in magnitude to the amount of tilt and with the phase or instantaneous polarity of the voltage dependent upon the direction of tilt.

The tilt signal amplifier is included in the control panel portion of the control cabinet, and is used to amplify the tilt signal before it is supplied to the leveling and azimuth control systems. The amplifier consists of a pentode stage (V301 fig. 13-8) and two cathode followers (V302A & B) one for the damping signal and the other for the meridian control signal. In addition to its normal 90-minute compass period with 65 percent damping, the compass includes a 30-minute settling period with 90 percent damping, which greatly reduces the time required for the compass to settle on the meridian after starting. The operation switch S302, in conjunction with the tilt signal amplifier, alters the amplification of the tilt signal to obtain these two operating conditions.

The tilt signal is fed to the grid of V301 through the series grid resistor R301, and blocking capacitor C301. Cathode bias for V301 is obtained from a voltage divider, R303 and R220, connected across the plate supply. The output of V301 is fed to the grid of the meridian control signal cathode follower V302B. Potentiometer R310 in the cathode circuit of V302B provides a method of adjusting the magnitude of the meridian control signal. This adjustment is set at the factory and should not be changed. A portion of the output of V302B is fed back from the cathode through blocking capacitor C302 to the common connection between the plate load resistors R305 and R302 of

Digitized by Google



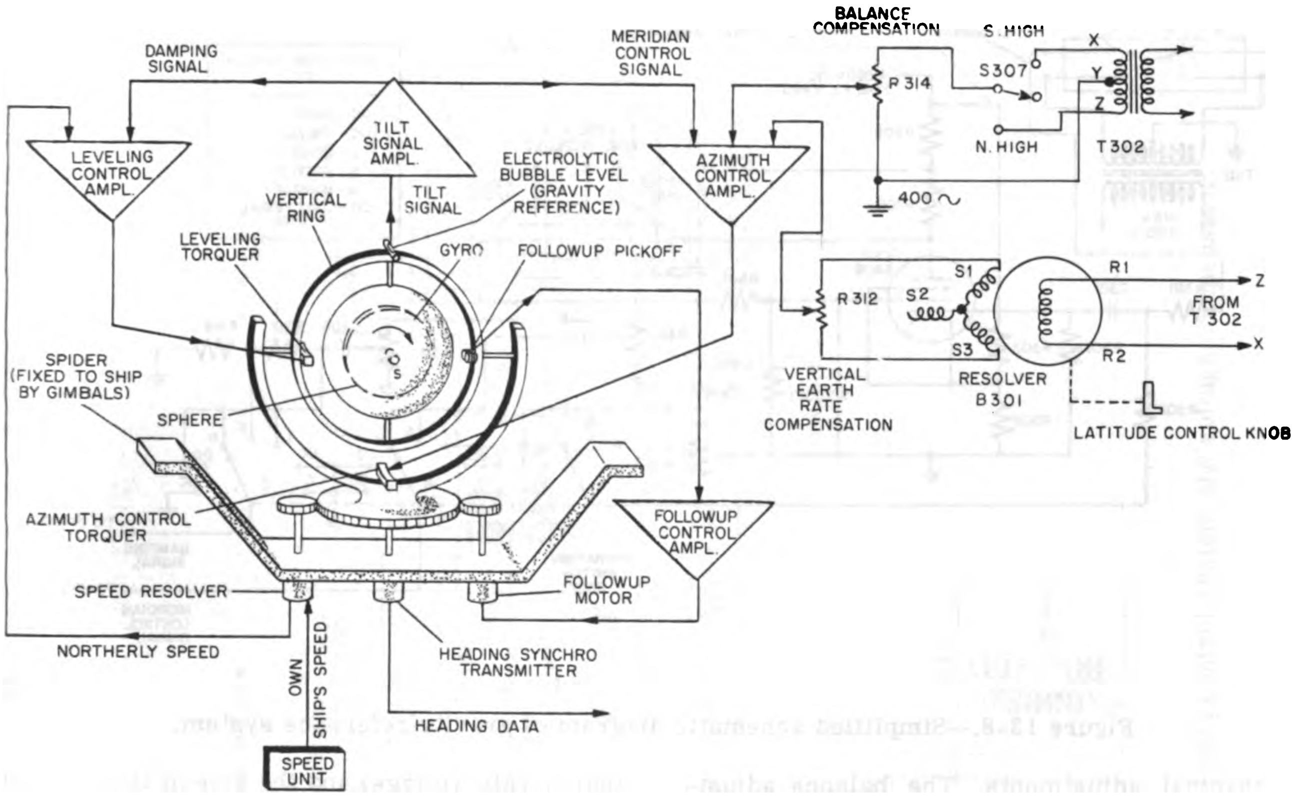
27.160

Figure 13-6.—Gyrocompass element.

V301. This feedback is of the same phase as the plate signal of V301 and therefore changes the potential at the common connection of R305 and R306 at the same time and in the same direction as the tilt signal input changes the potential at the plate end of R306. Thus, the voltage drop across R306 is maintained constant. This feature ensures that the V302B grid will remain negative with respect to the cathode and will not draw current. The change in voltage at the plate end of R306 is also reduced by negative feedback to the screen grid through voltage divider R307 and R308 to ground. The gain of the tilt signal amplifier without negative feedback is about 2000. The gain required for the 30-minute setting period is 90 and a gain of 10 is needed for the normal 90-minute period. To obtain the required gain for both periods, another feedback loop is provided from the V302B cathode through C304, R309, R302, and C301 to the V301 grid. For the 30-minute period (operation switch S302(A) in the SETTLE position) both resistors R309 and R302 are in the feedback loop and the amplifier gain is 90. For the 90-minute period (operation switch S302(A) in the NORMAL position) resistor R309 is shorted out and the amplifier gain is 10.

The meridian control signal is obtained from the cathode of V302B and is fed through R310, C305 and operation swtich S302(B), which connects the meridian control signal to the azimuth

Digitized by Google



7.170

Figure 13-7.—Simplified diagram of Mk 23 gyrocompass with all controls.

control amplifier during the normal and settle modes of operation.

The meridian control signal obtained from the V302B cathode is applied to the V302A grid. Potentiometer R311 in the cathode circuit, provides a factory adjustment of the damping signal. The damping signal is coupled through C306 to the voltage divider R317 and R318. The operation swtich S302(C) connects the proper damping signal network for the mode of operation selected. During the settle mode of operation the signal is taken from the voltage divider giving the compass 90 percent damping. During level, normal, and directional gyro modes of operation the signal is taken via C306 from potentiometer R311. As the gain of the amplifier is increased during level, settle, and directional gyro, the signal voltage at R311 will be greater during these modes of operation. The meridian control signal, however, is disconnected by operation switch S302(B) during certain modes of operation as discussed later.

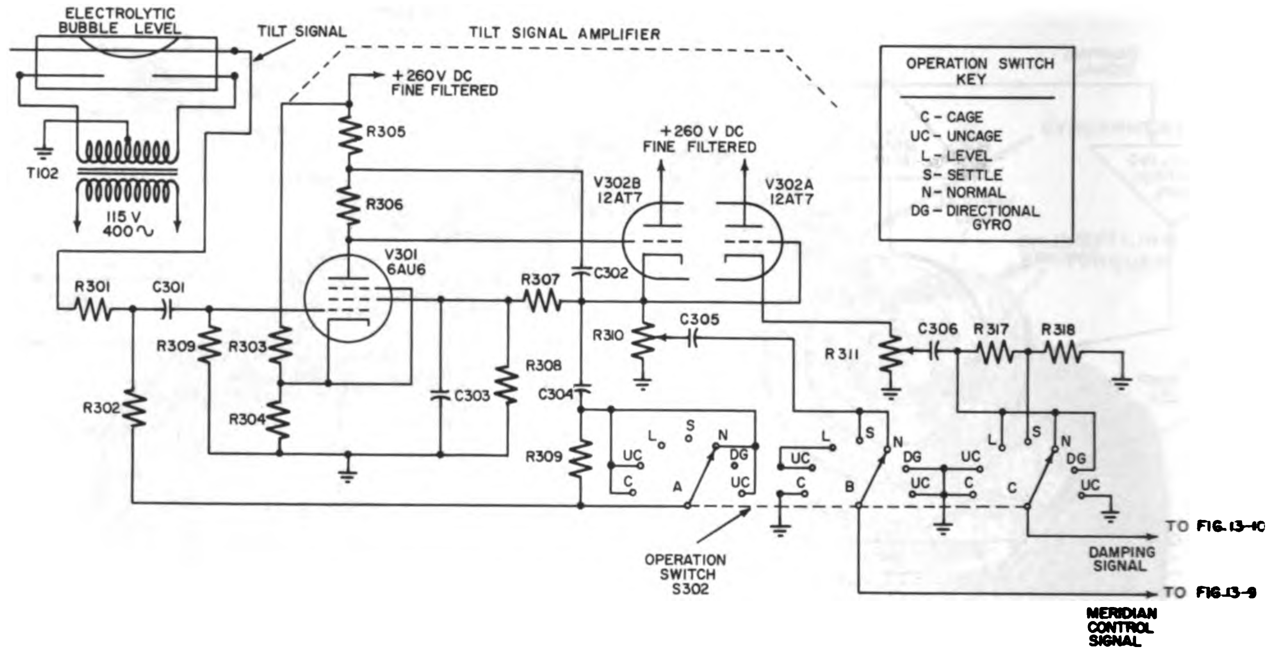
AZIMUTH CONTROL SYSTEM

The azimuth control system (fig. 13-9) consists of the latitude switch S308, balance sense switch S307, latitude resolver B301, azimuth control amplifier, and azimuth control torquers. The system functions to produce a torque about the gyro horizontal axis, causing precession about the vertical axis toward the meridian, thus making the compass north seeking.

To give the compass the same period both at high and low latitudes, a latitude switch (S308), is provided which alters the connection of the meridian control signal mixing resistors R601 and R602. Above 75 degrees latitude the period of the Mk 23 compass lengthens considerabley and the accuracy is thereby impaired. The directional gyro mode of operation is for use when in these latitudes. In this mode of operation the meridian control signal is disconnected from the azimuth control amplifier (by operation switch S302B fig. 13-8) and the gyro operates as a free gyroscope corrected for vertical earth rate and speed.

The balance adjustment (fig. 13-9) is provided as a convenience for shipboard operation. This adjustment permits the effects of mechanical unbalance in the master compass to be corrected without actually making the

Digitized by Google



27.162

Figure 13-8.—Simplified schematic diagram of gravity reference system.

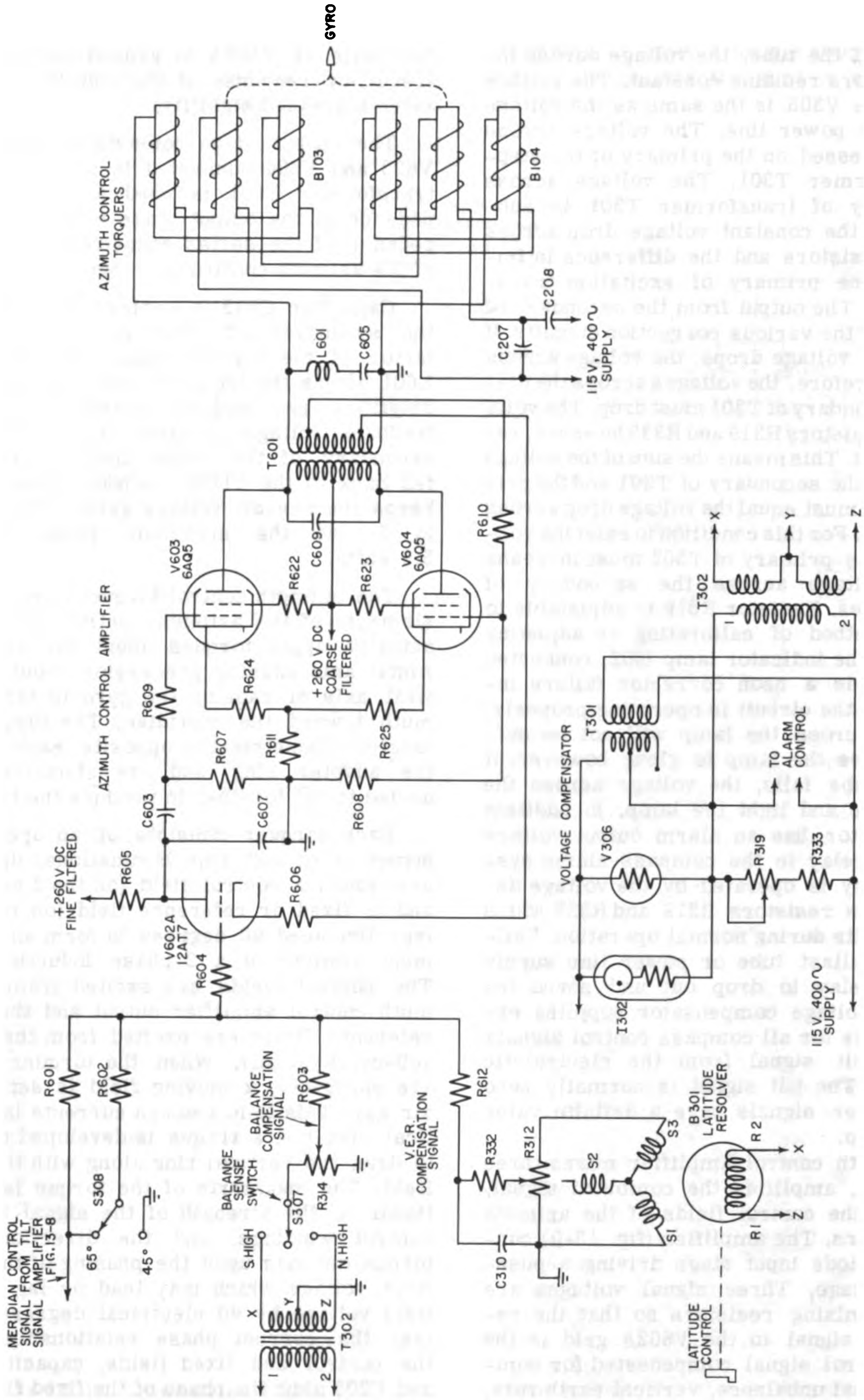
mechanical adjustments. The balance adjustment provides an electrical signal to the azimuth control amplifier to compensate for any mechanical unbalance. Power is supplied for the adjustment from the center tapped secondary of T302 in the voltage compensator. Balance sense switch S307 enables the operator to compensate for a north end high or south end high of the gyro axle. Potentiometer R314 is used to adjust the magnitude of the balance correction.

The effect of vertical earth rate causes the gyro to move in azimuth with respect to the earth as explained in the preceding chapter. To compensate for this effect, a vertical earth rate compensation circuit is provided consisting of a latitude resolver B301, potentiometer R312, resistor R332, and capacitor C310 (fig. 13-9). Vertical earth rate effect is the product of earth rate and the sine of the latitude. It is maximum at the poles (equal to earth rate itself) and zero at the equator. The input to the system is latitude which is set in manually by the latitude control knob on the control panel. The rotor of the resolver B301, is excited from the secondary of T302. This voltage is used as the earth rate reference voltage. The output voltage of the resolver (between S1 and S3) is the product of the excitation voltage (earth rate voltage) and the sine of the angle of the latitude control shaft displacement. This voltage is proportional to the local vertical earth rate. Potentiometer R312 across the resolver output is used to adjust and calibrate the vertical earth rate signal. Resistor R332 and capacitor C310 compensate for the phase shift in the resolver.

The voltage compensator shown in figure 13-9, although not considered a part of the azimuth control system, is essential to the proper functioning of the system. If the voltage on the torquer fields should vary due to power line variations the torque produced would consequently vary, and if not compensated for would unsettle the compass. The method used to compensate for power line variations is to compensate the excitation voltages of the signal sources. This compensation is such that the excitation voltages are changed by the same percentage as any power line change but in the opposite sense. If the power line voltage drops, the excitation voltage rises. The net result is that the torque produced by the torquers is constant.

The 115-volt 400-cycle power line voltage is impressed across the series circuit in the voltage compensator consisting of resistors R319 and R333, and ballast current regulating tube

Digitized by Google



27.164

Figure 13-9.—Simplified schematic diagram of azimuth control system and voltage compensator.

V306 (fig. 13-9). Because of the constant current design of the tube, the voltage across the series resistors remains constant. The voltage change across V306 is the same as the voltage change of the power line. The voltage across V306 is impressed on the primary of the step-down transformer T301. The voltage across the secondary of transformer T301 is subtracted from the constant voltage drop across the series resistors and the difference is impressed on the primary of excitation transformer T302. The output from the secondary of T302 is fed to the various correction circuits. If the power line voltage drops, the voltage across V306 and, therefore, the voltages across the primary and secondary of T301 must drop. The voltage across resistors R319 and R333 however, remains constant. This means the sum of the voltage drops across the secondary of T301 and the primary of T302 must equal the voltage drop across R319 and R333. For this condition to exist the voltage across the primary of T302 must increase when the voltage across the secondary of T301 decreases. Resistor R319 is adjustable to provide a method of calibrating or adjusting the circuit. The indicator lamp I302, connected across V306 is a neon corrector failure indicator. When the circuit is operating properly, the voltage across the lamp will not be sufficient to cause the lamp to glow; however, if the ballast tube fails, the voltage across the lamp will rise and light the lamp. In addition the compensator has an alarm output voltage to an alarm relay in the compass alarm system. The relay is operated by the voltage developed across resistors R319 and R333 which is about 70 volts during normal operation. Failure of the ballast tube or power line supply causes the relay to drop out and sound the alarm. The voltage compensator supplies excitation voltage for all compass control signals except the tilt signal from the electrolytic bubble level. The tilt signal is normally zero while the other signals have a definite value other than zero.

The azimuth control amplifier mixes three input signals, amplifies the combined signal, and supplies the control fields of the azimuth control torquers. The amplifier (fig. 13-9) consists of a triode input stage driving a push-pull output stage. Three signal voltages are fed through mixing resistors so that the resultant input signal to the V602A grid is the meridian control signal compensated for compass mechanical unbalance, vertical earth rate, and latitude. Capacitor C607 connected from the plate of V602A to ground limits the high frequency response of the amplifier and provides increased stability.

The output stage consists of two pentodes V603 and V604 connected in push-pull. Output transformer T601 is used to match the impedance of the output stage to the tuned impedance of the series connected control fields of the azimuth control torquers.

Capacitor C605 in series with L601 across the secondary of T601 corrects the power factor of the torquer load, and the inductor L601 alters the frequency characteristic of the amplifier and ensures stability. A negative feedback voltage is taken from a tap on the secondary of the output transformer and is fed back to the V602A cathode. This feedback keeps the overall voltage gain of the amplifier to 2 and the maximum power output to 5.5 watts.

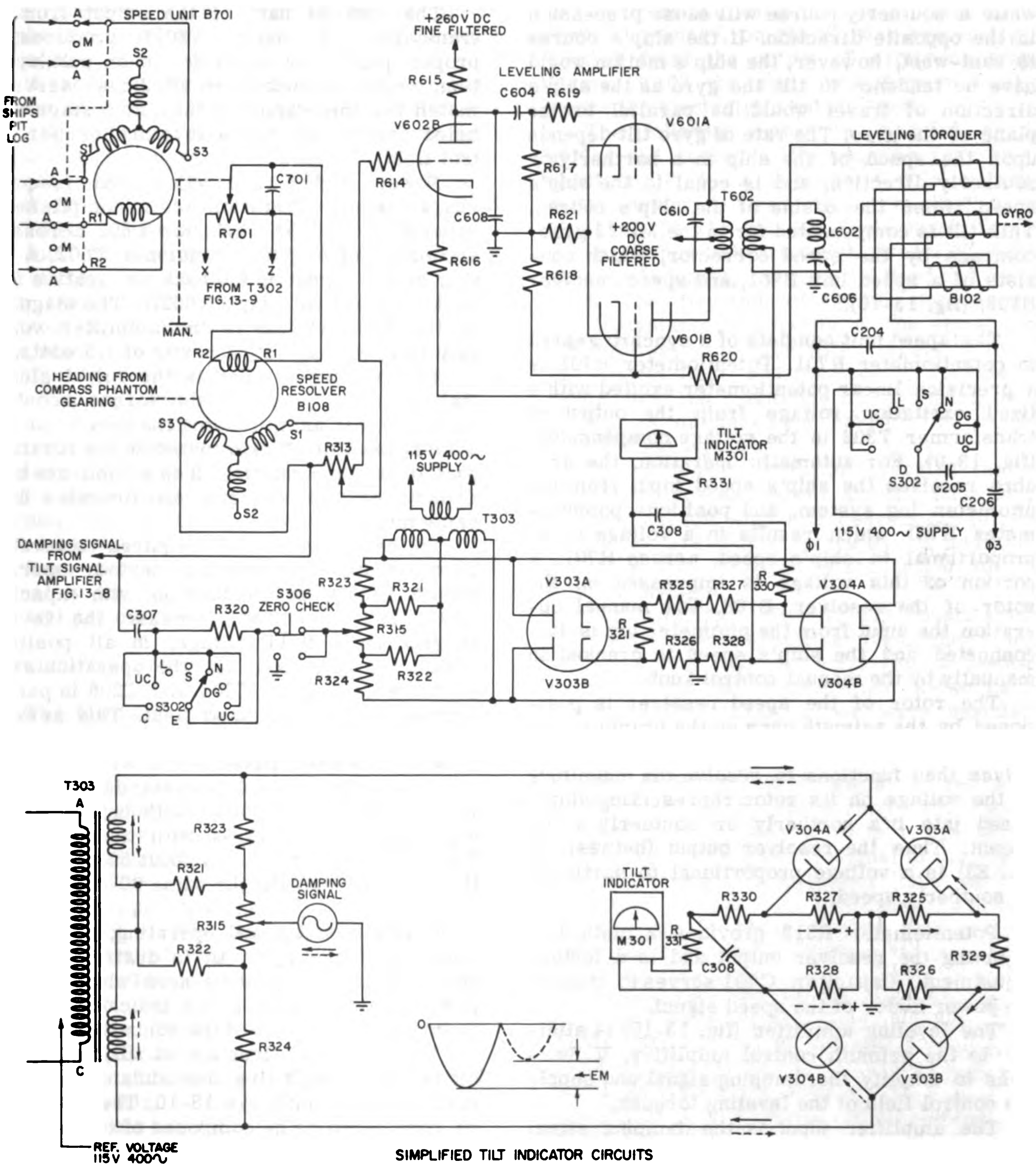
The azimuth control torquers are the output elements of the azimuth control system which actually apply torques about the gyro horizontal axis causing precession about the vertical axis or causing the gyro to turn in azimuth toward the meridian. The torquers are located diametrically opposite each other on the adapter ring, and are electrically connected to act together to produce the torque.

Each torquer consists of an open-E rack structure of soft iron laminations, upon which are wound a control field (on the 2 outer legs) and a fixed or reference field (on the center leg) displaced 90 degrees to form an arrangement similar to a 2-phase induction motor. The control fields are excited from the azimuth control amplifier output and the fixed or reference fields are excited from the 115-volt 400-cycle supply. When the torquer windings are energized, a moving field is set up in the air gap. This field induces currents in the vertical ring and a torque is developed that tends to drag the vertical ring along with the moving field. The magnitude of the torque is proportional to the strength of the signal fed to the control windings, and the direction of the torque depends upon the phasing of the control field voltage which may lead or lag the fixed field voltage by 90 electrical degrees. To obtain the correct phase relationship between the control and fixed fields, capacitors C207 and C208 shift the phase of the fixed field.

Digitized by Google

LEVELING CONTROL SYSTEM

The leveling control system (fig. 13-10) consists of the speed corrector, the leveling amplifier, and leveling torquer. The system functions to apply a torque about the gyro vertical axis causing the gyro to assume a level position.



27.164

Figure 13-10.—Simplified schematic diagram of leveling control system and tilt indicator.

Digitized by Google

If a ship is traveling on a north-south course, as it follows the curvature of the earth, the north end of the gyro would appear to tilt. For a northerly course, the resultant tilt signal will cause the gyro to precess to the west, while a southerly course will cause precession in the opposite direction. If the ship's course is east-west, however, the ship's motion would have no tendency to tilt the gyro as the ship's direction of travel would be parallel to the plane of the gyro. The rate of gyro tilt depends upon the speed of the ship in a northerly or southerly direction, and is equal to the ship's speed times the cosine of the ship's course. This tilt is compensated for in the Mk 23 gyrocompass by the speed corrector, which consists of a speed unit B701, and speed resolver B108, (fig. 13-10).

The speed unit consists of a synchro geared to potentiometer R701. Potentiometer R701 is a precision linear potentiometer excited with a fixed excitation voltage from the output of transformer T302 in the voltage compensator, (fig. 13-9). For automatic operation, the synchro receives the ship's speed input from the pitometer log system, and positions potentiometer R701 which results in a voltage drop, proportional to ship's speed, across R701. A portion of this voltage is impressed on the rotor of the resolver, B108. For manual operation the input from the pitometer log is disconnected and the ship's speed is cranked in manually by the manual control knob.

The rotor of the speed resolver is positioned by the azimuth gear on the phantom, and thus represents the ship's heading. The resolver then functions to resolve the magnitude of the voltage on its rotor representing ship's speed into it's northerly or southerly component. Thus the resolver output (between S1 and S3) is a voltage proportional to northerly or southerly speed.

Potentiometer R313 provides a method of adjusting the resolver output and is a factory adjustment. Capacitor C701 serves to correct the power factor of the speed signal.

The leveling amplifier (fig. 13-10) is similar to the azimuth control amplifier. It functions to amplify the damping signal and supply the control field of the leveling torquer.

The amplifier input is the damping signal from the tilt signal amplifier, compensated for northerly or southerly speed, and is fed through resistor R614 to the grid of V602B.

The output stage consists of the dual triode V601A and B. Output section V601A is excited from the output of V602B and V601B is excited from the secondary of output transformer T602.

The use of part of the output from the transformer to excite V601B produces the proper phase inversion for push-pull operation. Output transformer T602 also serves to match the impedance of the output stage to the tuned impedance of the leveling torquer control field.

Power factor correction and frequency characteristic alteration are accomplished by capacitor C606 and inductor L602 across the secondary of output transformer T602. A portion of the output is fed back as negative feedback to the input stage V602B. The magnitude of the feedback limits the amplifier voltage gain to 1, with an output power of 1.5 watts.

The leveling torquer is the output element that actually produces the torque about the gyro vertical axis, causing the gyro to assume a level position. It is mounted on the horizontal part of the vertical ring. It is a duplicate of the azimuth control torquers, and operates in the same manner.

To reduce the time required to level the gyro during the starting period, operation switch S302D, in conjunction with capacitors C204, 205, and 206, increase the leveling torquer fixed field voltage. In all positions, except the level position, the operation switch connects capacitors C204 and C205 in parallel across the torquer fixed field. This arrangement produces about 6 volts across the field with a 90-degree phase shift. With the operation switch in the level position, capacitor C205 is connected in parallel with capacitor C206 and both are in series with the fixed field. This connection produces about 60 volts across the fixed field, with the same 90-degree phase shift.

During starting and operating, a visual indication of the gyro tilt is desirable. As the compass level cannot be seen when the compass is assembled, a tilt indicator meter is provided on the front of the control panel.

To detect the direction of tilt, a full-wave diode phase sensitive demodulator circuit is used as shown in figure 13-10. The circuit may be considered to be composed of two half-wave sections, using the reference transformer T303 with resistor network R321. R322 and R324 and balance potentiometer R315 for both

Digitized by Google

half-wave sections. The input is the damping signal from the tilt signal amplifier and is applied effectively between the center tap of the diode load resistors and the center tap of the reference voltage transformer through balance potentiometer R315. The signal is either in phase or 180° out of phase with the reference voltage.

If the input signal is zero (gyro level) the output voltage of the demodulator section (to the tilt indicator) will also be zero. If an input signal is in phase or adding to the a-c reference voltage applied to V304A, it will subtract from the a-c reference voltage applied to V304B. Tube section V304A therefore will conduct more current. The voltage drop across the meter on one half cycle will be greater than that on the next half cycle, and the net d-c output voltage will be proportional to the a-c signal voltage. If the phase of the signal voltage is reversed, the polarity of the d-c output voltage will reverse.

As the voltage gain of the tilt signal amplifier is altered during certain operating modes, operations switch S302E shorts resistor R320 during the low gain periods, thus keeping the tilt meter calibration the same for both high and low amplifier gain.

Zero switch S306 is used to short the input signal to the tilt indicator circuit for calibrating and zeroing the tilt meter.

FOLLOWUP SYSTEM

The followup system functions to drive the phantom bowl in azimuth, so that the vertical ring is continuously aligned with the plane of the gyro. The system is a closed-loop servosystem in which a followup pickoff device between the vertical ring and gyrosphere provides a misalignment signal to a followup amplifier. The followup amplifier amplifies the signal and operates the followup or azimuth motor which drives the phantom, and therefore the vertical ring, into alignment with the gyrosphere. The followup motor driving through the azimuth gearing also positions the synchro heading data transmitter and the speed resolver as indicated in figure 13-7.

The system consists of the followup pickoff, followup motor, followup amplifier, manual azimuth controls and followup alarm.

The followup pickoff consists of an E core followup transformer mounted on a horizontal portion of the vertical ring under the electrolytic bubble level, and a ferramic armature cemented to the gyrosphere, that bridges the E core gap. The followup pickoff is constructed in the same manner and its operation is identical to the followup transformer described in the preceding chapter. The followup transformer primary, on the E core center leg, is excited from the output of excitation transformer T102 the same transformer used to excite the electrolytic bubble level.

The followup motor is mounted on the spider and geared to the azimuth gear on the phantom. It is a 2-phase 4-pole induction motor having a fixed field connected to one phase of the 115-volt 400-cycle supply through a capacitance network which gives a 90-degree phase relationship between the fixed and control field. The direction of rotation depends upon the instantaneous polarity of the signal from the followup amplifier with respect to that of the control field, and the speed of rotation depends upon the magnitude of the signal, or the amount of displacement between the vertical ring and gyrosphere.

The followup amplifier provides the required voltage and power amplification to the followup pickoff signal to operate the followup motor as previously indicated. In addition it provides the required stabilization for the followup system.

The amplifier (fig. 13-11) consists of a half-wave phase sensitive demodulator input stage, V501A and B, employing a feedback loop to rate and displacement networks for system stabilization, a half-wave modulator second stage, V502A and B, and a push-pull output stage, V503 and V504.

The followup pickoff signal is fed to the primary of input transformer T501 and is stepped up by a ratio of 10 to 1. The secondaries feed the stepped up signal to the grids of the twin-triode demodulator tube sections. Each tube receives the same magnitude signal but opposite in phase. Series grid resistors R501 and R502 prevent loading the input transformer and provides tube protection on positive grid excursions. The plates of the demodulator tube are excited with a 400-cycle voltage obtained from the plate reference transformer T502, phased so that the plates of both tubes are positive or negative at the same time. (Note upper and lower plate windings of T502). This voltage is phase-locked with the excitation voltage of the followup pickoff. Thus, the followup signal voltage is either in phase or 180 degrees out

Digitized by Google

7.186

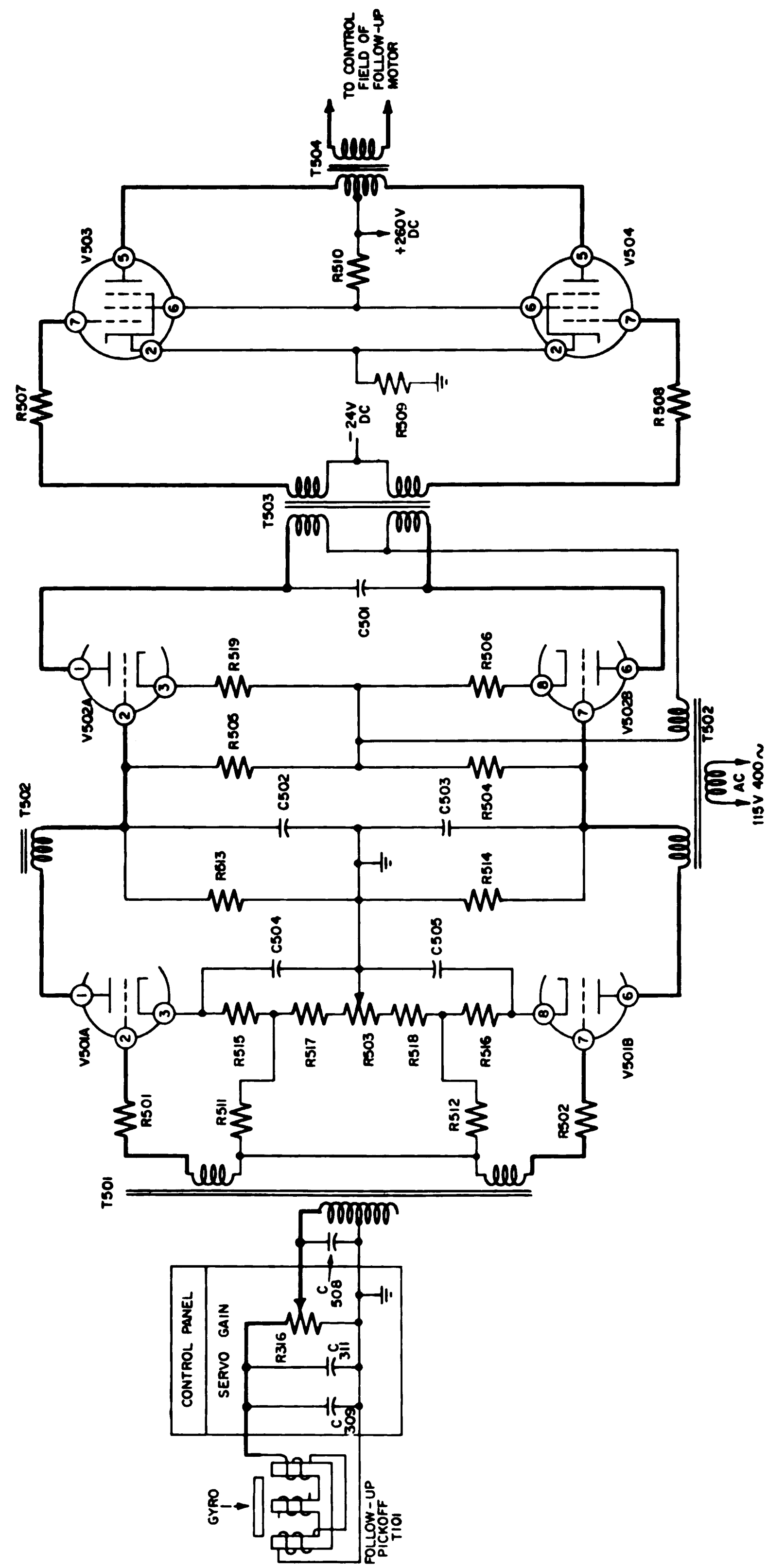


Figure 13-11.—Simplified schematic diagram of followup amplifier.

Digitized by Google

of phase, with the voltage applied to the plates of V501A and B, depending upon the direction of the displacement between the vertical ring and gyrosphere. As current flows through the tube only during the positive plate excursion, the output of each tube section is a half-wave rectified current. A d-c voltage is developed across R504 and R505 proportional to the magnitude of the followup pickoff signal, with its polarity dependent upon the phase of the pickoff signal. Capacitors C502 and C503 serve to suppress the harmonics and smooth the rectified half-wave d-c signal. A negative feedback signal across R519 and R506 in the modulator stage V502A and B, required for the stabilization of the control loop, is generated from this d-c voltage.

A network in the positive feedback loop of V501A and B serves to produce a signal, proportional to the rate of change of the followup pickoff signal, for momentarily increasing the demodulator gain. This network, called a rate circuit, enables a servo to overcome the effect of inertia in the moving parts of the followup system. The effect of the rate signal is to prevent a large momentary displacement between the pickoff and the gyrosphere.

For most effective servo control it is necessary to combine displacement and rate signals. Two circuits combining these signals are used in the demodulator stage. The feedback loop for V501A consists of part of potentiometer R503 resistors R517, R515, and R511, and capacitor C504. The feedback loop for V501B consists of part of potentiometer R503 resistors R518, R516, and R512 and capacitor C505.

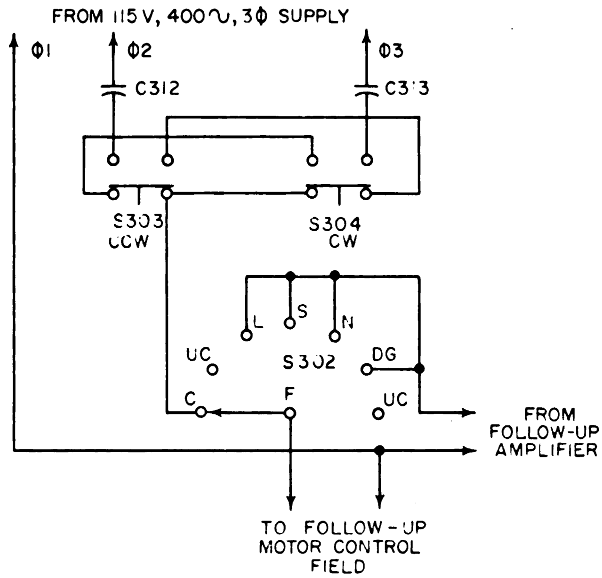
The d-c output voltage of the demodulator stage is applied to the grids of the half-wave modulator tube sections V502A and B. The plates of each half of the tube are connected to opposite ends of the center-tapped primary winding of modulator transformer T503. The center tap of this winding is connected to the 400-cycle reference voltage obtained from one winding of the plate reference transformer T502. As the plates are excited through the center tap of transformer T503, the two sections conduct at the same time during their positive voltage excursions.

If the input voltage is zero, V502A and B conduct the same amount of current. The current from V502A through the primary of T503 is opposite to that from V502B, therefore the secondary output of T503 is zero.

The output voltage of the modulator is applied to the grids of the push-pull power output tubes, V503 and V504. Transformer T504 is the output transformer and matches the plate impedance of V503 and V504 to the tuned impedance of the followup motor.

All plate voltages, the bias voltage for the output stage, and the filament voltages are obtained from the d-c power supply in the control cabinet. Capacitors C309, C311, and C508 serve as phase shift correction for the pickoff signal. Potentiometer R316 at the T501 input is the servo gain adjustment.

A manual azimuth control circuit (fig. 13-12) is provided for slewing the sensitive



27.166

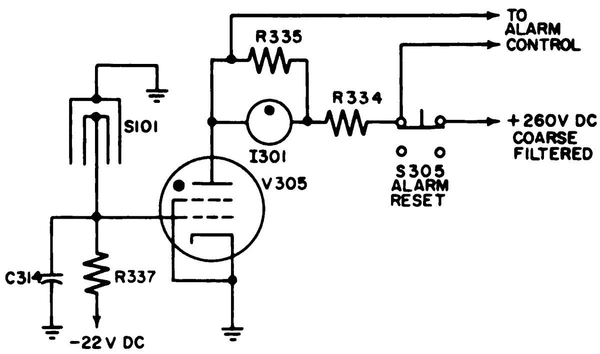
Figure 13-12.—Simplified schematic diagram of manual azimuth control circuit.

element in azimuth to the meridian when starting. This allows the compass to settle on the meridian in a minimum time. The manual azimuth switches S303 and S304 are connected to the followup motor control field when operation switch S302 is in the cage position. The voltage applied to the control field is obtained from the 115-volt 400-cycle 3-phase supply. Capacitors C312 and C313 provide the correct voltage and also the necessary phase shift, with respect to the fixed field, to drive the motor. Switch S303 applies voltage to the control field,

Digitized by Google

phased properly to slew the compass in a counterclockwise direction and switch S304 applies voltage 180 degrees out of phase, to slew in a clockwise direction.

The movement in azimuth of the sensitive element with respect to the phantom is restricted to about ± 8 degrees by mechanical limit stops. To indicate when the phantom reaches this limit, a followup failure alarm circuit (fig. 13-13) is provided. The circuit



27.167
Figure 13-13.—Simplified schematic diagram of followup alarm circuit.

consists of a followup failure switch S101 a thyratron tube, V305 and a neon followup failure indicator light, I301.

The followup failure switch is mounted on the vertical ring and consists of two fine V-shaped wires insulated from each other. An actuator on the equatorial band of the gyrosphere (fig. 13-3) shorts the two wires when the limits of travel are reached.

Thyratron V305 has its grid connected to the negative bias supply through resistor R337. The plate is connected to a positive 260-volt coarse-filtered direct current through the indicator lamp series resistor R334 and normally closed alarm reset contacts. One of the V-shaped wires of S101 is connected to the V305 grid and the other to the d-c common (ground).

Under normal conditions the thyratron is biased so no plate current will flow. When switch S101 is actuated, the grid will be connected to the d-c common, removing the bias, causing the thyratron to fire. The indicator lamp I301 will glow, and the voltage output to the alarm control energizes an alarm relay to actuate the alarm. The thyratron will continue to conduct until the alarm reset button is pushed, removing the plate voltage.

Resistor R335 across the neon failure lamp is used to ensure that the lamp will glow when the thyratron fires.

OPERATION

The operating procedure for the Sperry Mk 23 gyrocompass is summarized on the starting instruction plate (fig. 13-14) located on the front of the control cabinet (fig. 13-1). Normally the compass should be started at least two hours before it is needed for service.

If it becomes necessary to stop the compass in a heavy sea for any reason, other than failure of the followup system, the following procedure should be followed:

1. Place the power switch in the AMPL's position.

2. Wait 30 minutes then place the operation switch in the CAGE position.

3. Place the power switch in the OFF position. In case of followup system failure, place the operation switch in the CAGE position immediately, and the power switch in the OFF position.

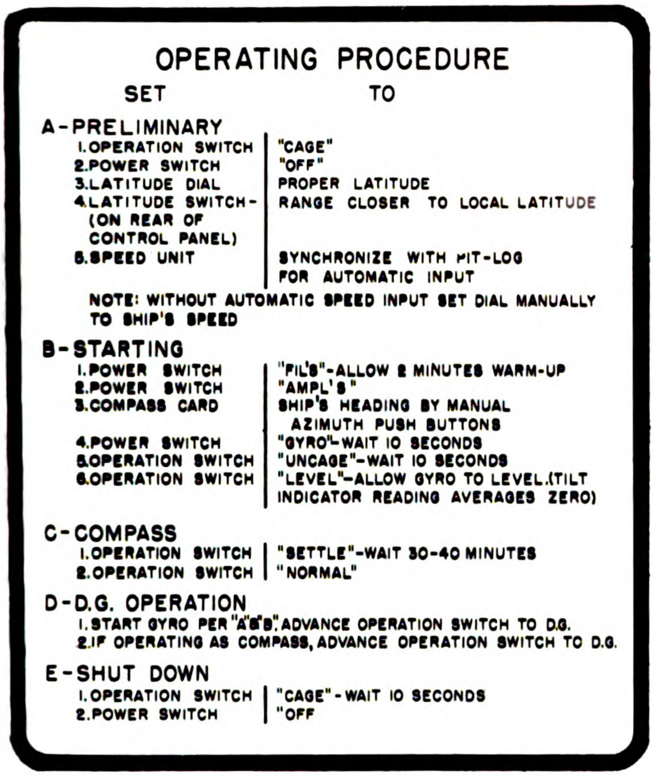
If power to the compass fails, place the power switch in the FIL'S position and the operation switch in the CAGE position. When the power is restored, restart the compass in the usual manner.

Setting Correction Devices

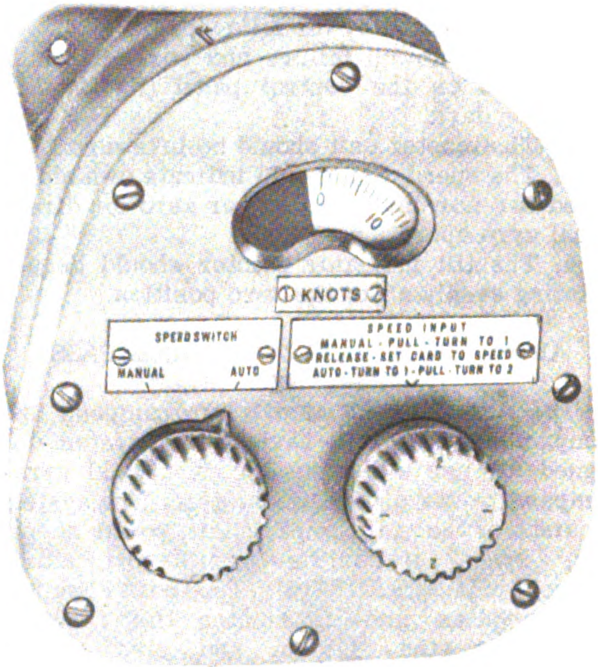
Correction device settings for the Mk 23 gyrocompass include the manual speed setting on the speed unit, the latitude control knob setting on the control panel, and the latitude switch setting on the rear of the control panel.

When operating the speed unit manually, adjust the speed settings to correspond to the average ships speed. Change the latitude control knob setting on the control panel when the ship's latitude changes as much as two degrees or as ordered by the ship's navigator. Throw the latitude switch on the rear of the control panel to the 65 degree position for normal operation when the ship's latitude is above 60 degrees. The position of the latitude switch is immaterial for directional gyro operation.

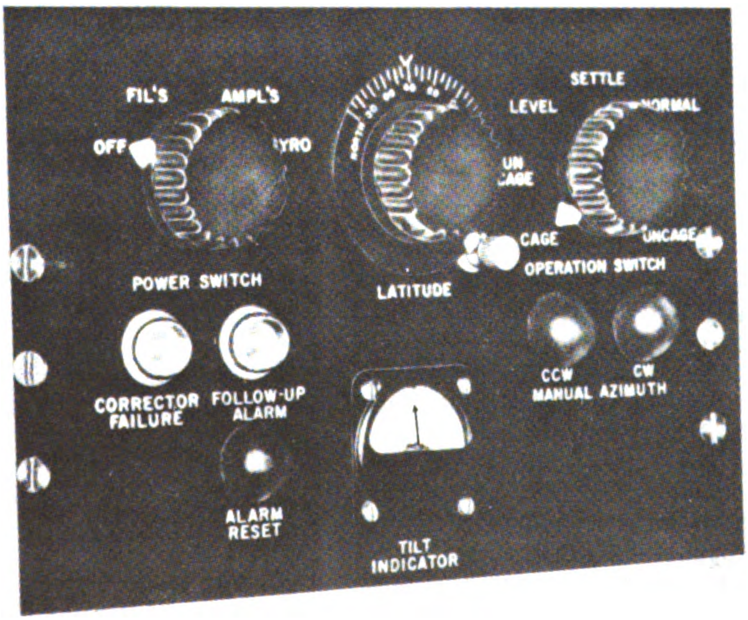
Digitized by Google



STARTING INSTRUCTION PLATE



SPEED UNIT SHOWING CONTROLS



CONTROL PANEL

77.225

Figure 13-14.—Operating procedure and controls, Sperry Mk 23 Mod 0 gyrocompass.

Digitized by Google

Indications of Normal Operation

Normal operating conditions for the compass are indicated by the following:

1. The followup failure and corrector failure lamps on the control panel (fig. 13-14), should be dark.
2. The master unit should be lukewarm.
3. The speed dial should indicate own ship's speed for normal operation or zero for directional gyro operation.
4. The tilt indicator pointer should be oscillating evenly about the zero position.

ARMA MK 26 MOD 2 GYROCOMPASS

The Arma Mk 26 Mod 2 gyrocompass is a compact and accurate navigational system designed for use either as a conventional gyrocompass or as a directional gyro. The system consists of the gyrocompass unit, power supply unit, speed transmitter unit, and alarm control unit (fig. 13-15). The power supply unit supplies and distributes the required power for the system and also serves as the central distribution point through which the system circuits are routed (fig. 13-16).

GYROCOMPASS UNIT

The gyrocompass unit contains the sensitive element assembly, the azimuth and tilt gimbal assembly, the servomotor and gear train assembly, the control box assembly and the mounting base.

Sensitive Element Assembly

The sensitive element assembly (fig. 13-17) is composed of the gyro ball the float tank which supports the gyro ball, the gyro position sensing coils, and the pendulum assembly. The float tank is filled with a high density fluid in which the gyro ball is immersed.

GYRO BALL.—The gyro ball is a hermetically sealed spherical shell that contains the gyro spin motor and two electromagnets. The gyro ball is supported by a floating gimbal that is nested into a deep annular groove around the equator of the ball. Two horizontal torsion wires center the ball within the floating gimbal which is perpendicular to the spin axis of the gyro rotor. The horizontal torsion wires are comparable to frictionless bearings. However, a measurable angular off-set in tilt between the gyro ball and the gimbal twists the torsion wires, and a torque is produced about the horizontal axis of the gyro.

The floating gimbal is centered within the float tank by two vertical torsion wires. A measurable angular off-set between the gimbal and the tank twists these torsion wires, and a torque is produced about the vertical axis of the gyro ball. Power is applied to the gyro ball through the torsion wires, and through four flexible silver wire helical coils, located concentrically about the torsion wires.

FLOAT TANK.—The float tank contains the gyro ball and floating gimbal. The volume between the gyro ball and the tank is filled with a high density fluid which suspends the gyro ball in a state of neutral buoyancy at the normal operating temperature of the fluid. Because of the neutral buoyancy, the torsion wires are not required to transmit any forces to the ball when the tank is subjected to accelerations.

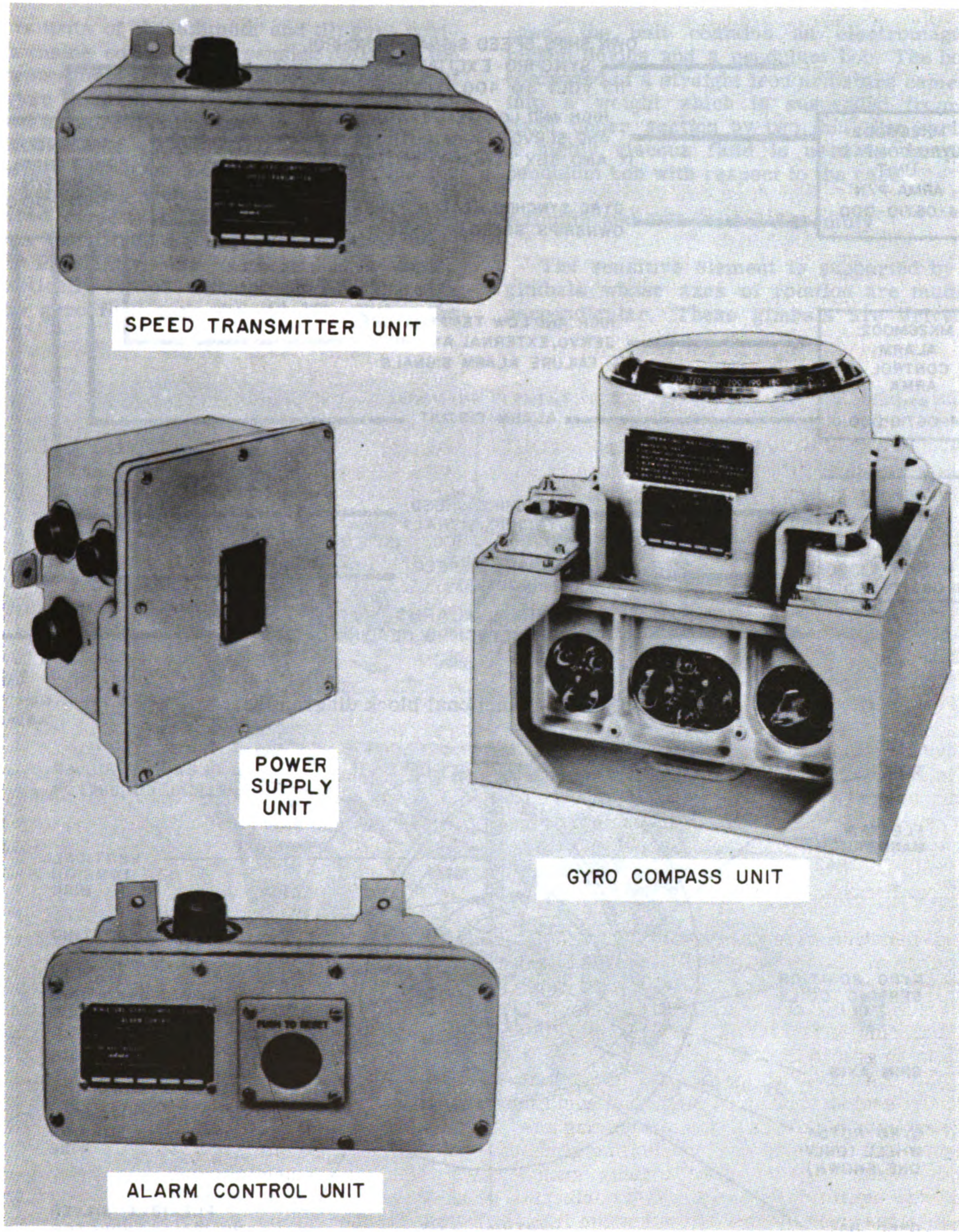
The float tank is trunnioned to the tilt gimbal by means of pivots on an axis normally collinear with the gyro spin axis. The tank is then free to swing about the pivots between plus and minus 60 degrees (stop settings) and is made pendulous so that its average position is true vertical. Viscous damping is introduced between the gyro tank and tilt gimbal to dampen swinging of the tank caused by East-West accelerations.

There are two heaters (not shown) mounted on the tank. These heaters are used to bring the sensitive element up to operating temperature as quickly as possible when the gyro is put into operation.

GYRO POSITION SENSING COILS.—Two sets of coils are mounted in the float tank collinear with the gyro spin axis. These coils are referred to as the azimuth and tilt gyro position sensing coils and are situated opposite the electromagnets inside the gyro ball. The electromagnets supply a magnetic field sensed by the coils. An angular displacement between the gyro spin axis and the tank causes the sensing coils to produce a voltage that is proportional to the displacement.

The interconnection of the two sets of coils allows the voltages induced by any translational displacement to be cancelled out and thereby result in no net output. The motion is translated into a proportional output voltage which is then introduced into the servoloops along

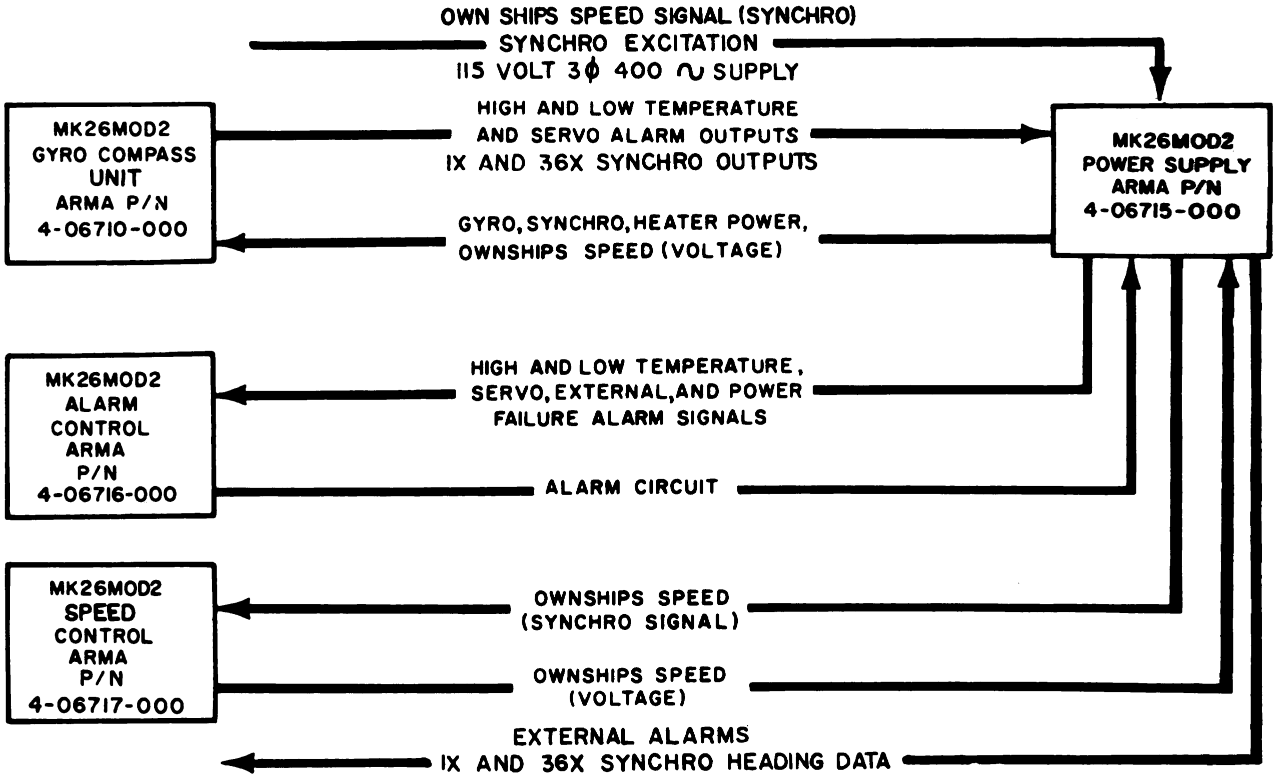
Digitized by Google



140.49

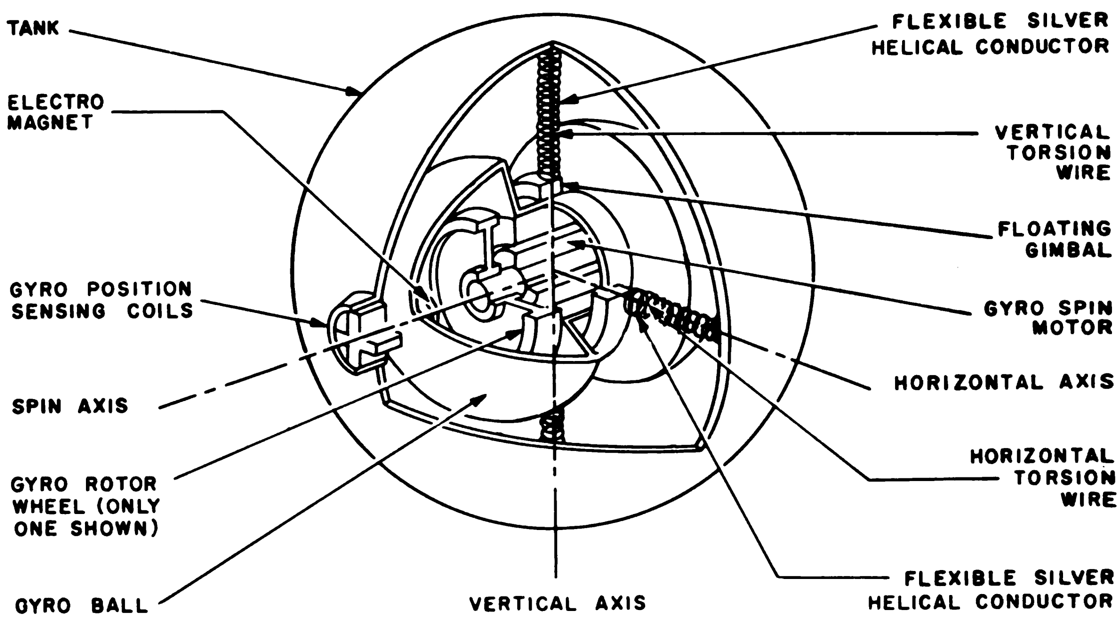
Figure 13-15.—Arma Mk 26 Mod 2 gyrocompass equipment.

Digitized by Google



140.50

Figure 13-16.—Functional block diagram.



140.51

Figure 13-17.—Sensitive element assembly, simplified diagram.

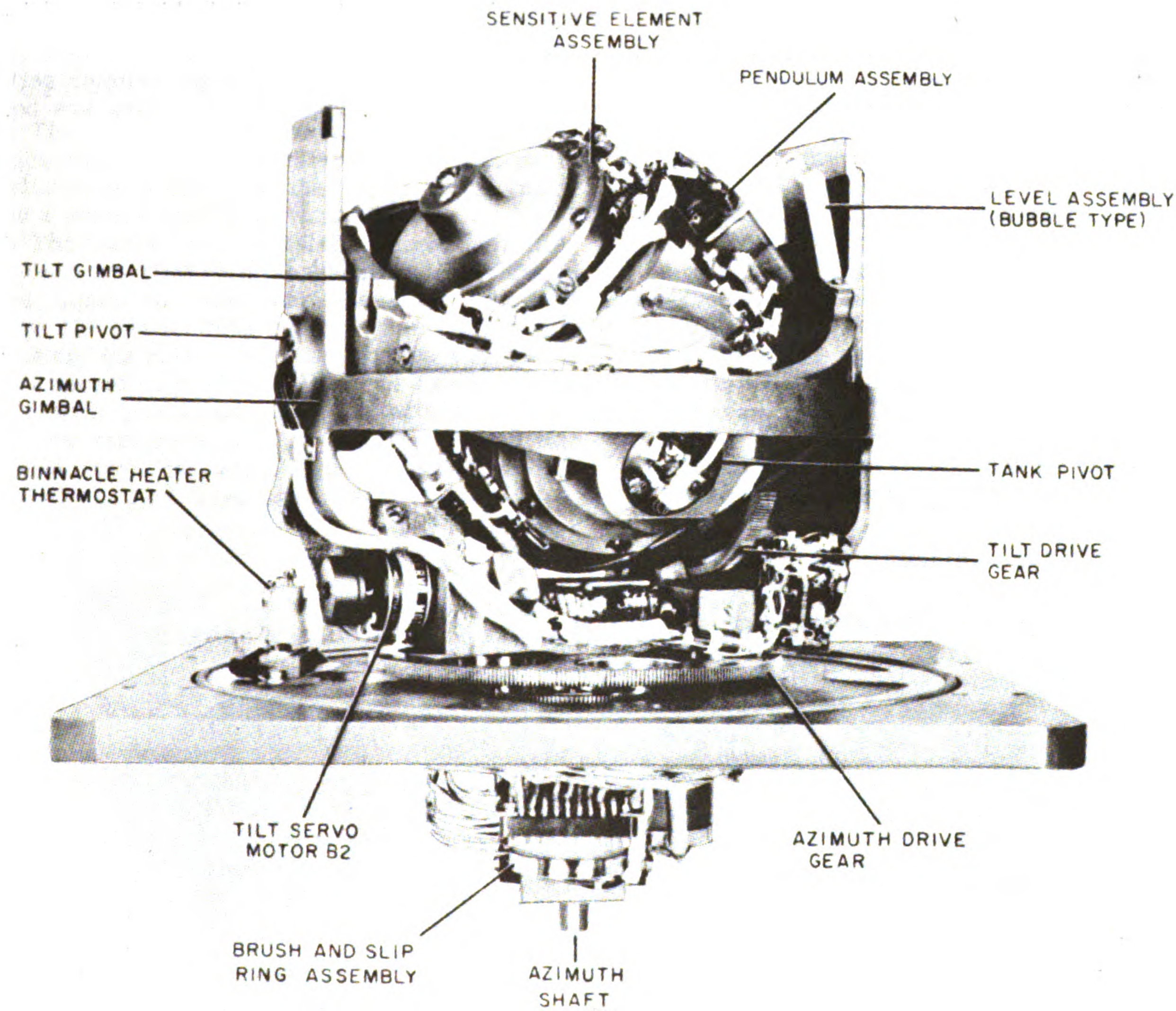
Digitized by Google

with outputs of the azimuth and tilt gyro position sensing coils. These sensing coils and the electromagnets are the major components of the gyro position sensing system, and are discussed in more detail later.

PENDULUM ASSEMBLY.—The pendulum assembly provides the vertical reference for the sensitive element. The pendulum is mounted directly on the gyro float tank and senses the tilt of the tank about its East-West axis. Physically, the pendulum is a small, hermetically-sealed unit mounted on the side of the gyro float tank (fig. 13-18). Within the case, the unit contains an electromagnetic pickup device and a pendulum bob. The bob is composed of a straight iron armature cemented into a weight which is suspended from the fixed upper section by two thin, flat springs. A highly viscous fluid is used to damp the pendulum bob with respect to the case.

Azimuth and Tilt Gimbal Assembly

The sensitive element is supported by two gimbals whose axes of rotation are mutually perpendicular. These gimbals are driven in



140.52

Figure 13-18.—Azimuth and tilt gimbal assembly with gyro ball.

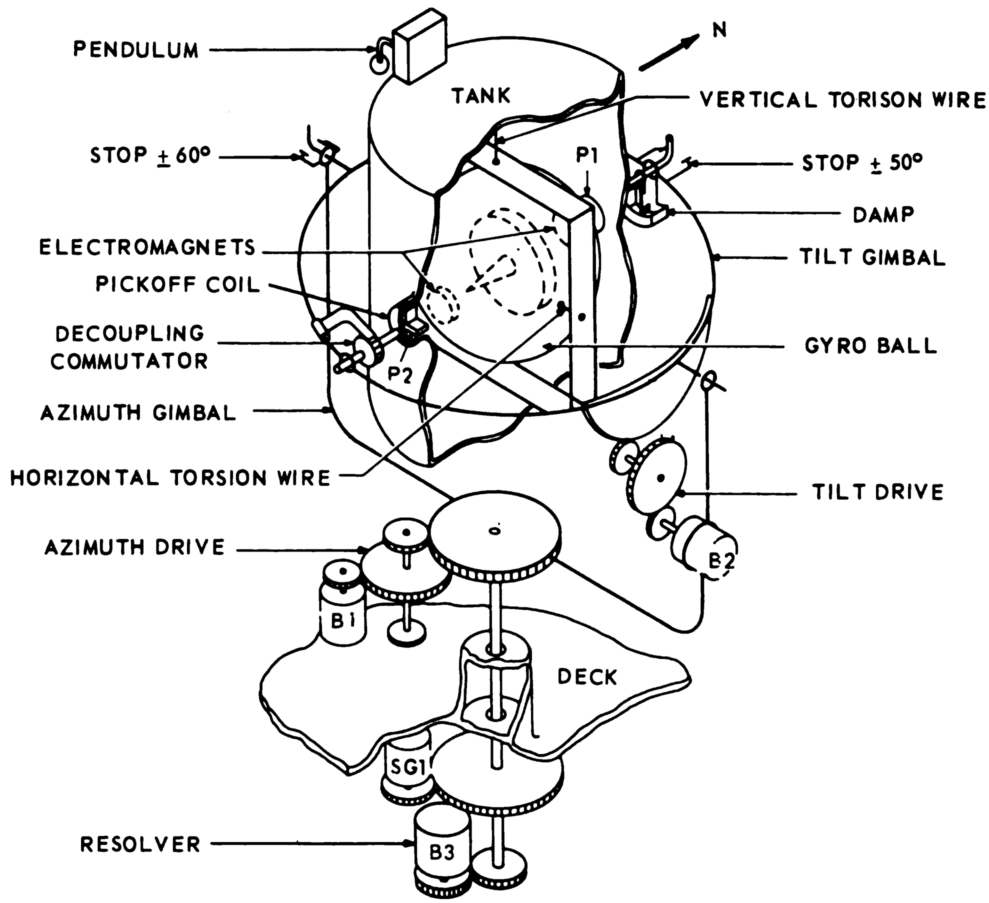
Digitized by Google

azimuth and in tilt by their respective servo drive assemblies. The tilt gimbal supports the sensitive element by free swinging pivots. The tilt gimbal is in turn supported along its nominally East-West axis by the tilt pivot on the azimuth gimbal. Stops are provided to prevent the tilt gimbal from rotation through an angle of more than ±60 degrees with respect to the azimuth gimbal. The tilt gimbal is mechanically linked to the azimuth gimbal by the tilt drive servo gear train. Tilt servo motor B2 (fig. 13-18), is mounted on the azimuth gimbal and is able to rotate the tilt gimbal with respect to the azimuth gimbal through its gear train.

The Azimuth Gimbal rotates about a vertical axis. Its bearings are supported by the gyro compass chassis; which is in turn fixed with respect to the ship. All electrical connections between the components within the azimuth gimbal and the control box are made by a slip ring assembly mounted on the azimuth gimbal shaft, underneath the compass chassis. Mounted on the azimuth gimbal is the azimuth indicator dial. Heading reference is obtained from the gyro compass by a direct reading of this dial with respect to the index mounted on the binnacle heater support. The azimuth gimbal is driven about its vertical axis by the azimuth servo motor and gear train (fig. 13-19).

Synchro Transmitters

To provide heading information to locations remote from the compass, single-speed and 36-speed synchro transmitters are used. There are two synchro transmitters SG1 and SG2 (fig. 13-19), mounted on the azimuth servo drive assembly. These transmitters are both



140.53

Figure 13-19.—Gyrocompass gear diagram.

Digitized by Google

geared to the azimuth gimbal and convert mechanical heading information received from the azimuth gimbal into electrical information. The output of these transmitters is applied to the remotely located repeaters which indicate the heading.

Binnacle Heater

Surroundig the azimuth gimbal, but not attached to it, is the binnacle heater assembly. After the sensitive element has been brought to its normal operating temperature by the heaters mounted on the tank, the binnacle heater maintains this proper temperature. This is accomplished by thermostatically controlling the average temperature of the air within the binnacle. The thermostat is shown in figure 13-18.

Control Box Assembly

The control box assembly, contains the transistor servo amplifiers, all front-panel switches and controls, the Servo Alarm relay, and a printed circuit terminal board.

The same type transistor servo amplifier is used for both azimuth and tilt servo motors. The inputs to these amplifiers are obtained from the pendulum assembly, the gyro position sensing circuitry, and the various correction bias circuits. Each amplifier is a plug-in type unit with provision made for externally connecting resistors into the amplifier circuit for convenience in adjusting the gain of the amplifier.

The printed circuit terminal board contains the power supply circuitry for the transistor servo amplifiers. The Servo Alarm Control Relay senses malfunctioning of the servo system of the Gyro Compass Unit and operates a circuit in the Alarm Control Unit.

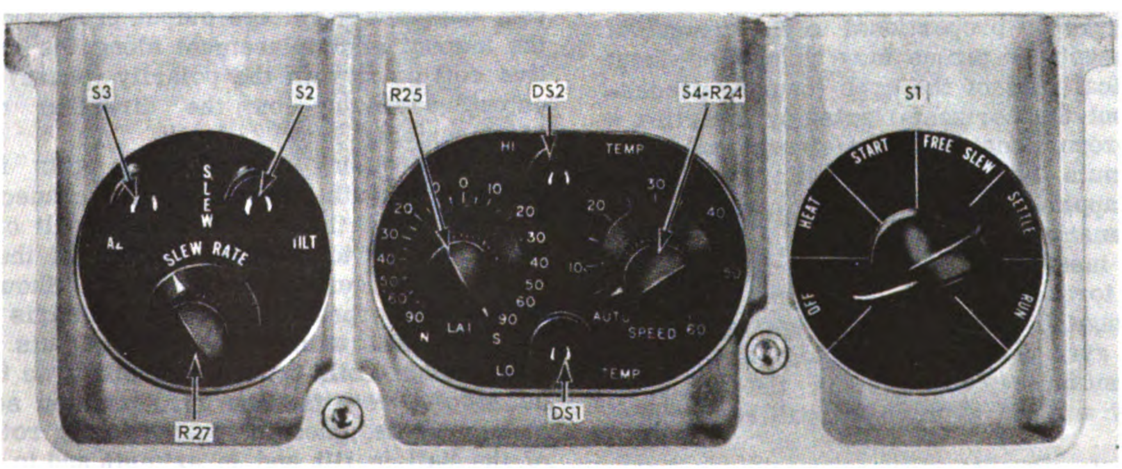
FRONT PANEL CONTROLS.—The front panel controls and indicators (fig. 13-20) consists of the rotary control switch S1, the tilt and azimuth pushbutton switches S2 and S3, the rotary speed control switch S4 and R24, the rotary latitude control R25, the slew rate control R27, and the low and high temperature indicator lamps DS1 and DS2. The operation of these controls is discussed later in this chapter.

POWER SUPPLY UNIT

The power supply unit contains two isolation step-down transformers which convert 115 volt ships power into 24 volts for the compass spin motor and heater circuits. Also included in the power supply is a high temperature protection relay which disables compass heater power in the event of a malfunction which may cause overheating of the compass. A relay is also provided which disconnects the transformers from the ships supply when the Gyro Compass Control Switch is in the OFF position.

SPEED TRANSMITTER UNIT

The speed transmitter unit receives a synchro signal representing the ship's speed and



140.54

Figure 13-20.—Front panel controls.

Digitized by Google

converts it into a proportional voltage which is fed to the speed correction circuits. The unit consists of a synchro receiver mechanically coupled to a low friction potentiometer. The potentiometer is excited by 24 VAC from the power supply. The synchro receiver is positioned by signals from the underwater log. The output of the potentiometer, which is a voltage proportional to ship's speed, is fed to a resolver in the gyrocompass unit. The output from the resolver supplies the speed correction signal as discussed later.

ALARM CONTROL UNIT

The alarm control unit receives 24 volt 400 cycle failure indication signals from the gyrocompass unit. These signals are rectified by diode bridges and energize 24 VAC failure relays. The relay contacts are in series forming a normally closed circuit wired for external alarms.

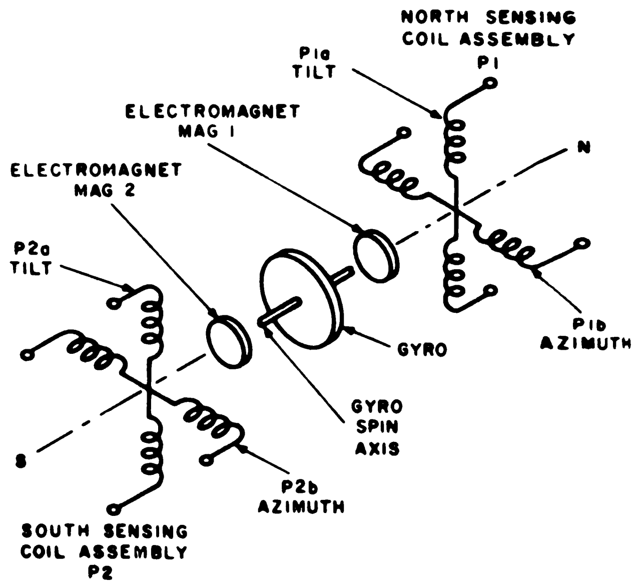
The alarm control unit provides an indication of the following; compass servosystem failure; main power failure; external synchro amplifier system failure; high temperature; and low temperature.

FUNCTIONAL OPERATION

The torques to cause the necessary precession of the gyro and make it north indicating are applied to the vertical and horizontal axes of the gyro via the vertical and horizontal torsion wires. A displacement between the gyro spin axis and the tank twists the torsion wires centering the gyro within the tank. The torque on the gyro is proportional to the amount of displacement. A torque may be applied about the vertical axis of the gyro (causing precession about the horizontal axis) by inserting a signal proportional to the desired torque into the azimuth servo loop. Similarly a torque may be applied about the horizontal axis of the gyro (causing precession about the vertical axis) by inserting a signal proportional to the desired torque into the tilt servo loop. The proper angular displacement between the tank and the gyro spin axis is maintained by the gyro position sensing system, the pendulum assembly and the azimuth and tilt servoloops.

Gyro Position Sensing System

The electromagnets and pickoff coils (fig. 13-21), constitute the components of the gyro position sensing system. Electromagnets MAG1 and MAG2 are mounted in the gyro ball, collinear with the gyro spin axis. These magnets induce voltages in sensing coils P1 and P2 which are mounted on the north-south axis of the figure-eight coils with mutually perpendicular axes. When the electromagnet on the gyro ball is directly opposite the center of the pickoff coil assembly, the output of both coils is zero. When the electromagnet is displaced from the center of the coil assembly, each coil develops a voltage output proportional to the amount of displacement along the respective coil axis, with the polarity (phase) of the output depending on the direction of the displacement.



140.55

Figure 13-21.—Gyro position sensing system.

Corresponding figure-eight coils in the north and south assemblies are connected in series. When the ball rotates in tilt or azimuth relative to the tank, outputs of the corresponding figure-eight coils add. Should the ball move perpendicular to its spin axis inside the tank, but without rotating, outputs of the figure-eight coils oppose each other, so that no net output results. The gyro position sensing system is designed to measure only rotations of the ball in tilt and in azimuth and to be insensitive to ball translations. The outputs of the position-sensing system are applied to the azimuth and tilt servoloops.

Digitized by Google

If the gyro is displaced from the axis of its ank by a small angle (fig. 13-22), the electro- aagnets on the gyro ball are no longer cen- ered with respect to the tilt position sensing oils, and a tilt signal voltage will be pro- uced. This signal voltage is proportional to ie amount of tilt and of a polarity depending pon the direction of the tilt.

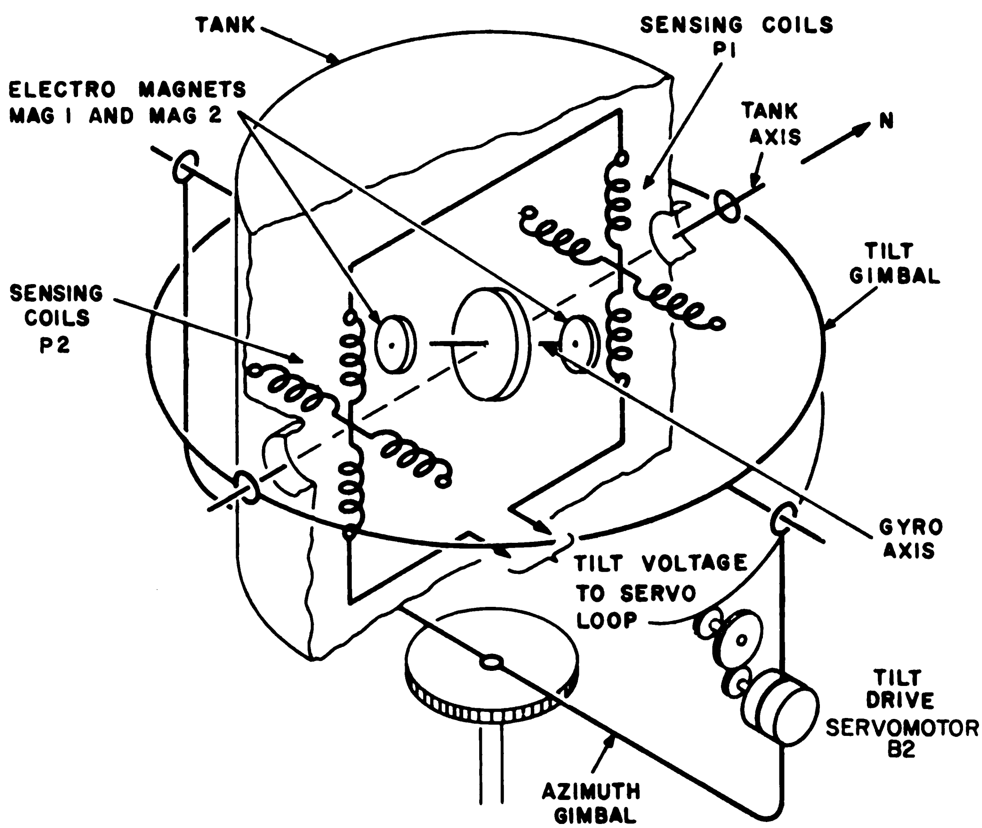
The sensing coil output voltage is amplified nd applied to the tilt servo motor. If there re no other inputs to the tilt servo, the tilt imbal will be driven so as to align the tank rith the axis of the sensitive element. As the isplacement becomes less and less due to the aotion of the tilt gimbal the output of the ver- ical sensing coils is reduced accordingly. Vhen the tank is aligned with the axis of the ensitive element, the output of the sensing oils will be zero, and the tilt servo motor rill stop.

Similarly if the sensitive element is dis- laced in azimuth with respect to the axis of the tank, the output of the azimuth sensing coils will be applied to the azimuth servo. The azimuth servo drives the azimuth gimbal until the azimuth displacement is eliminated. The circuit is designed so that the slightest displacement between the ball and the tank can be instantaneously eliminated.

Pendulum Assembly

The pendulum assembly is mounted on the gyro float tank and senses tank tilt as started previously. Electrically the assembly operates similar to the followup transformer discussed in chapter 12 of this training course.

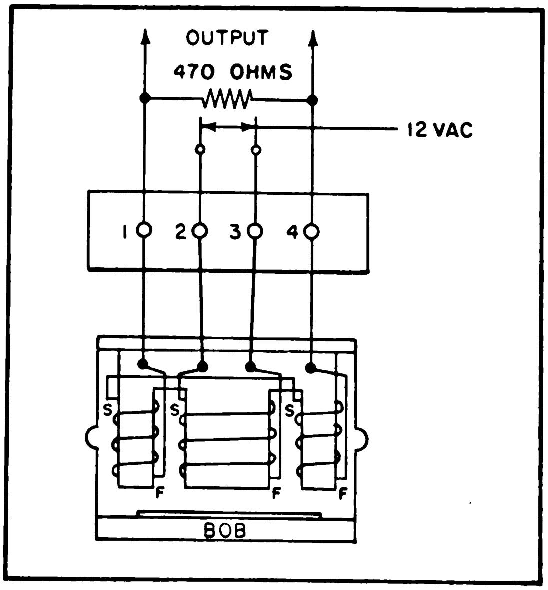
With no tank tilt the pendulum bob is centered (fig. 13-23), and the voltages induced in the two secondaries are equal in amplitude but differ in phase by 180°, resulting in no voltage output across terminals 1 and 4. When the tank tilts the bob moves to the right or left, depending upon the direction of tilt, unequal fluxes pass through the secondaries and the



140.56

Figure 13-22.—Gyro during vertical displacement.

Digitized by Google



140.57
Figure 13-23.—Schematic diagram of pendulum assembly.

two voltages become unbalanced. The resultant voltage output across terminals 1 and 4 will be the vector sum of the two voltages, and the phase of the output voltage will be the same as the phase of the voltage of the greatest amplitude. The output of the pendulum assembly is applied in the azimuth and tilt servoloops, discussed below.

AZIMUTH AND TILT SERVOLOOPS

The azimuth servoloop (fig. 13-24), is a closed loop followup system in azimuth between the azimuth gimbal and the float tank, and thus controls the azimuth orientation of the float tank. The signal inputs to the loop are; the output from the azimuth gyro position sensing coils; a portion of the signal output from the pendulum assembly; and the output of the speed correction circuit.

The tilt servoloop is a closed loop followup system in tilt between the gyro spin axis and the float tank, and controls the tilt orientation of the float tank. The signal inputs to the loop are; the output from the tilt gyro position sensing coils; a portion of the signal output from the pendulum assembly; the output of the latitude correction circuit; and the output of the tilt bias potentiometer.

Pendulum Assembly Signal Inputs

The signal output from the pendulum assembly is added into the servoloops (depending upon the mode of operation) by the contacts of control switch S1 (fig. 13-24). A portion of the signal output from the assembly is added into the tilt servoloop to make the compass north-seeking. This output is connected into the tilt servoloop so that when the north end of the spin axis rises relative to the horizontal, the north end is made to precess to the west. When the north end dips, precession is to the east. Thus the spin axis is made to precess toward the meridian. A portion of the signal output from the pendulum assembly is added into the azimuth servoloop as a damping signal, causing the compass to settle on the meridian.

When switch S1 (fig. 13-24), is set to the SETTLE position, the pendulum output is introduced in both the azimuth and tilt servo loops through 274 ohm and 562 ohm resistor R33 and R9. These resistors provide heavy coupling of the pendulum signal into the servo loops because of their low value. In addition external gain resistor R36 is paralleled with a resistor in the azimuth servo amplifier emitter circuit (not shown) to increase the amplifier gain.

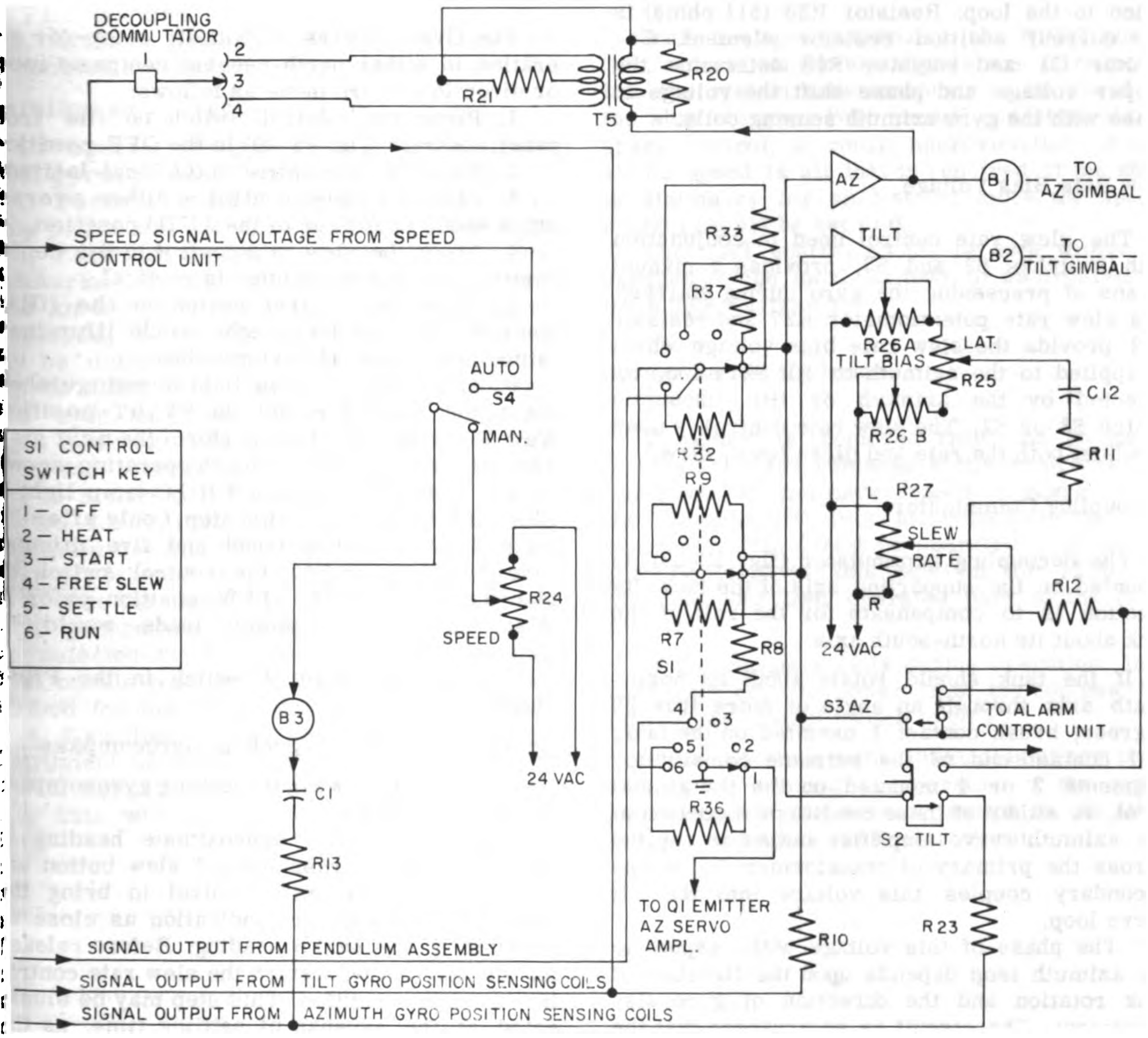
When switch S1 is set to the RUN position, the pendulum output voltage is introduced equally in both servo loops through 3.32K resistors, R32 and R7. When switch S1 is set to the FREE SLEW mode, no pendulum output is introduced into the tilt servo loop, however the pendulum output is introduced into the azimuth servo loop through a 1.6K resistor R37.

Other sections of control switch S1 (not shown) control the 24 volt heater supply, the 24 volt supply to the interlock relay which prevents the alarms from operating during the heating cycle, and the 24 volts, 3-phase supply to the gyro motor.

Latitude Correction and Tilt Bias Signals

Potentiometers R25, R26A, and R26B provide an interrelated resistance network for supplying a latitude correction voltage proportional to the vertical component of the earths rotation (vertical earth rate) and a tilt bias voltage. This correction is applied to the tilt servo loop and is added in shunt addition to this loop. Resistor R10 (511 ohms) is the current addition resistor element. Capacitor C2

Digitized by Google



140.58

Figure 13-24.—Simplified schematic diagram of azimuth and tilt servoloops.

nd resistor R11 determine the proper correction voltage and also phase shift the voltage n phase with the gyro tilt sensing coils. Potentiometer R25 is manually set to the local atitude and provides a bias voltage for the ilt servoloop that compensates for vertical arth rate. Ganged potentiometers R26A and R26B provide additional control of the tilt servo bias which is used to counteract any ixed North-South gyro unbalance of the sensitive element.

Speed Correction Signal

During Manual Speed operation, the output of Potentiometer R24 which is adjusted to ship speed is supplied to the rotor of Resolver B3 which is mechanical geared to the azimuth shaft of the compass. The output of B3 represents the North-South component of ships speed. During Auto Speed operation the output of the Speed Transmitter Unit is supplied to Resolver B3. The resolver output is applied to

Digitized by Google

the azimuth servoloop and is added in shunt addition to the loop. Resistor R23 (511 ohms) is the current addition resistor element. Capacitor C1 and register R13 determine the proper voltage and phase shift the voltage in phase with the gyro azimuth sensing coils.

Slew Rate Bias Voltage

The slew rate control used in conjunction with switches S2 and S3, provides a manual means of precessing the gyro during starting. The slew rate potentiometer R27 and resistor R12 provide the slew rate bias voltage which is applied to the azimuth or tilt servoloop as selected by the azimuth or tilt pushbutton switch S3 or S2. The slew rate control is used to adjust both the rate and direction of slew.

Decoupling Commutator

The decoupling commutator (fig. 13-24), is mounted on the supporting axis of the tank. Its function is to compensate for the roll of the tank about its north-south axis.

If the tank should rotate about its north-south axis through an angle of more than 25 degrees, brush contact 1 mounted on the tank, will contact one of the extreme commutator segments 2 or 4 mounted on the tilt gimbal pivot. In either of these conditions a portion of the azimuth servo amplifier output is applied across the primary of transformer T5, whose secondary couples this voltage into the tilt servo loop.

The phase of this voltage with respect to the azimuth loop depends upon the direction of tank rotation and the direction of gyro displacement. The circuit is so arranged that the coupling between the azimuth and tilt servo loops through the commutator compensates for sensing distortion due to tank roll.

OPERATION

The Arma Mk 26 Mod 2 gyrocompass may be used as a north-seeking gyrocompass or as a directional gyro as mentioned previously. The directional gyro mode of operation is especially useful at latitudes greater than 80 degrees. The operating procedures for the compass in both the north-seeking and directional modes are presented below.

Initial Setup

The Gyrocompass is initially setup for operation in either north-seeking compass mode or directional gyro mode as follows:

1. Place the Control Switch on the front panel controls (fig. 13-20) in the OFF position.
2. Place the lat control to the local latitude.
3. Place the speed control to either average ships speed (knots) or to the AUTO position.
4. Place the slew rate control to the center position, so that the pointer is vertical.
5. Place the control switch in the HEAT position. The LO temp light should illuminate immediately upon switching to heat.
6. After the LO temp light is extinguished, place the control switch in START position. Wait 5 minutes and then perform the next step. This allows the gyro to reach operating speed. Do not proceed with step 7 if LO temp light is illuminated. Proceed with step 7 only after LO temp light is extinguished and five minutes have elapsed. Should the control switch be placed in the FREE SLEW position prior to this, the flexible power leads would be damaged.
7. Place the control switch in the FREE SLEW position.

Operation as a North-Seeking Gyrocompass

To operate as a north-seeking gyrocompass proceed as follows:

1. Determine the approximate heading of the ship then depress the AZ slew button and operate the slew rate control to bring the compass azimuth card indication as close as possible to the ship's heading. Before releasing the AZ button, return the slew rate control to its center position. This step may be eliminated at the expense of settling time, as the compass will eventually settle on the meridian. For minimum settling time however, obtain as accurate a heading as possible and slew the compass to this heading.
2. Depress the tilt slew button and operate the slew rate control to level the tank. The level position is established by slowly centering the bubble in the liquid level mounted on the top of the tilt gimbal (fig. 13-18). Before releasing the tilt button re-center the slew rate control.
3. Check the level bubble position 2 minutes after performing step 2. Re-slewing may be necessary due to the time lag in the pendulum circuit.

Digitized by Google

4. Operate the control switch to the SETTLE position.
5. After a period of 40 minutes, operate the control switch to the RUN position.

Operation as a Directional Gyro

To operate the gyrocompass as a directional gyro, proceed as follows:
1. Perform steps 1 through 4 of the initial setup procedure with the speed control set at 0.
2. Establish the heading of the ship by using landmarks or celestial observations. Determine an appropriate heading for the compass. If desired, a compass heading other than north may be used—for example, if a grid coordinate map is used. The maximum deviation of the gyro spin axis from true north (amount by which operator sets gyro spin axis from true north) for satisfactory directional gyro operation is a function of latitude. (Deviation is unlimited for latitudes above 63 degrees.) The maximum deviations are listed in the Manufacturer's Technical Manual.
3. Use the slew rate control, and AZ and TILT pushbuttons to precess the compass to the selected heading and level it. Check the level bubble position every two minutes as described for the North-seeking operation mode.
4. Establish check points to correct the instrument according to the accuracy required. Due to azimuth drift, the direction of the gyro spin axis will change slowly as a function of time.

Speed and Latitude Settings

With the speed control in the AUTO position, speed correction signals are introduced into the system instantaneously as the speed of the ship changes. With manual operation of the speed control, a rough approximation of the ship's speed is all that is required. If the ship is stationary for an hour or more the speed control should be set to 0.

The LAT control should be kept within 10 degrees of the local latitude, or as ordered by the ship's Navigator.

Emergency Precautions

If power is removed from the compass momentarily the compass settle point may be disturbed. If you have reason to suspect that the compass indication has been disturbed, the control switch should be operated to the settle position, left in this position for 15 to 25 minutes, and then operated back to the RUN position.

If the compass fails during operation, immediately remove power from the compass by turning the control switch to OFF.

If the HI temp light illuminates at any time during the starting or operation of the compass, operate the control switch to the OFF position and check the heater circuit.

Digitized by Google

CHAPTER 14

THE MAGNESYN COMPASS

The IC Electrician is required to service and perform preventive maintenance on a variety of shipboard IC components, one of which is the Magnesyn compass. Although the gyrocompass is standard equipment on all naval vessels, it is supplemented by the magnetic compass. A special type of magnetic compass (described in this chapter) called the remote indicating Magnesyn compass system is used on many naval vessels, principally those with steering control consoles, and on older type landing craft.

COMPONENTS

The Magnesyn compass system comprises a compass transmitter mounted in a position as free as possible from magnetic distrubances, and one or more indicators (fig. 14-1) which reproduce movements of the compass magnet in the transmitter. The indicators are installed in a location convenient to the helmsman, and sometimes in the secondary conning station.

Magnetic materials near the indicator will not affect the accuracy of the Magnesyn compass system. Such disturbances must be avoided only in the neighborhood of the transmitter.

An inverter for changing d-c from batteries to 400-cps a-c for operation of the system is mounted in a waterproof box which may serve as a junction box for all connecting cables. A 120/26-volt 400-cycle stepdown transformer provides the normal power supply for the system on ships other than landing craft. A selenium rectifier is furnished for charging the battery. The input to the rectifier is 117-volt 60-cycle single-phase power and the output of the rectifier is 12-volt d-c power at 2 amperes.

The transmission of the magnetic indications of the compass to the indicator is entirely electrical. The only moving parts in the system are in the inverter, the compass float assembly, and the indicator rotor.

THEORY OF OPERATION

In order to understand the principle of operation of the Magnesyn compass we will review briefly the characteristics of a magnet, the magnetic properties of the earth, and the problems involved with the conventional magnetic compass.

A magnet has magnetic lines of force which surround it, extending outward from the north pole and entering at the south pole to form closed loops. These lines of force are associated with the familiar attraction of unlike poles and the repulsion of like poles (refer to Basic Electricity NavPers 10086A). When no other magnetic material is near, the lines of force form a symmetrical pattern around the magnet. When a piece of soft iron is placed near the magnet, most of the lines of force will pass through the piece of soft iron because soft iron is a good conductor of magnetic lines of force and offers lower reluctance than that of air.

The earth is in reality a huge magnet with its "north" pole situated in the Arctic Circle and its "south" pole within the Antarctic Circle. Magnetic lines of flux extend from the region of the "south" magnetic pole and enter the region of the "north" magnetic pole. A compass needle tends to align itself with the earth's magnetic field so that the magnetic lines of flux enter the south pole of the compass needle and extend outward from the north pole. Thus the north pole of the compass needle points toward the "north" magnetic pole except when the earth's field is distorted, for example, by the magnetic materials of a ship. (The so-called "north" magnetic pole is really a south pole because the lines of force of the earth's field enter it.)

The error to which a ship's magnetic compass is subjected due to the influence of the ship's magnetism is called deviation error. Deviation error is caused by the magnetism of the steel

Digitized by Google

7.161
Figure 14-1.—Magnesyn compass indicator.

nd soft iron parts of the ship and by electrical onductors carrying direct current. Also, the oft iron parts of a ship readily acquire tranient magnetism by magnetic induction from the arth's field. The magnetism thus induced in oft iron varies as the ship changes course. The ompass deviation error may change as the ship hanges course.

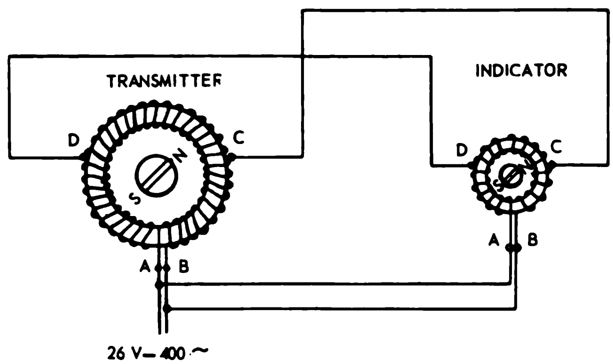
The locations at which compass readings are nost needed are very often in close proximity to he greatest magnetic disturbances. Because of he remote indicating feature of the magnesyn ystem the transmitting unit can be mounted in position in the ship where it will be least ffected by the magnetic field of the ship itself, nd therefore will be free to a very great extent rom the effect of deviation. This feature is articularly advantageous where the magnetic ield of the ship tends to shift from time to time s a result of changes in position or from the ise of armament. The indicator on the other and, may be placed anywhere without regard to he ship's magnetic field.

PRINCIPLE OF ELECTROMAGNETIC NDUCTION

This compass system operates on the prin-iple of electromagnetic induction whereby an lectrical voltage is induced in an electrical onductor when it is cut by magnetic lines of flux (fig. 14-2). In this system the cores of the transmitter and indicator are saturated twice each cycle when excitation reaches a peak value. At such times, no additional magnetic effects can be produced within the cores. At other times, the cores are free to assume such magnetic characteristics as may be imposed on them. The magnetic field produced by the compass magnet will pass through the core of the transmitter coil when the value of the exciting current falls toward zero. It will be prevented from passing through the core when the core is saturated.

The result of the above action is the induction of a magnetic flux in the core of the transmitter coil between points opposite the poles of the compass magnet. This flux rises and falls and is superimposed on the flux produced by the exciting current. The ebb and flow of this magnetic flux sets up, at the four take-off points, alternating voltages the values of which are dependent on the position of the compass magnet with respect to the transmitter coil. Since the four points of the transmitter coil are directly connected to four similar points of the indicator coil, any potential difference between connected points causes a current flow in the indicator coil so as to equalize the voltages between the two coils. This current flow through the windings of the indicator is superimposed on and independent of the flow of the indicator excitation current.

The secondary currents produce their own magnetic effects within the core of the indicator, and since the indicator rotor magnet is shielded from the earth's magnetic field and free to



7.162
Figure 14-2.—Principle of electromagnetic induction.

Digitized by Google

revolve, it follows the rotation of the transmitter magnet.

Any change in the position of the compass magnet in the transmitter, caused by change of heading of the ship, produces a change in the characteristics of both the transmitter and indicator coils, and a corresponding change in position of the rotor magnet of the indicator. Since the indicator pointer is attached to the shaft on which the rotor magnet is mounted, it provides at all times an accurate indication of the position of the compass magnet in the transmitter.

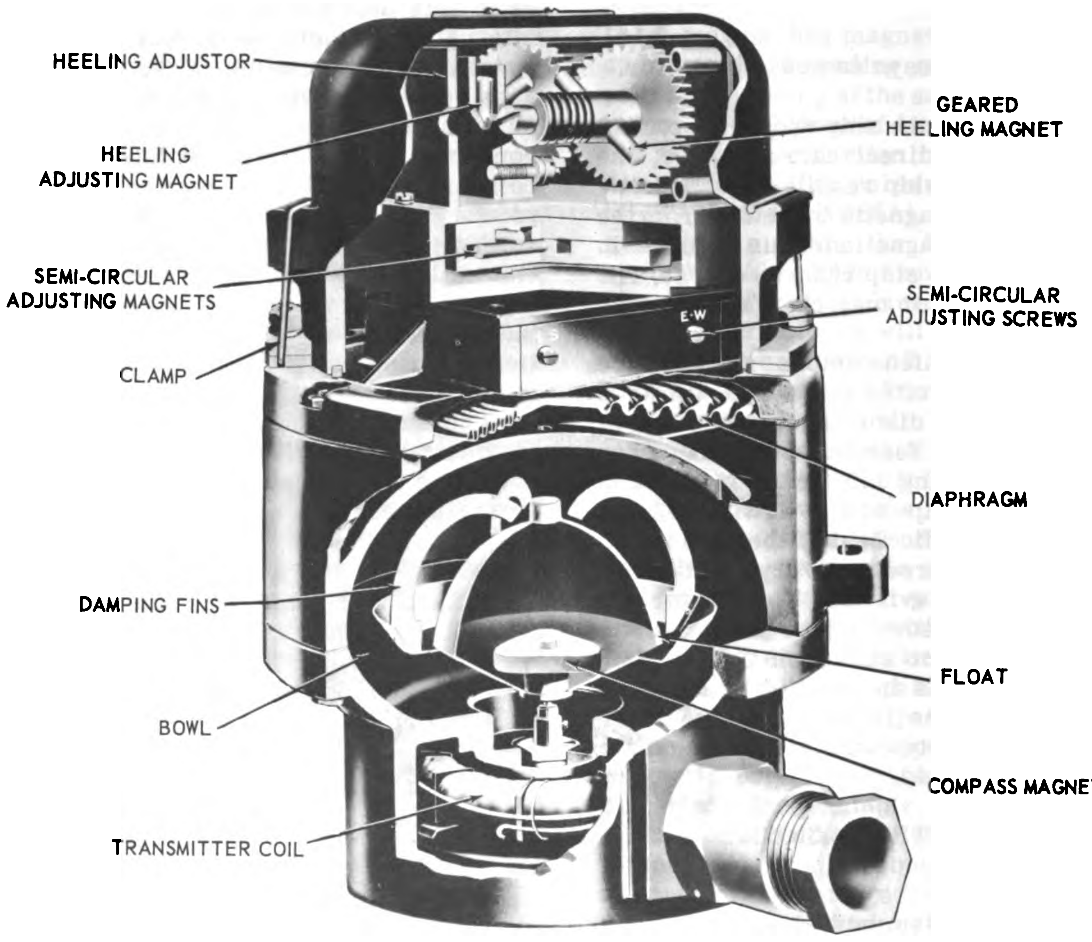
DESCRIPTION OF COMPONENTS

TRANSMITTER

The transmitter consists of a float assembly, a transmitter coil, and a compensator assembly.

The transmitter float assembly (fig. 14-3) is immersed in compass fluid (Varsol) in a smooth-surfaced bowl. The bowl is spherical in shape (fig. 14-3) so that the compass float will, so far as possible, be free of swirl errors, and so that liquid drag will be reduced. To provide for the expansion and contraction of the compass fluid, a diaphragm is incorporated in the bowl. The float is equipped with four damping fins and is pivoted on a single shock mounted jewel, spun in a jewel post. The float contains the directive or compass magnet. The float is free to rotate and to tilt at any angle up to 20 degrees from the horizontal.

The transmitter coil (or flux gate) is mounted directly beneath the compass magnet in the float



7.163

Figure 14-3.—Magnesyn compass transmitter.

Digitized by Google

assembly. It consists of high permeability, circular laminations (similar to permalloy) around which is a toroidal winding. Four leads go to the coil. Two of these go to the power supply. The remaining two leads are tapped into the coil so that they are 120 degrees apart and each is 120 degrees from the nearest power lead.

Suitable wiring connections are made so that the transmitter and indicator are connected together in parallel (fig. 14-2).

A universal-type compensator is provided immediately above the transmitting unit. By means of this assembly, corrections may be introduced for heeling errors and semicircular errors (deviation errors) caused by the magnetic field of the ship. For instructions for its use, see NavShips 324-0090.

INDICATOR

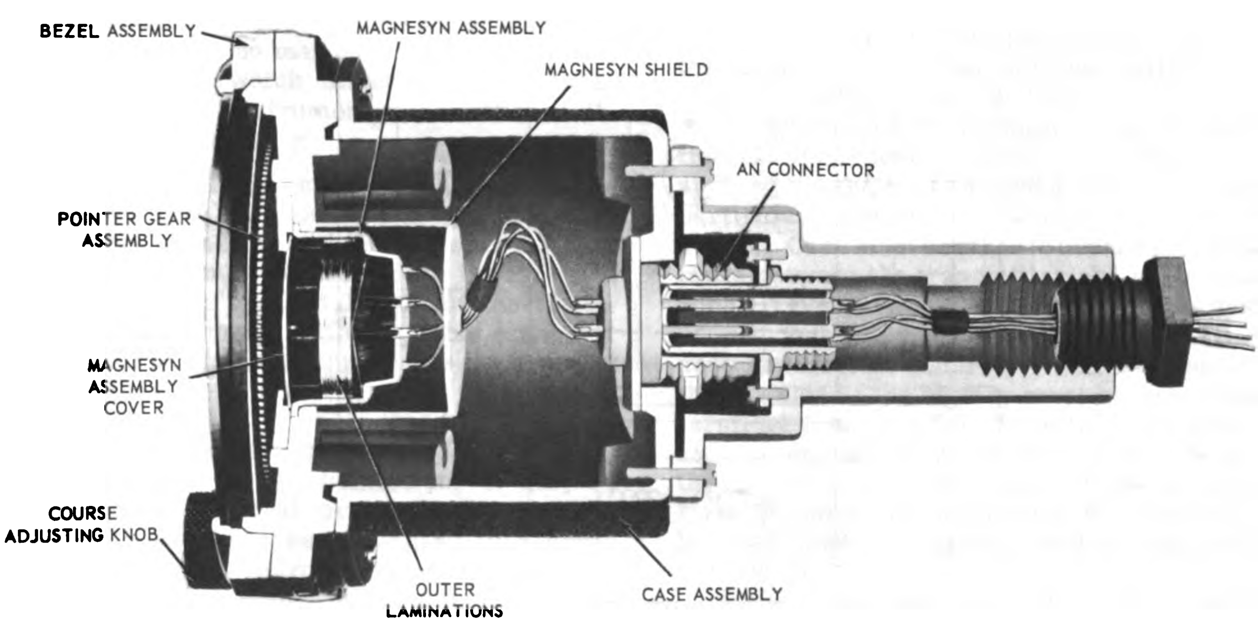
The Mark 1 indicator (fig. 14-4) consists of a permanent magnet rotor, a stator assembly, and a return magnetic path enclosed by a case. The Magnesyn case assembly has jeweled bearings in which the shaft of a permanent magnet rotor turns. A pointer is attached to this shaft.

The stator is made up of circular laminations with a toroidal winding. The return path for the flux of the rotor magnet consists of outer laminations that are concentric with the stator. A magnetic shield, which surrounds the brass Magnesyn case, is used to minimize the effect of stray magnetic fields around the indicator. The housing consists of a dusttight, waterproof case for the component parts of the indicator.

A course-setting pointer is provided on the indicator dial and may be adjusted by turning a knob at the lower left-hand corner of the indicator. The indicating pointer, course-setting pointer, dial numerals, and divisions are treated with a luminous material.

When operating without lights, the parallel lines of the course-setting pointer between which the indicating pointer should be held will be helpful to the helmsman in holding his course.

The Mark 3 indicator contains an identical permanent magnet rotor, stator assembly, and Magnesyn case as the Mark 1 indicator; its operation and wiring connections are also identical to the Mark 1 indicator. However, the Mark 3 indicator lacks the course setting pointer, has a larger dial, a longer pointer, and controllable, internal red illumination. This illumination is provided by three 6.3-volt incandescent lamps



7.164

Figure 14-4.—Mark 1 Magnesyn indicator.

Digitized by Google

supplied via a stepdown transformer mounted in the indicator case. The transformer is energized from the 120-volt ship's lighting system.

INVERTER

The inverter power supply (fig. 14-5) consists of a miniature shunt motor driving a permanent magnet rotor a-c generator. The inverter operates on 12 volts d-c and draws approximately 2 amperes. The a-c output voltage is 26 volts at a frequency of 400 cycles. The speed is 8000 rpm.

The inverter is mounted in a box in such a way that when the cover is removed the brushes are accessible. A low-pass filter is mounted beside the inverter and connected across the commutator to reduce r-f interference to a minimum. Three leads go to the inverter. These are for d-c input, 26-volt a-c output, and a common ground. The leads are connected to appropriate terminals in the inverter box.

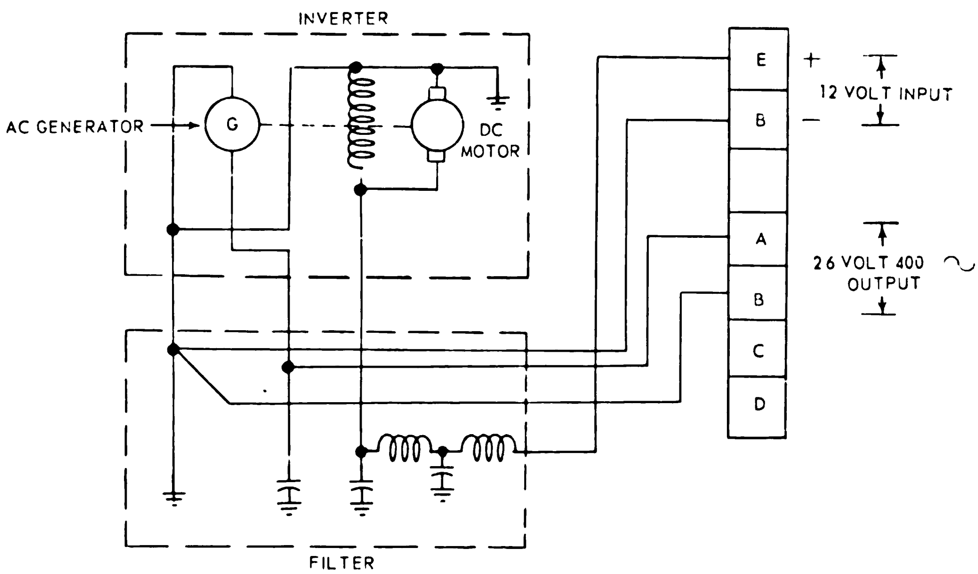
INSTALLATION

Although the IC Electrician may seldom be required to install the Magnesyn compass system, it is important that he understand the installation requirements for satisfactory operation. To that end the following information is included in this training course.

In order to obtain accurate performance it is essential that the transmitter be installed in a location having a minimum of magnetic interference. It is advisable to install the transmitter as far as possible from all movable magnetic material such as steel structures, guns, cables, ammunition, and loads which may be taken on and off the ship. It is not possible to adjust for the effects of movable magnetic masses since the disturbances set up will vary with their position. In general, the Bureau of Ships specifies a nonmagnetic circle of 6-foot radius for fixed magnetic material and a nonmagnetic circle of 8-foot radius for movable magnetic material around a Magnesyn transmitter.

Care should be taken to avoid the proximity of electric cables carrying direct current, such as power and lighting circuits. Disturbances set up by these circuits are impossible to adjust because their intensity varies with the amount of current.

The transmitter should be located with a test compass (direct reading). The test compass should be mounted in the selected location and the effects noted of changes in the position of all movable masses of magnetic material and of switching d-c power on and off in any circuit thought likely to cause interference. The tests should be made on two headings 90 degrees apart. If a change of compass reading occurs on



7.165

Figure 14-5.—Schematic diagram of inverter.

Digitized by Google

either of the two headings, choose another location and repeat the test for the new position.

If the flow of d-c power affects the compass and the location is satisfactory in other respects, it may be possible to eliminate the disturbance by rerouting the d-c cables, or to neutralize the disturbance by using a twisted pair for the d-c output and return in place of a single conductor and ground return.

If the location is found to be satisfactory as far as the previously mentioned disturbances are concerned, the ship's navigator should be requested to swing ship and determine if the compass performance is acceptable in the selected location.

The transmitter, so far as the electrical system is concerned, could be mounted at any height. It is desirable, however, to locate it as low as possible to avoid undue swing as the vessel rolls and pitches, and to prevent whip in the mounting structure. In general, the maximum height should not be more than 6 feet above the deck, above the chart house, or above any similar structure which is used for mounting purposes.

The transmitter should be mounted on a rigid nonmagnetic platform to avoid the possibility of its twisting or vibrating in resonance with the engines of the ship. It is essential that nonmagnetic materials such as brass, aluminum, K-monel, and the like, be used for all mounting parts, including screws, washers, bushings, and the metal parts of shock mounts and brackets, so that there will be no magnetic disturbance near the transmitter which might prevent proper adjustment of the instrument or make the resulting adjustment unstable.

The plane of the mounting lugs must be horizontal. The line passing through the center of the cable connector and the center of the rear mounting hole must be parallel to the fore-and aft axis of the ship. Installation of the transmitter must be made with the cable connector pointing forward. Fine adjustments in alignment may be made by rotating the unit in its mounting slots.

The indicator may be installed in any location convenient to the helmsman. It may be mounted in a vertical or horizontal attitude. However, it should not be mounted within 8 inches of a direct reading magnetic compass.

Additional indicators up to a total of three may be operated from one transmitter. The additional indicators should be connected in parallel with the first indicator. If more than one indicator is used, all compensating adjustments must be made with reference to one of the indicators only. The other indicators must be operating during the procedure. Because of slight differences in their electrical characteristics, individual correction cards will be necessary for each indicator.

The inverter box should be installed not closer than 8 feet from the transmitter or any direct reading magnetic compass, and as near the battery power supply as possible. Free air space should be allowed around the inverter box so that heat may be dissipated. The inverter box should be mounted securely to the ship's structure.

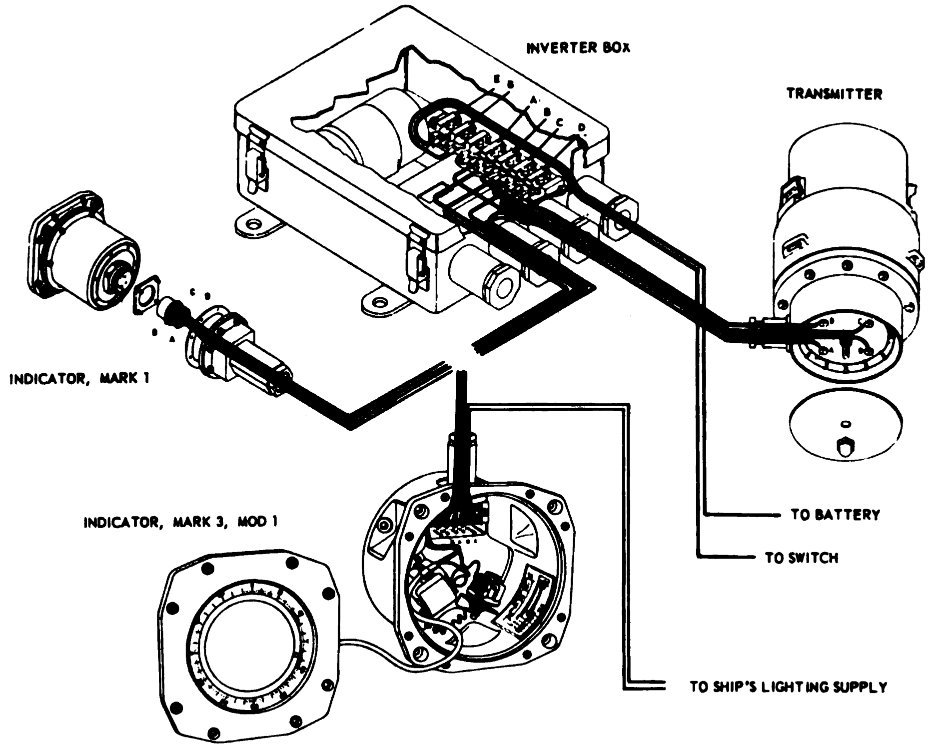
CONNECTIONS AND WIRING

The transmitter and indicator contain similarly wound coils connected as shown in figure 14-2. Power is normally supplied from the 400-cycle bus on the IC switchboard via a 120/26-volt stepdown transformer. An emergency supply is also available on some ships. This supply consists of a separate battery, battery charger, and inverter, and is controlled by a switch on the IC switchboard. The 12-volt battery and battery charger supply power to the inverter whose output of 26 volts at 400 cycles is applied across terminals A-B of the transmitter and indicator. Additional indicators are installed on some ships. These indicators are normally controlled by a transfer switch in the pilot house so that only two indicators can be energized at the same time.

A pictorial of the wiring in a typical installation is illustrated in figure 14-6. Refer to the applicable BuShips drawing for your ship's particular installation which may differ in details. Care must be taken to avoid reversing the leads between the transmitter and the indicator. Such a reversal might cause failure of the system and serious damage to the instrument. All connections must be securely made. The lead from the hot side of the battery must be connected to terminal E and the lead from the other grounded side to terminal B in the inverter box. Note that the common a-c—d-c lead of the inverter is already connected to terminal B in the inverter box and that the hot a-c lead is connected to terminal A.

Before energizing the system, all connections should be checked carefully. Failure to make connections correctly, or through error, to supply the transmitter, the indicator, or the a-c

Digitized by Google



7.166

Figure 14-6.—Pictorial wiring diagram of remote indicating compass system.

terminal of the inverter with d-c power will cause serious damage to the instrument.

When connecting cable leads to terminals in the transmitter, care must be exercised to prevent the fine wiring leading from the terminal posts to the transmitter coil from being broken or disturbed. Guard against striking the coil itself or subjecting it to any stress. Strain on the laminations around which the coil is wound will affect the accuracy of the instrument.

MAINTENANCE

Whenever the ship gets underway, the Magnesyn system should be checked for erratic or sluggish operation. If either of the above occur, reference should be made to paragraph on Mechanical Troubles.

PERIODIC INSPECTION

At the end of each 500 hours of operation, the inverter should be inspected for brush wear. Unscrew the brush caps and remove the brush assemblies. Mark the brushes so that they may be put back in the same position after being cleaned and inspected. Replace the brushes if they are worn and spring pressure is weak. Refer to the manufacturer's technical manual for proper spring pressure and method of replacing brushes.

Check the condition of the commutator. Clean it with a dry cloth. If it is rough or pitted, polish it, using 000 sandpaper.

On ships employing a battery charger for the Magnesyn system battery, the battery and charger should be checked to determine that a trickle charge is maintained and the battery fully charged.

MECHANICAL TROUBLES

If excessive oscillation or other erratic operation is noted, insufficient liquid in the transmitter bowl or a loose pointer in the indicator may be suspected. Examine the transmitter for leakage of compass liquid by removing the filling cap on the opposite side from the stuffing tube and viewing the level of liquid. If additional liquid is required, a corroded diaphragm may be at fault. This may be determined

Digitized by Google

by inverting the transmitter and observing if there is leakage of fluid from the gauge hole located under the magnet compensator assembly. If the diaphragm is faulty, a new unit should be requisitioned from stock, or the old unit overhauled by an authorized repair activity. If the diaphragm is not faulty, refill the float chamber with compass fluid (Varsol).

If a defective indicator is suspected, replace the indicator with the portable spare unit provided each ship for transmitter adjusting purposes.

Special care should be taken to prevent the battery input from becoming accidentally connected to output terminal A of the inverter. The effect might be to demagnetize the permanent magnet rotor of the a-c generator rotor on the inverter, resulting in greatly reduced a-c output voltage.

If it is necessary to replace a transmitter or an indicator, follow the instructions outlined for their original installation. Slight differences in each instrument will call for adjustments (swinging the ship) and a new correction card.

When replacing a transmitter, readjustment of the compass is essential because the transmitter carries the whole compensating assembly. It would not be practicable to switch compensating assemblies on the units to avoid readjustment of the compass.

ELECTRICAL TROUBLES

As an aid in locating errors in wiring, table 14-1 shows possible wiring faults. Indicator behavior is considered as referred to a transmitter on a north magnetic heading. Letters refer to wires corresponding to terminal markings anywhere in the circuit. The causes starred with an asterisk (*) will result in the application of excessive voltage to a part of the transmitter or indicator windings. This may affect the calibration of the instrument. Therefore if such a condition is found and the condition corrected, the ship should be swung and readings of the compass checked at the 12 headings on the compass correction card as described in the manufacturer's technical manual.

Slight errors indicate changes in deviation caused by changes in the magnetic characteristics of the ship. Large errors or the failure of the compass to follow through a turn indicate instrument damage. It is probable that only the indicator is affected in this case; therefore, replace this unit first. Then swing the ship a second time and check the performance of the compass before replacing the transmitter also.

As a final precaution remember that excessive voltage will seriously damage the instrument. Make sure that the d-c voltage input does not vary more than ± 20 percent of the rated voltage. Also remember that d-c instead of the 26-volt 400-cps a-c will destroy the instrument, and that d-c applied to the a-c leads of the inverter will damage it.

Table 14-1.—Wiring Faults
(Refer to figure 14-6.)

Trouble		Probable Cause	
1.	No rotation.	1. 2.	A shorted to B. Power supply not operating.
2.	Reversed rotation.	1.	A and B reversed and C and D reversed.
3.	Erratic operation in the 90° arc between 330° and 60°.	1.	C open.
4.	Erratic operation in the 90° arc between 300° and 30°.	1.	D open.

Digitized by Google

Table 14-1.—Wiring Faults—Continued.
(Refer to figure 14-6.)

5.	Pointer takes either 30° position or 210° position and will not revolve with rotation of transmitter.	1. 2. 3. 4.	A open (power supply reaching one unit). D shorted to A or B.* A-D phase open in either transmitter or indicator. A and D reversed.
6.	Pointer takes either 330° or 150° position.	1. 2. 3. 4.	B open (power supply reaching one unit). C shorted to A or B.* B-C phase open in either transmitter or indicator coils. B and C reversed.*
7.	Erratic operation in the 120° arc between 300° and 60°.	1.	C-D phase open in either transmitter or indicator coils.
8.	Pointer takes either 0° position or 180° position.	1. 2.	A and C reversed with B and D reversed.* A and D reversed with B and C reversed.*
9.	Pointer takes either 60° or 240° position.	1.	A and C reversed.*
10.	Pointer takes either 120° or 300° position.	1.	B and D reversed.*
11.	Pointer takes either 90° position or 270° position.	1. 2. 3.	C shorted to D.* C and D reversed. A and B reversed.

*Asterisks are explained in the text under "Electrical Troubles"

Digitized by Google

CHAPTER 15

SHIP CONTROL ORDER AND INDICATING SYSTEMS

Ship control order and indicating systems include among others the engine order system, propeller order system, rudder order system, and rudder angle indicator system. These systems comprise units that pertain to ship control orders and indications. The units are either synchro transmitters, synchro receivers, or a combination of both, and operate on a standard synchro transmission system.

The units comprising the ship control order and indicating systems are enclosed in splashproof metal cases designed for pedestal, or universal panel bulkhead mounting, depending on the stations in which they are located. Where required, windows for viewing dials are provided in the unit covers. The internal subassemblies can be withdrawn individually from the case for troubleshooting and repairs.

Cables are brought into the unit cases through watertight terminal tubes and the leads are connected to terminal strips or female connectors. The leads for the synchros, bell circuits, and other components are connected to corresponding terminal strips or male connectors within the cases.

ENGINE ORDER SYSTEM

The engine order system, circuit MB, is used to transmit the desired engine orders from the pilot house, open bridge, or secondary conning station to the enginerooms, firerooms (boiler operating stations), and superheat operator stations. Separate circuits are installed for the starboard engines (circuit 1MB) and the port engines (circuit 2MB).

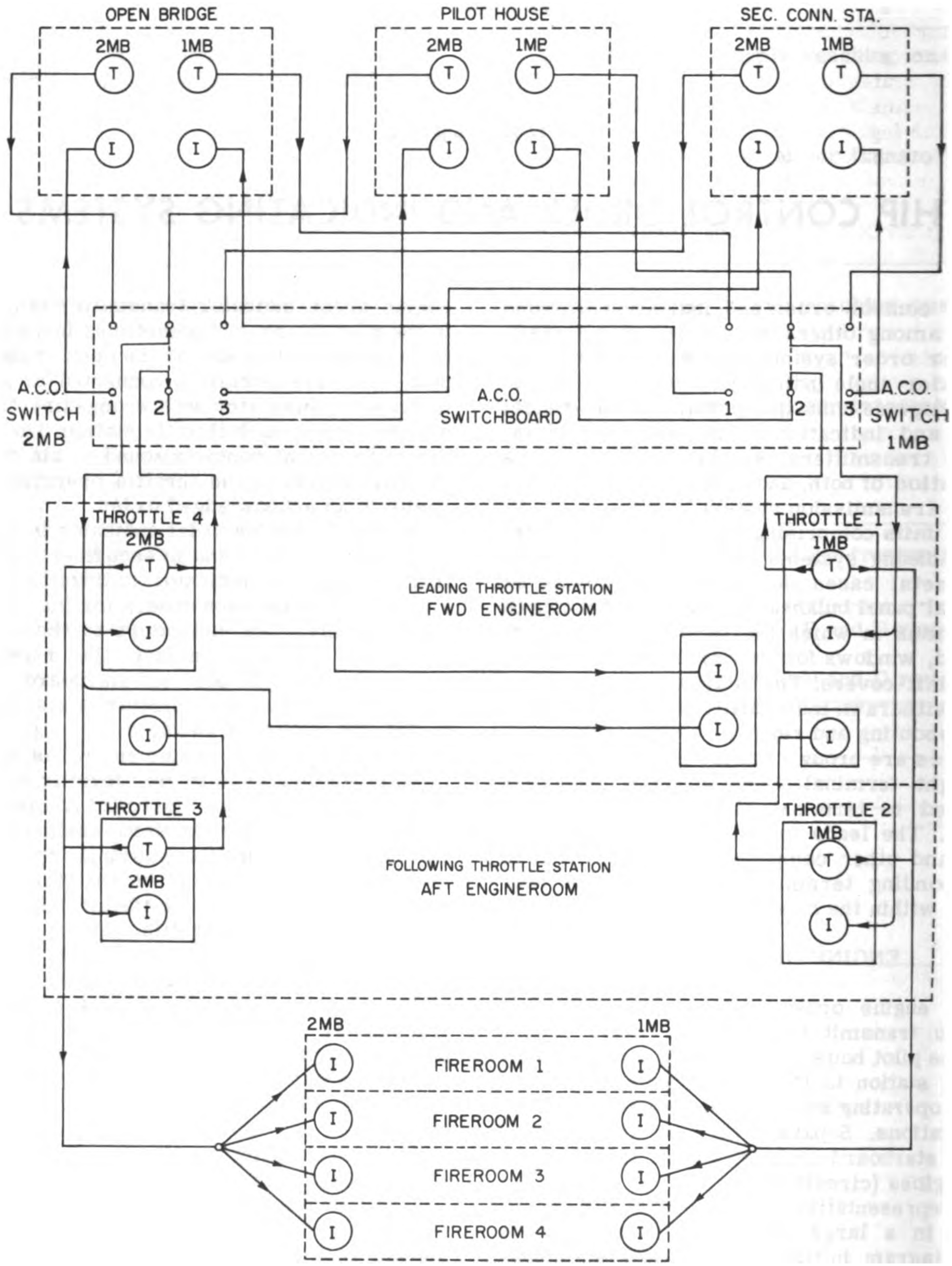
A representative engine order system installed in a large ship is illustrated by the block diagram in figure 15-1. The system consists of various transmitters and indicators installed in the conning stations, enginerooms, and firerooms. A combined port and starboard engine order indicator-transmitter is installed in the pilot house, and sometimes in the secondary conning station and on the open bridge. This unit is electrically connected to a single indicator-transmitter with wrong-direction signal contacts in each throttle station. The wrong-direction signal contacts sound an alarm at the throttle station if the throttle operation is opposite to an acknowledged order.

A double engine order indicator is installed in throttle station 1 and in each fireroom operating station. The indicator in throttle station 1 receives and answers orders for the starboard engines only. The indicators in the fireroom operating stations receive the repeat-back orders for both the port and starboard engines. A single engine order indicator is also installed in throttle stations 1 and 4.

The entire main engine control is vested in throttle station 1. However, throttle stations 1 and 4, located on the starboard and port sides respectively, in the forward engineroom are called leading throttle stations, and throttle stations 2 and 3, located on the starboard and port sides respectively, in the after engineroom are called following throttle stations.

An engine order is orginated at one of the conning stations by moving the operating handle of the double indicator-transmitter until the transmitter is over the selected order on the dial. The transmitted order is received on all indicators in the circuit. The order is answered by turning the operating knob on the indicator-transmitter at the following throttle station until the reply pointer of the transmitter is over the received order on the dial. The reply is received on the single engine order indicator at the leading throttle stations. The leading throttle station then replies in a similar manner and this reply is received on the double indicator-transmitter in the conning station that originated the order. Thus, the conning station is

Digitized by Google



7.115

Figure 15-1.—Block diagram of engine order system.

Digitized by Google

assured that the transmitted order has been correctly received and interpreted at both leading and following throttle stations.

The units in the enginerooms and boiler operating stations are provided with bells that ring each time a transmitted order is originated at the conning station. An audible signal is not provided on the circuits between the forward and after enginerooms.

ACTION CUTOUT AND TRANSFER SWITCHES

The operation of the engine order system depends on the setting of various action cutout and transfer switches (not shown).

The different positions on the various transfer switches are used to connect the engine order and repeat-back circuits to the various stations throughout the ship that are concerned with this information.

Action cutout (ACO) switches, like the transfer switches, are installed at various locations throughout the ship. The different positions of these switches are to add flexibility to the system. With this flexibility, many different combinations of normal operation are permitted, troubleshooting is facilitated, and the isolation of defective circuits is possible.

Normal operating conditions are obtained by setting the action cutout and transfer switches to the required position so that a 1MB order from the pilot house is transmitted to the engine order indicator-transmitter in throttle stations 1 and 2. Throttle station 2 replies to the single engine order indicator in throttle station 1, and also to the double engine order indicators in firerooms 3 and 4. Throttle station 1 then replies to the pilot house and firerooms 1 and 2.

A 2MB order from the pilot house is transmitted to the engine order indicator-transmitters in throttle stations 3 and 4. Throttle station 3 replies to the single indicator in throttle station 4, and also to the double indicators in firerooms 3 and 4. Throttle station 4 then replies to the pilot house and firerooms 1 and 2.

Emergency operating conditions are obtained by setting the action cutout and transfer switches to the required positions. For example, if engineroom 1 is inoperative the switches are set so that a 1MB order from the pilot house is transmitted to the indicators in throttle station 2 with repeat-back to the pilot house, secondary conning station, and firerooms 1, 2, 3, and 4.

A 2MB order from the pilot house is transmitted to the indicators in throttle station 3 with repeat-back to the pilot house, secondary conning station, and firerooms 1, 2, 3, and 4.

DOUBLE ENGINE ORDER INDICATOR-TRANSMITTER

The double engine order indicator-transmitter installed in each conning station (fig. 15-2) is used to transmit engine orders and to receive acknowledgement of these orders. It is a dual unit with a port and a starboard indicator-transmitting subassembly, each operating independently of the other.

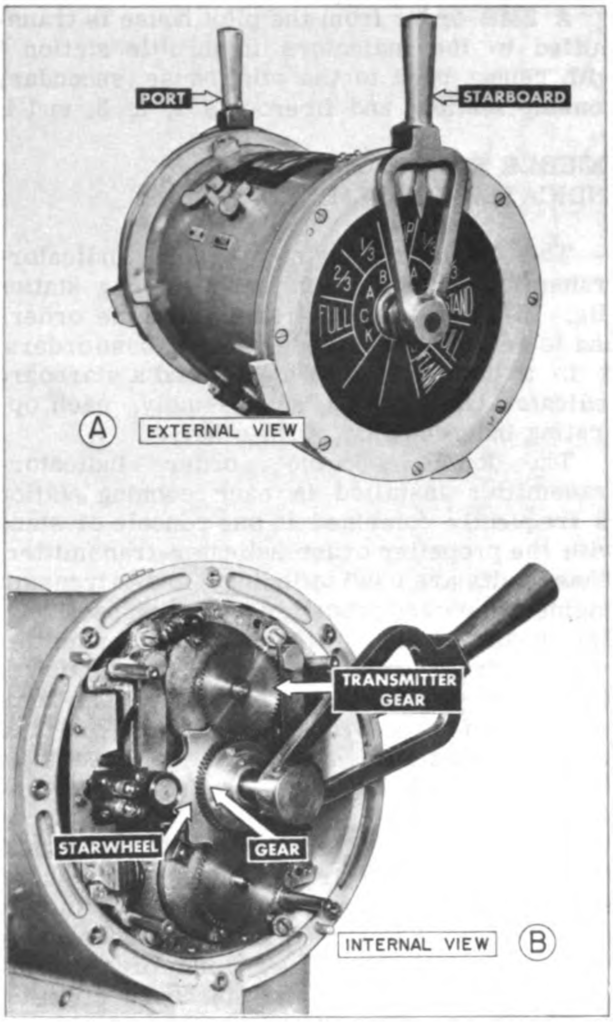
The double engine order indicator-transmitter installed in each conning station is frequently combined in one console or stand with the propeller order indicator-transmitter. These units are used to indicate and to transmit engine orders and propeller orders respectively. The double engine order indicator-transmitter is of the drum type and forms the top section of the complete combined assembly. The unit consists of two synchro receivers and two synchro transmitters indicating on two fixed dials (port and starboard) by concentric revolving pointers.

Synchro types are indicated in figure 15-3. The receivers and transmitters are mounted on individual baseplates to form two complete and identical indicator-transmitter subassemblies that are mounted in each side of the drum-type housing for port and starboard circuits.

The transmitter of each subassembly is positioned by a side operating handle which is an extension of the transmitter pointer. The operating handle with its pointer is connected through a dovetail coupling and gears to the shaft of a synchro transmitter. A detent wheel secured concentrically to one of these gears actuates a microswitch through a roller and lever arm to close the alarm bell circuit when the operating handle is moved. This action causes a bell to ring on the engineroom unit. A spring-operated lever stop is provided in the operating handle to lock the transmitter pointer in the selected position.

The indicator pointer of each subassembly is secured directly to the shaft of a synchro receiver. This pointer indicates the reply from the engineroom unit by matching the transmitted order on the dial.

Digitized by Google



7.116
Figure 15-2.—Double engine order indicator-transmitter.

The dials are attached to the sides of the drum-type housing. They are made of a translucent material having a dull white background with black markings. The dial markings are so arranged that a forward movement of either transmitter operating handle selects ahead orders and an aft movement of the handle selects back orders on either the port or starboard dial.

Dial illumination is provided by five 6-volt lamps located around the perimeter of a light-conducting panel mounted behind each dial. Two 115/6-volt transformers mounted on the baseplates supply the port and starboard dial lamp circuits. A rheostat in series with this circuit controls the intensity of illumination. A pilot light is provided in each subassembly to indicate (through two windows placed in the covers at the top of the drum-type housing) when the 1MB and 2MB circuits are energized.

A pushswitch connected in parallel with the microswitch in each subassembly is located on the after side of the drum-type housing for manual signaling to the port and starboard indicators. These pushswitches, when operated, cause bells to ring on the engineroom units. A bell is mounted externally on the port and starboard side of the pedestal below the drum-type housing. These bells ring when the reply is received from the engineroom units.

The wiring diagram of the double engine order indicator-transmitter and the propeller order indicator-transmitter is illustrated in figure 15-3.

ENGINE ORDER INDICATOR-TRANSMITTER WITH WRONG-DIRECTION CONTACTS

The engine order indicator-transmitter with wrong-direction signal contacts installed in each throttle station is used to indicate orders pertaining to engine speed and direction from the conning station and to acknowledge these orders. The wrong-direction signal contacts close an alarm bell circuit when the movement of the throttle will cause the ship to move in a direction opposite to the order acknowledged to the conning station in control.

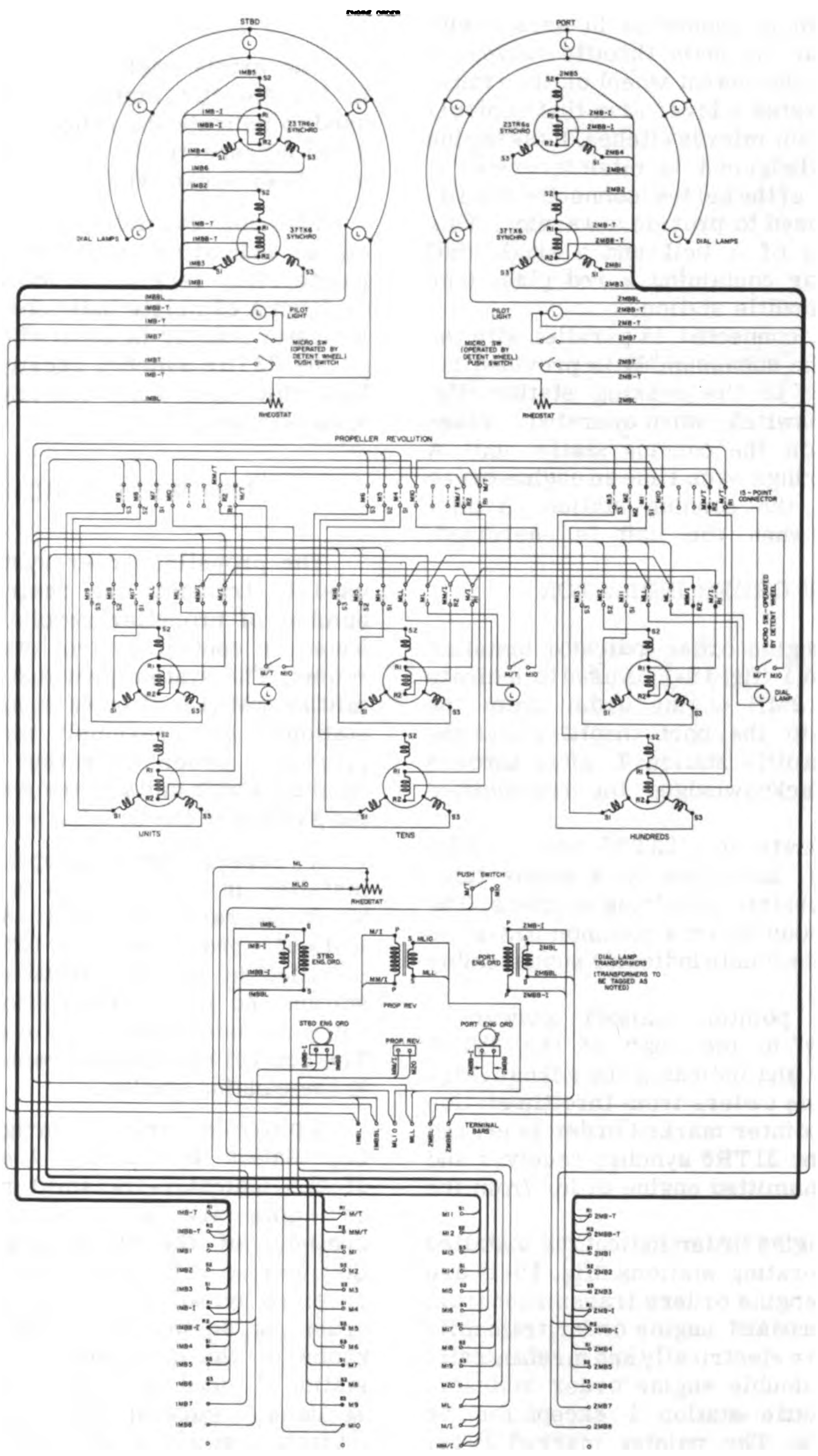
The unit consists of a 23TR6 synchro receiver and a 37TX6 synchro transmitter indicating on a fixed dial by two revolving concentric pointers. The receiver and transmitter are mounted on a common baseplate to form a complete indicator-transmitter subassembly.

An indicator pointer marked order is attached directly to the shaft of the synchro receiver and indicates the order from the conning station.

A transmitter pointer marked answer is geared to the shaft of the synchro transmitter and is positioned by an operating knob to indicate the transmitted order. A detent wheel secured concentrically to one of the transmitter gears actuates a microswitch through a roller and lever arm to close the alarm bell circuit when the transmitter-operating knob is moved. This action causes a bell to ring on the conning station unit.

The wrong-direction contacts consist of two microswitches provided in the ahead and back

Digitized by Google



7.117

Figure 15-3.—Wiring diagram of double engine order indicator-transmitter and propeller order indicator-transmitter.

Digitized by Google

positions of the transmitter operating handle. Each microswitch is connected in series with a microswitch at the main throttle valves. A cam attached to the detent wheel on the transmitter shaft operates a lever arm that controls the wrong-direction microswitches. If the engine direction acknowledgment is misinterpreted at the throttle, both of the series-connected microswitches are closed to provide a warning. This warning consists of a bell and a single dial (2-lamp) indicator containing a red glass lens located at each throttle station.

A pushswitch connected in parallel with the microswitch in the subassembly is provided for manual signaling to the conning station (fig. 15-4). This pushswitch, when operated, causes a bell to ring on the conning station unit. A bell on this unit rings each time an engine order is originated at the conning station. A pilot light indicates when the unit is energized.

DOUBLE ENGINE ORDER INDICATOR

The double engine order indicator installed in throttle station 1 (fig. 15-1) is used to indicate the transmitted 2MB engine order from the conning station to the port throttles and the answer from throttle station 4, after throttle station 3 has acknowledged the transmitted order.

The unit consists of a 23TR6 and a 31TR6 synchro receiver, indicating on a single fixed dial by two concentric revolving pointers. The receivers are mounted on a common baseplate to form a complete double indicator subassembly (fig. 15-5).

An indicator pointer marked answer is secured directly to the shaft of the 23TR6 synchro receiver and indicates the acknowledgment of the engine orders from throttle station 4. An indicator pointer marked order is geared to the shaft of the 31TR6 synchro receiver and indicates the transmitted engine order from the conning station.

The double engine order indicators installed in the boiler operating stations (fig. 15-1) are used to indicate engine orders transmitted from the port and starboard engine order transmitters. The units are electrically and mechanically identical to the double engine order indicator installed in throttle station 1 except for the pointer markings. The pointer marked P indicates orders relative to the port engine, and the pointer marked S indicates orders relative to the starboard engine.

SINGLE ENGINE ORDER INDICATOR

The single engine order indicator installed in the throttle stations 1 and 4 (fig. 15-1) is used to indicate the reply from throttle stations 2 and 3 respectively after the transmitter order has been acknowledged by these stations.

The unit consists of a 23TR6 synchro receiver indicating on a fixed dial by a revolving pointer. The receiver is mounted on a baseplate to form a complete indicator subassembly. The indicator pointer is secured directly to the shaft of the 23TR6 synchro receiver. A bell rings on this unit each time the transmitted order is acknowledged.

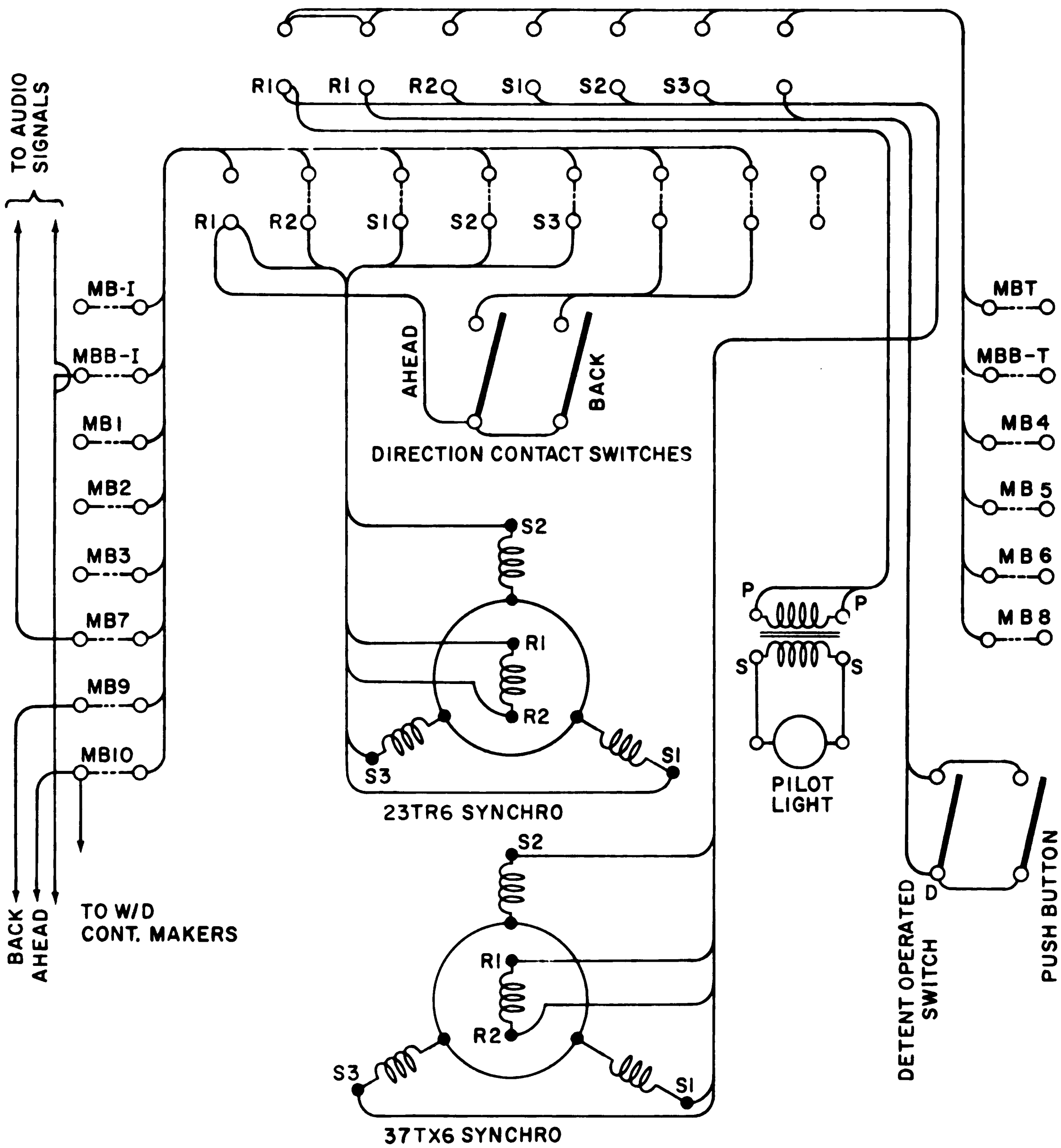
PROPELLER ORDER SYSTEM

The propeller order system, circuit M, is used to transmit the desired changes in the number of propeller revolutions from the pilot house or central control station to the enginerooms. The system provides a method of transmitting SMALL changes in speed to the throttle stations. As previously stated, units of the propeller order indicating system are often combined with units of the engine order indicating system in the conning stations.

A representative propeller order system installed in a large ship is illustrated by the block diagram in figure 15-6. The system consists of a propeller order indicator-transmitter installed in the pilot house and central control station and in throttle station 1. A single indicator is installed in throttle stations 2, 3, and 4. The control engineroom repeats the orders back to the conning station.

A propeller order is originated at the conning station by turning the operating knobs of the indicator-transmitter until the selected digits are indicated in the transmitter sections of the three windows provided in the unit cover. The transmitted order is received on all indicators in the circuit. The order is answered by turning the operating knobs of the indicator-transmitter at throttle station 1 until the digits in the transmitter sections correspond with those in the indicator sections of the three windows. The reply is received at the propeller order indicator-transmitter at the conning station that orginated the order. Thus, the conning station

Digitized by Google



7.118

Figure 15-4.—Wiring diagram of engine order indicator-transmitter with wrong-direction contacts.

is assured that the transmitted order has been correctly received and interpreted.

A selector switch is installed on the ACO switchboard for selecting the indicator-transmitter to control the circuit and a cutout switch is provided at the engine-room unit.

PROPELLER ORDER INDICATOR-TRANSMITTER

The propeller order indicator-transmitter installed in each conning station and in throttle station 1 (fig. 15-6) is used to transmit orders relative to propeller speed and to receive acknowledgment of these orders.

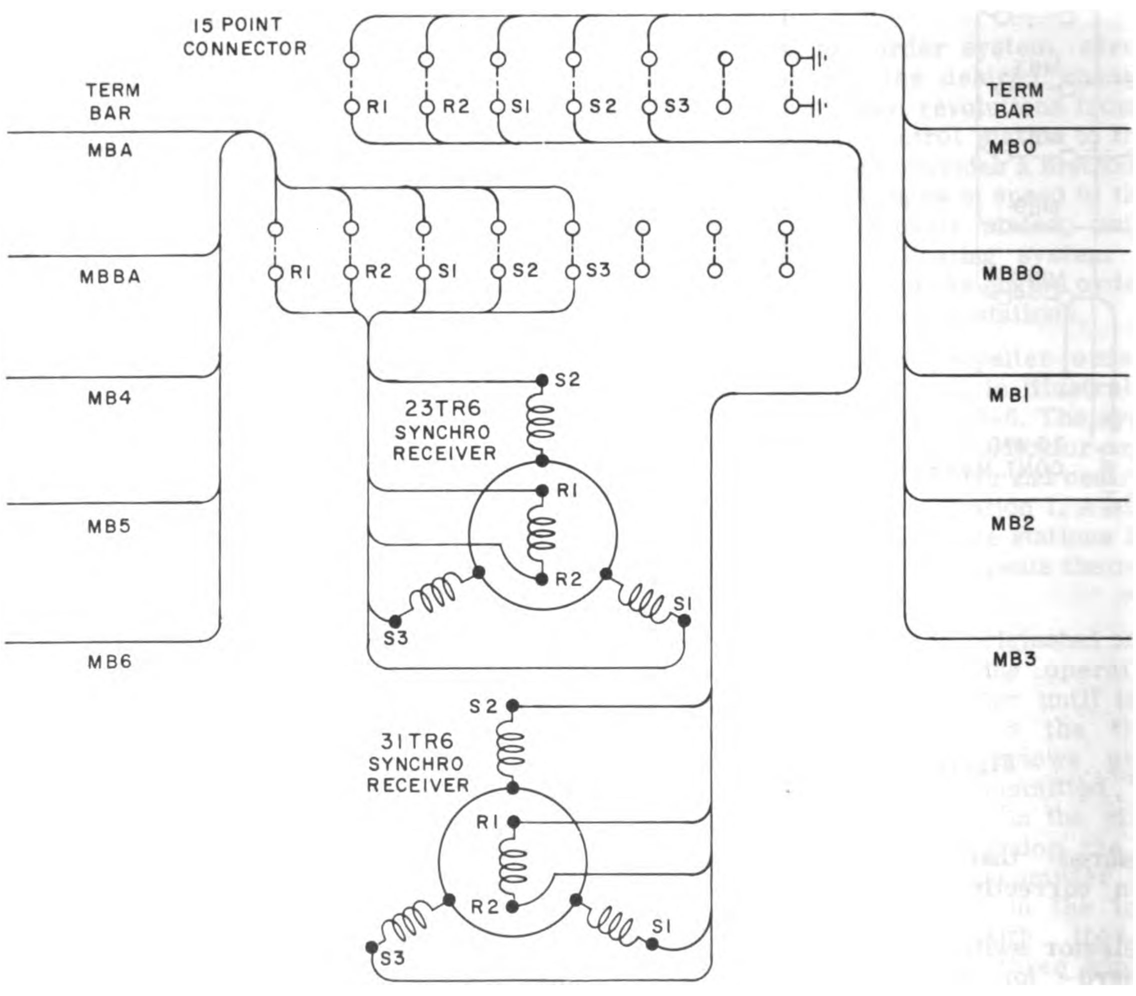
Digitized by Google

The unit consists of three 23TR6 synchro receivers and three 37TX6 synchro transmitters indicating on six circular dials marked 0 through 9. The transmitters and receivers with the associated dials are mounted on individual baseplates to form three complete and identical indicator-transmitter subassemblies enclosed in a metal case.

The subassemblies are mounted in the case so that the three indicator dials are directly above the three transmitter dials, each showing one numeral through its associated window in the cover (fig. 15-7). The numerals form a 3-digit number (units, tens, hundreds) for the indicators and transmitters respectively. The dials, which are rotating disks, are provided with segregated digit control so that any desired number from 000 to 999 can be set on the transmitters manually by external operating knobs.

Each indicator dial is secured through a dial coupler to the shaft of a 23TR6 synchro receiver and indicates the reply from the engineroom unit by matching the transmitted order on the associated dial.

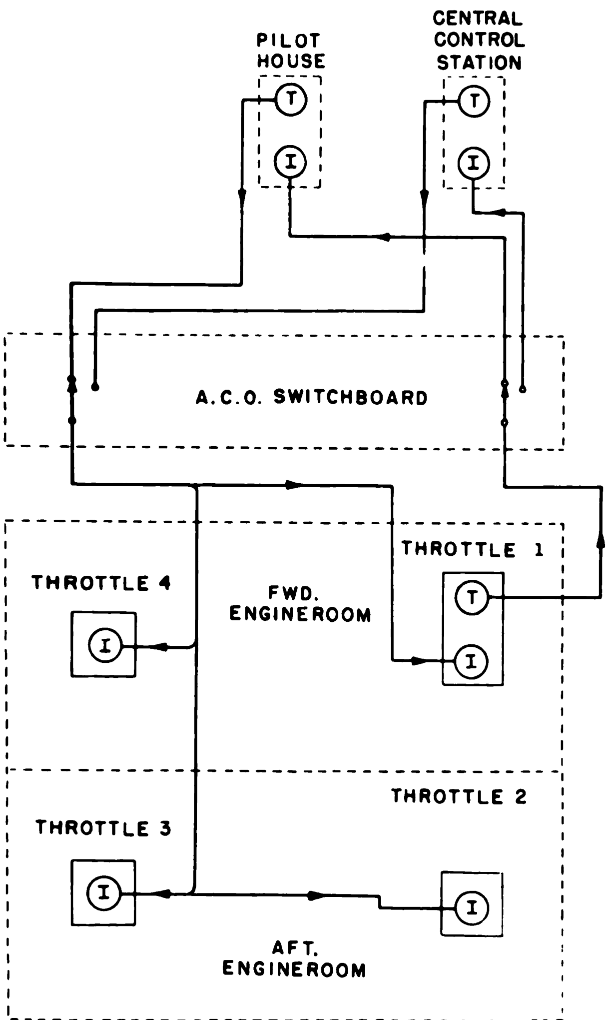
Each transmitter dial is secured through a dial coupler to the shaft of a 37TX6 synchro transmitter. The dial is positioned by an operating knob connected through a clutch assembly to the transmitter shaft and indicates the transmitted order on the associated dial. A detent wheel secured to each transmitter shaft actuates a microswitch through a roller and lever arm



7.119

Figure 15-5.—Wiring diagram of double engine order indicator.

Digitized by Google



7.121

Figure 15-6.—Block diagram of propeller order system.

to close the alarm bell circuit when the transmitter operating knob is moved. This action causes a bell to ring on the indicator unit.

A pushswitch connected in parallel with the microswitch is used for manual signaling to the indicator units. The pushswitch, when operated, causes bells to ring on the indicator units. A buzzer for the ringing circuit is located externally between the port and starboard bells for the engine order circuit. The buzzer sounds an audible signal when the reply is received from the transmitter units.

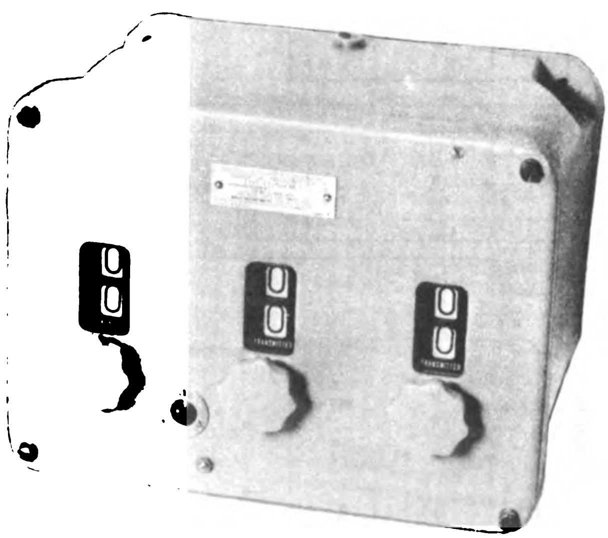
Dial illumination is provided in the conning station units by three 6-volt lamps located between the receiver and transmitter in each subassembly. The dial lamp circuit is supplied from a 115/6-volt transformer, and the intensity of illumination is controlled by a dimmer knob that operates a rheostat (fig. 15-8).

PROPELLER ORDER INDICATOR

The propeller order indicators installed at throttle stations 2, 3, and 4 (fig. 15-6) are used to indicate the propeller orders. The unit consists of three 23TR6 synchro receivers indicating on three circular dials marked 0 through 9. The receivers with the associated dials are mounted on individual baseplates to form three complete and identical indicator subassemblies.

The subassembles are mounted in the case so that each indicator dial shows one numeral through its associated window in the cover to form a 3-digit number. The dials, similar to those previously described for the propeller order indicator-transmitter, are provided with segregated digit control so that any desired number from 000 to 999 can be indicated.

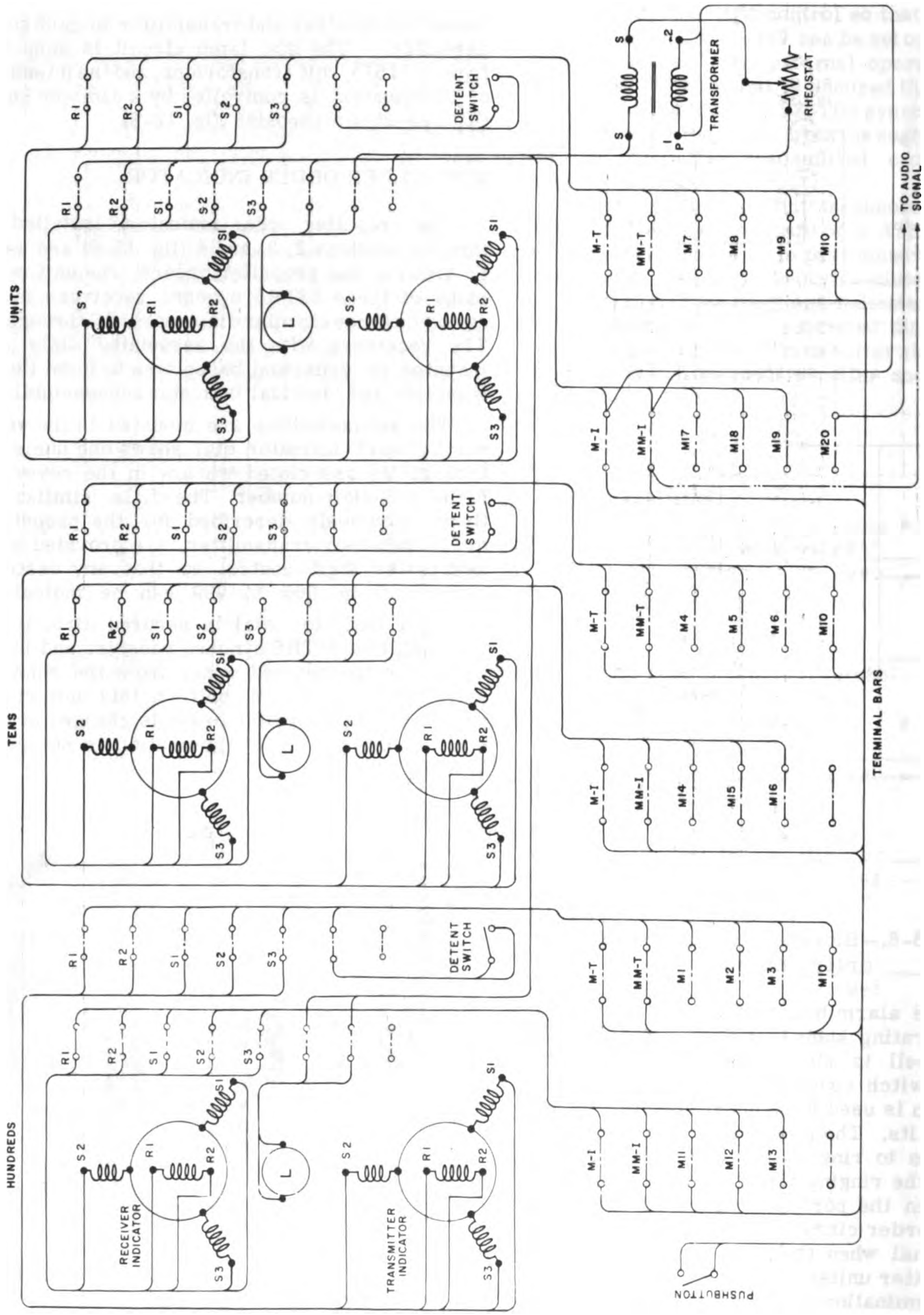
Each indicator dial is secured directly to the shaft of a 23TR6 synchro receiver and indicates the transmitted order from the conning station (fig. 15-9). A bell on this unit rings each time the propeller order is changed at the conning station. Dial illumination is not provided.



7.122

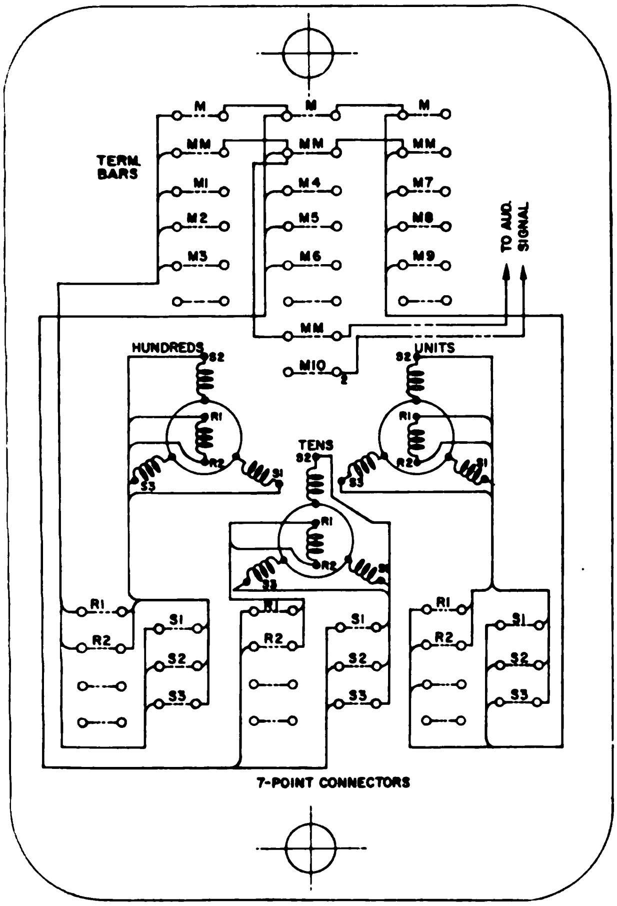
Figure 15-7.—Propeller order indicator-transmitter.

Digitized by Google



7.123
Figure 15-8.—Wiring diagram of propeller order indicator-transmitter.

Digitized by Google



7.124

Figure 15-9.—Wiring diagram of propeller order indicator.

RUDDER ORDER SYSTEM

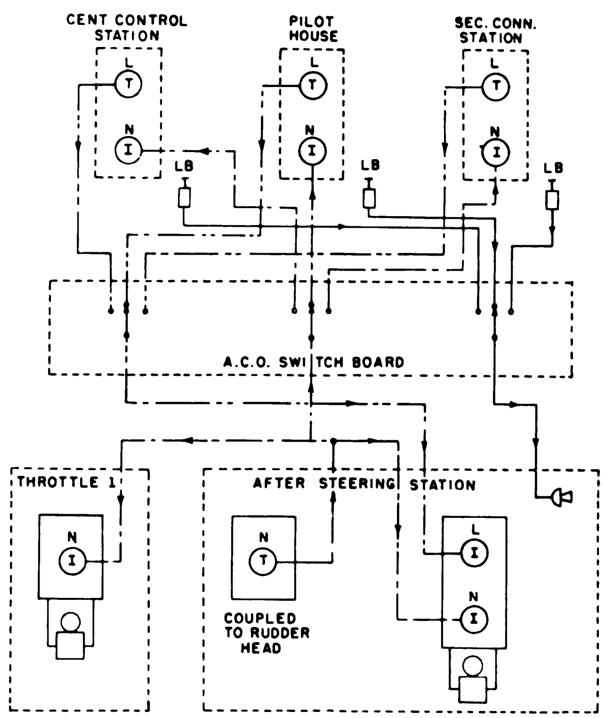
The rudder order system, circuit L, is used to transmit the desired rudder orders from the pilot house, and conning stations to the after steering station when the ship is being conned at one station and the rudder(s) controlled from the after steering station(s). The rudder angle indicator system, circuit N, is used as the repeat-back indicator for the rudder order system. Thus, combined rudder order and rudder angle indicator units are installed at all stations equipped with both units. The rudder order system is associated with the steering emergency signal system, circuit LB, to provide an audible signal for the after steering station to take over the steering control locally.

A representative rudder order system combined with the rudder angle indicator system and the steering emergency signal system in a large ship is illustrated by the block diagram in figure 15-10.

The rudder order system consists of a combined rudder angle-order indicator-transmitter installed in the pilot house and conning stations. This unit is electrically connected to a combined rudder angle-order indicator in the after steering gear room and a rudder angle indicator in throttle station 1.

A rudder order is originated at the conning station by turning the operating knob on the rudder angle-order indicator-transmitter until the transmitter pointer marked 0 indicates the desired order on the dial. The transmitted order is received on the rudder angle-order indicator in the after steering station.

A selector switch is installed on the ACO switchboard for selecting the combined rudder angle-order indicator-transmitter to control the circuit.



7.125

Figure 15-10.—Block diagram of combined rudder order, rudder angle indicator, and steering emergency signal systems.

Digitized by Google

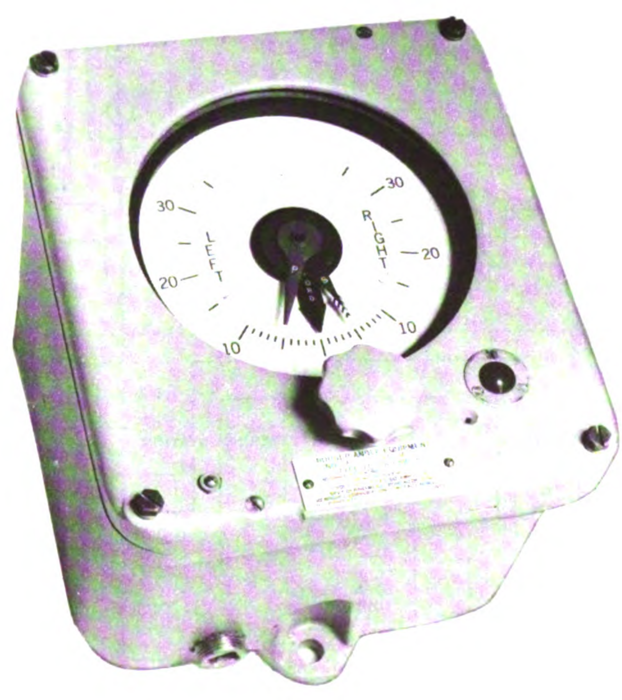
The double rudder angle indicator is installed in ships with rudders that are powered by separate machinery but controlled from the same steering wheel or helm.

DOUBLE RUDDER ANGLE-ORDER INDICATOR-TRANSMITTER

The combined double rudder angle-order indicator-transmitter installed in each conning station (fig. 15-10) is used to transmit rudder orders and to indicate the actual position of a port and starboard rudder.

The unit consists of a 37TX6 synchro transmitter, a 31TR6 and a 23TR6 synchro receiver indicating on a fixed dial of three concentric revolving pointers. The transmitter and receivers are mounted on brackets to form a complete subassembly (fig. 15-11).

The dial is made of a translucent material having a dull white background with black markings. The markings are graduated in degrees to read from 0° to 40° left rudder, and from 0° to 40° right rudder.



7.126

Figure 15-11.—Double rudder angle-order indicator-transmitter.

The pointer marked ORD indicates the transmitted rudder orders. It is geared to the shaft of the 37TX6 synchro transmitter and to the operating knob on the cover below the dial. A friction brake in the subassembly holds the order pointer in the selected position.

The pointer marked S is geared to the shaft of the 31TR6 synchro receiver and indicates the actual position of a starboard rudder. This indication is the reply from the rudder angle transmitter (coupled to a starboard rudder head).

The pointer marked P is directly connected to the shaft of the 23TR6 synchro receiver and indicates the actual position of a port rudder. This indication is the reply from the rudder angle transmitter (coupled to a port rudder head). The reply from the rudder angle transmitters are also indicated on other units throughout the ship.

A pushswitch is provided for manual signaling to the after steering station (fig. 15-12). This pushswitch rings a bell on the unit in the after steering station. The dial is illuminated by 6-volt lamps in the corners of a light panel mounted behind the dial. A pilot light indicates when the system is energized.

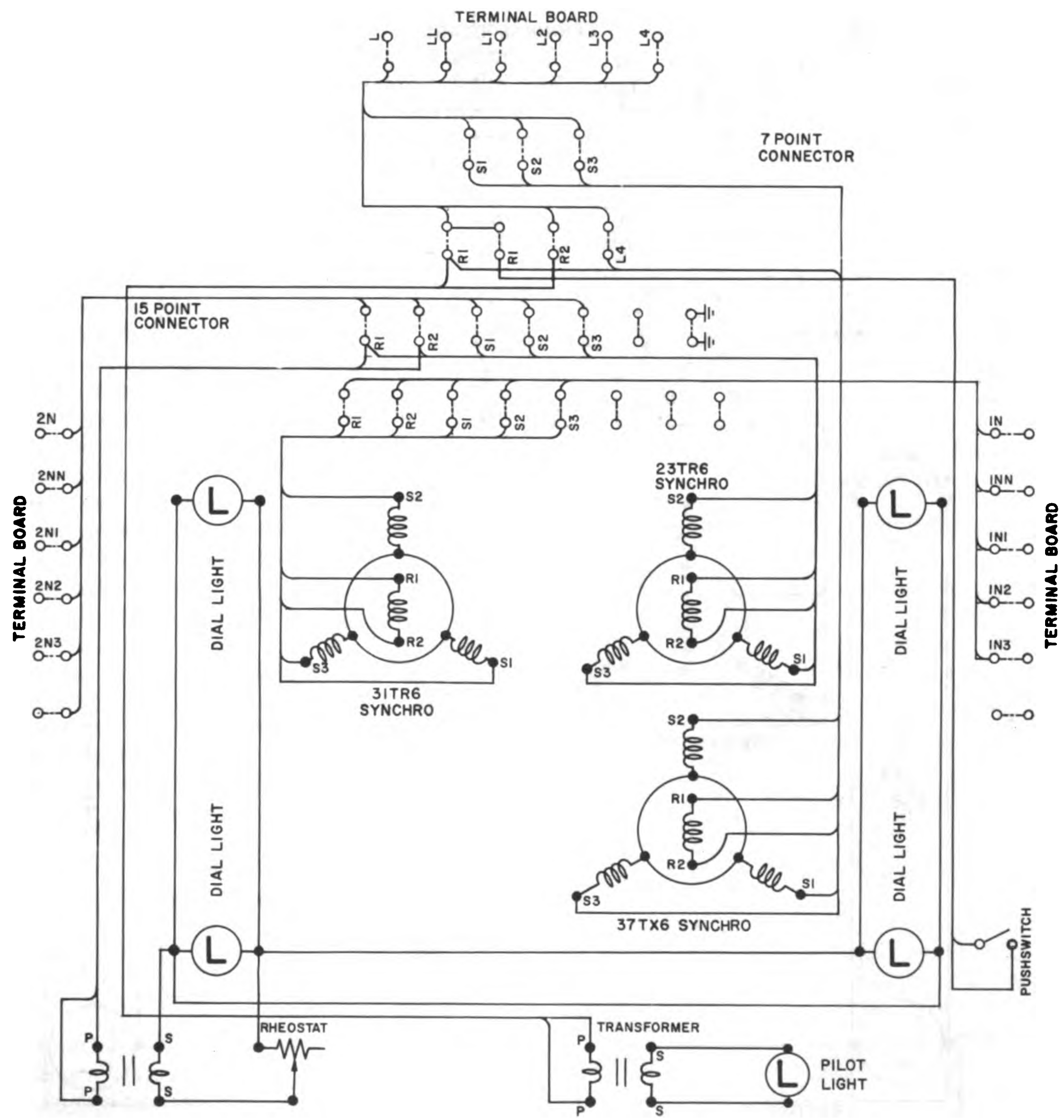
DOUBLE RUDDER ANGLE-ORDER INDICATOR

The combined rudder angle-order indicator installed in the after steering station (fig. 15-10) is used to indicate the transmitted order from the conning station and the positions of the rudders as they respond to the trick wheel (emergency helm).

The unit consists of two 31TR6 synchro receivers and a 23TR6 synchro receiver indicating on a fixed dial of three concentric revolving pointers. The three receivers are mounted on brackets to form a complete rudder angle-order indicator assembly.

The pointer 0 is geared to the shaft of a 31TR6 synchro receiver and indicates the rudder orders transmitted from the conning station. The pointer marked S is geared to the shaft of a 31TR6 synchro receiver and indicates the actual position of a starboard rudder. The pointer marked P is directly attached to the shaft of the 23TR6 synchro receiver and indicates the actual position of a port rudder. A bell on the unit rings each time the rudder order is changed.

Digitized by Google



7.127

Figure 15-12.—Wiring diagram of double rudder angle-order indicator-transmitter.

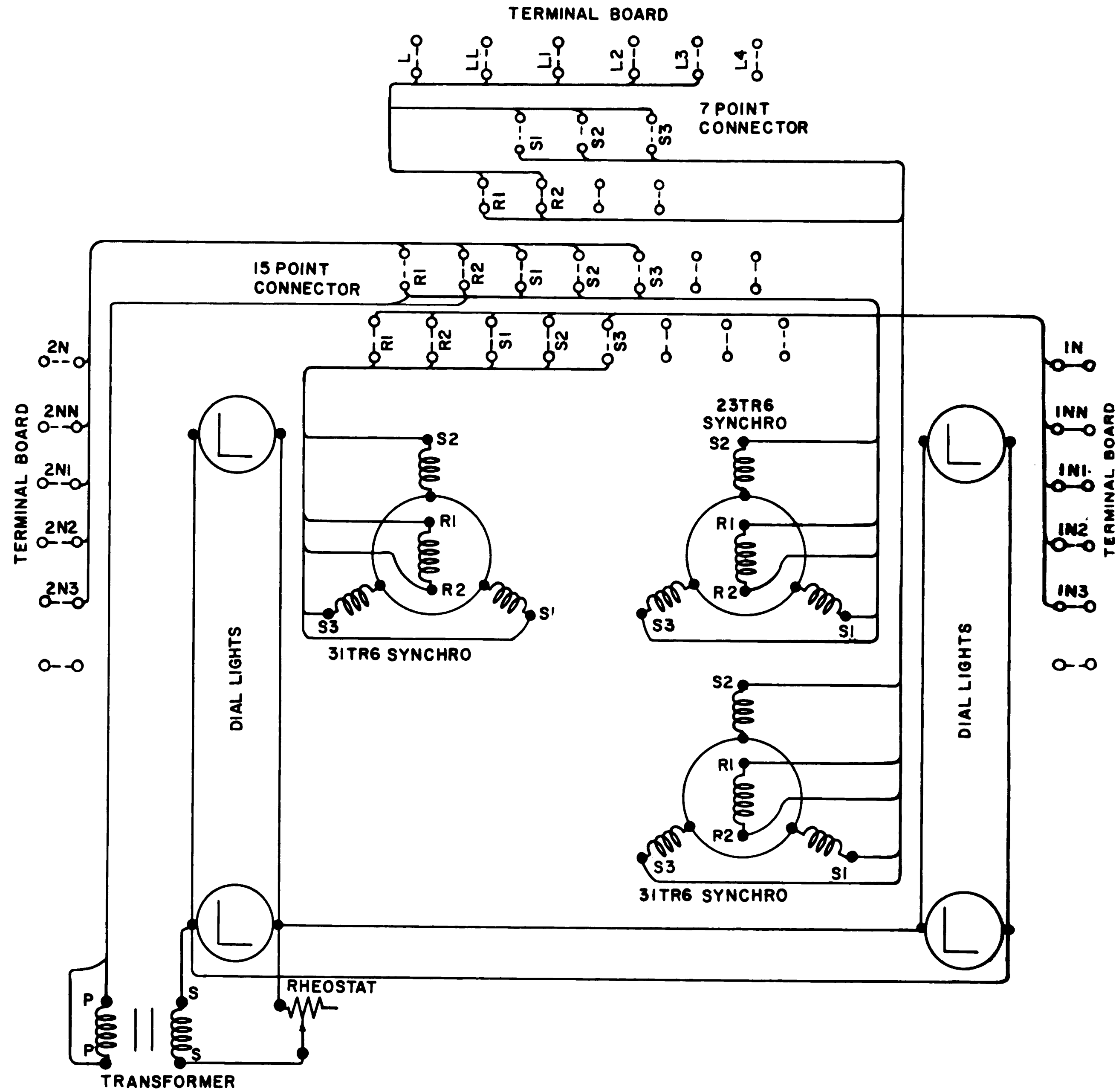
The dial is similar to that of the combined double rudder angle-order indicator-transmitter (fig. 15-11). Dial illumination is provided by 6-volt lamps located in the corners of a light-conducting panel mounted behind the dial. The dial lamp circuit is supplied from a

Digitized by Google

transformer and the intensity of illumination is controlled by a rheostat (fig. 15-13).

RUDDER ANGLE INDICATOR SYSTEM

The rudder angle indicator system, circuit N, is used to transmit indications of the actual position of the rudder to the after steering station, conning stations, throttle stations and other remote positions throughout the ship. The rudder angle indicator system (fig. 15-10) consists of a rudder angle transmitter(s) coupled mechanically to the rudder head(s) in the after



7.128

Figure 15-13. —Wiring diagram of double rudder angle-order indicator

Digitized by Google

steering station(s). For simplicity, only one rudder angle transmitter is shown. The unit is electrically connected to a combined rudder angle-order indicator-transmitter in each conning station, a combined rudder angle-order indicator in the after steering stations, and double rudder angle indicators at other stations.

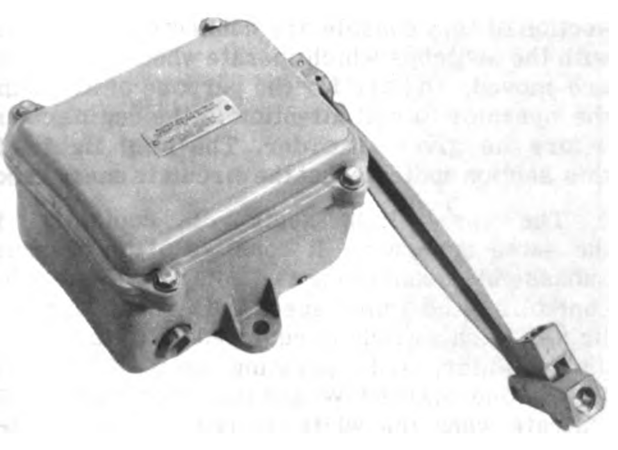
When the position of the rudder is changed to correspond with the transmitted order from the conning station (in emergencies) or from the conning helm or steering wheel (normal), the rudder angle transmitter transmits the angular position of the rudder to the rudder angle indicators.

RUDDER ANGLE TRANSMITTER

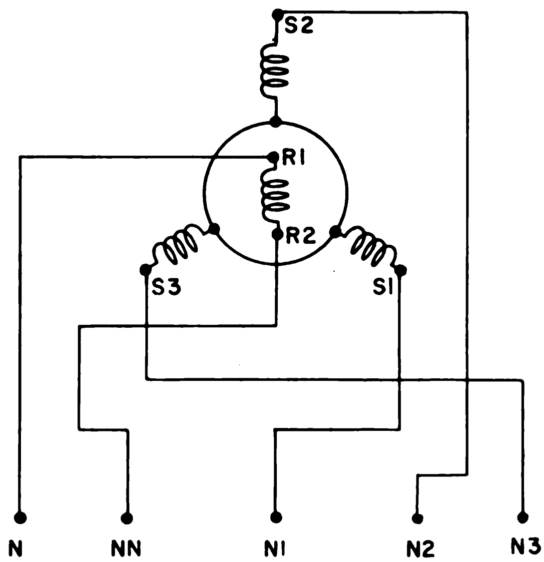
The rudder angle transmitter coupled to the rudder head in the after steering station (fig. 15-10) is used to transmit the actual position of the rudder to indicators at the conning stations, after steering station, and other stations.

The unit consists of a 37TX6 synchro transmitter enclosed in a metal case designed for bulkhead mounting (fig. 15-14). The shaft of the transmitter is geared to a lever arm that is mechanically linked to the rudder by couplings. The gear ratio between the input shaft and the transmitter shaft is 4 to 1, so that a 4° movement of the transmitter shaft equals 1° on the input shaft. As previously stated, the transmitter is connected electrically to indicators throughout the ship.

The wiring diagram of the rudder angle transmitter is illustrated in figure 15-15.



7.129
Figure 15-14.—Rudder angle transmitter.



7.130
Figure 15-15.—Wiring diagram of rudder angle transmitter.

DOUBLE RUDDER ANGLE INDICATOR

The double rudder angle indicator installed in throttle station 1 (fig. 15-10) is used to indicate the actual positions of a starboard and port rudder.

The unit consists of a 31TR6 and a 23TR6 synchro receiver (fig. 15-16). The receivers are mounted on brackets to form a complete double rudder angle indicator subassembly.

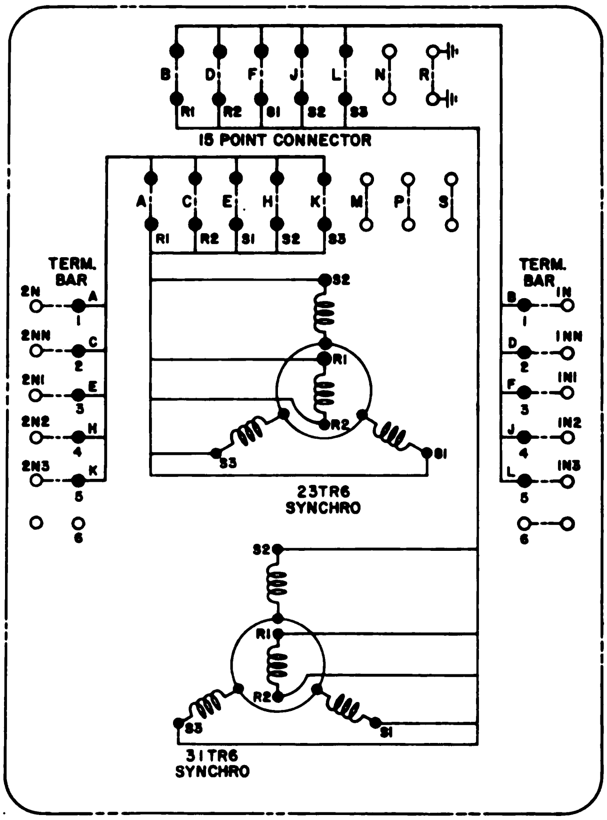
The dial is similar to that of the combined rudder angle-order indicator-transmitter (fig. 15-11).

The pointer marked S is geared to the shaft of the 31TR6 synchro receiver and indicates the actual position of a starboard rudder. The pointer marked P is directly attached to the shaft of the 23TR6 synchro receiver and indicates the actual position of a port rudder. The unit may or may not be provided with dial illumination.

STEERING EMERGENCY SIGNAL SYSTEM

The steering emergency signal system, circuit LB, provides a signal from the conning station to the after steering station for shifting the steering control to the trick wheel in the steering gear room.

Digitized by Google



7.131
Figure 15-16.—Wiring diagram of double rudder angle indicator.

The steering emergency signal system (fig. 15-10) consists of a contact maker installed adjacent to the combined rudder angle-order indicator-transmitter in the pilot house, and conning stations. These contact makers are electricially connected to a siren in the after steering station.

When steering control is lost at the conning station, the contact maker is manually operated to complete the circuit to the siren in the after steering station. This signal is an emergency warning to the steering gear room to take over the steering control locally.

SHIP CONTROL AND STEERING CONTROL CONSOLES

Ship control and steering control consoles are normally installed in the pilot house and serve as a direct method of controlling the ship. These consoles concentrate in one location many of the interior communications units formerly scattered in several locations about the bridge. The units are combined in two consoles which usually weigh less and require less space than the same units installed separately. The components of the consoles are mounted so that they are easily visible and accessible to the personnel concerned with the control of the ship.

SHIP CONTROL CONSOLE

The ship control console (fig. 15-17) consists of the (1) engine order section, (2) speed light section, and (3) propeller order section.

The engine order section contains the port and starboard engine order indicator-transmitters with the associated pilot lights and ringing pushswitches. When the operating handles on this section are manually set to the desired order, the synchro transmitters which are geared to these handles, transmit the angular positions to the synchro receivers in the engineroom indicator-transmitters. The pointers on the receivers will indicate the same position as the transmitters. A repeat-back is incorporated in the system to enable the engineroom operator to acknowledge the received orders. The repeat-back system is the same as the order system, except the synchro transmitters are in the engineroom indicator-transmitters and the synchro receivers are in the engine order section of the pilot house console.

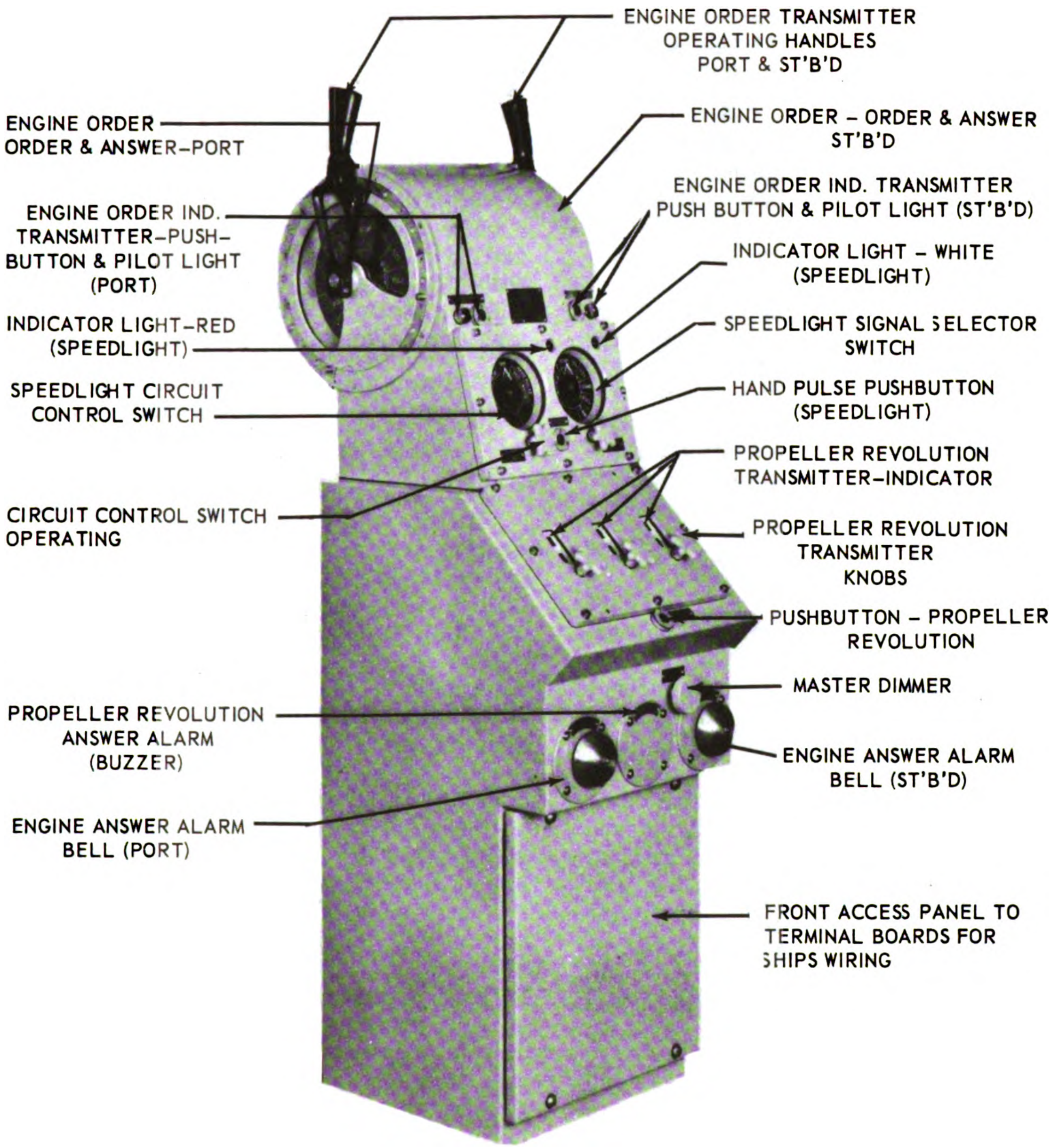
Each time an operating handle is moved from one order to another a switch is actuated which rings bells at both the transmitters and receivers. The pushswitches in the engine order section of this console are connected in parallel with the switches which operate when the handles are moved, and are for the purpose of allowing the operator to call attention to the engineroom before he gives an order. The pilot lights in this section indicate that the circuit is energized.

The speed light section is contained in the same enclosure. It consists of an internal subassembly containing two rotary switches for controlling the ship's speed and aircraft warning lights. Each switch is equipped with its proper dial, pointer, and operating knob. Two pilot lights, one marked W and the other marked R, indicate when the white or red lights are energized. A pushswitch is provided to actuate the "hand pulse" circuit.

Digitized by Google

The propeller order section contains the propeller order indicator-transmitter with the associated ringing pushswitch. This section is operated in the same manner as the engine order section, except that it transmits and receives propeller orders instead of engine orders, and is operated by knobs in lieu of handles.

A panel directly below the propeller order section contains two bells, one each for the port and starboard engine order indicator-transmitters; a buzzer for the propeller order indicator-transmitter; and a master dimmer for controlling the intensity of illumination on the dials.



7.132

Figure 15-17. —Ship control console.

Digitized by Google

STEERING CONTROL CONSOLE

The steering control console (fig. 15-18) is used in conjunction with the ship control console. It consists of units such as the rudder angle-order indicator-transmitter, helm angle indicator, steering transmitter, ship's course indicator, course-to-steer-indicator, magnetic compass repeater, and steering emergency switch.

The rudder angle order indicator-transmitter consists of a 37TX6 synchro transmitter, and a 23TR6 and a 31TR6 synchro receiver, indicating on a fixed dial by three concentric revolving pointers.

When the operating knob is set to the desired position of the rudder on the dial, the synchro transmitter transmits this angular position to the synchro receiver in the rudder angle-order indicator in the steering gear room. The repeat-back is the rudder angle indicator system. The synchro transmitters of this system, which are geared to the rudder heads located in the after steering stations, are electrically connected to the synchro receivers in the rudder angle-order indicator-transmitter unit of the steering control console, and in rudder angle indicator units at other required stations. The pushswitch, associated with the rudder angle-order indicator-transmitter of the steering control console, operates a bell in the steering gear room to call attention to a change of orders.

An emergency rudder angle indicator system has been added to the steering control system on all the latest large ships. The emergency system consists of a transmitter, mechanical linkage, and selector switch. The transmitter is of the same type as that used in the normal system. This transmitter is located in a compartment above the after steering station and connected to the rudder head by a mechanical linkage. The selector switch located in the pilot house energizes the emergency rudder angle indicating system whenever it is required.

The helm angle indicator consists of two synchro receivers, indicating on a fixed dial by two concentric revolving pointers. The synchro receivers are connected electrically to synchro transmitters on the steering gear and indicate the angle of the helm as received from the steering control transmitter in the console. A mechanical helm angle indicator, geared to the steering control transmitter is sometimes used in lieu of the synchro type.

The steering control transmitter, actuated by the steering wheel, is electrically connected to a synchro receiver mounted on each steering gear mechanical differential control box (port or starboard).

The ship's course indicator and the course-to-steer indicator consist of synchro receivers electrically connected to synchro transmitters on the master gyrocompass. These indicators indicate own ship's course and provide own ship's course inputs to fire control systems, electronics systems, and navigational equipment.

The rudder angle transfer switch is a standard Navy-type JR rotary switch having a normal and an emergency position. It is used to transfer from the normal to the emergency rudder angle indicator system in the event of power failure.

The steering emergency switch is a standard Navy-type on-off switch used in conjunction with the steering gear to signal from the conning stations to the steering gear room that a steering control casualty has occurred.

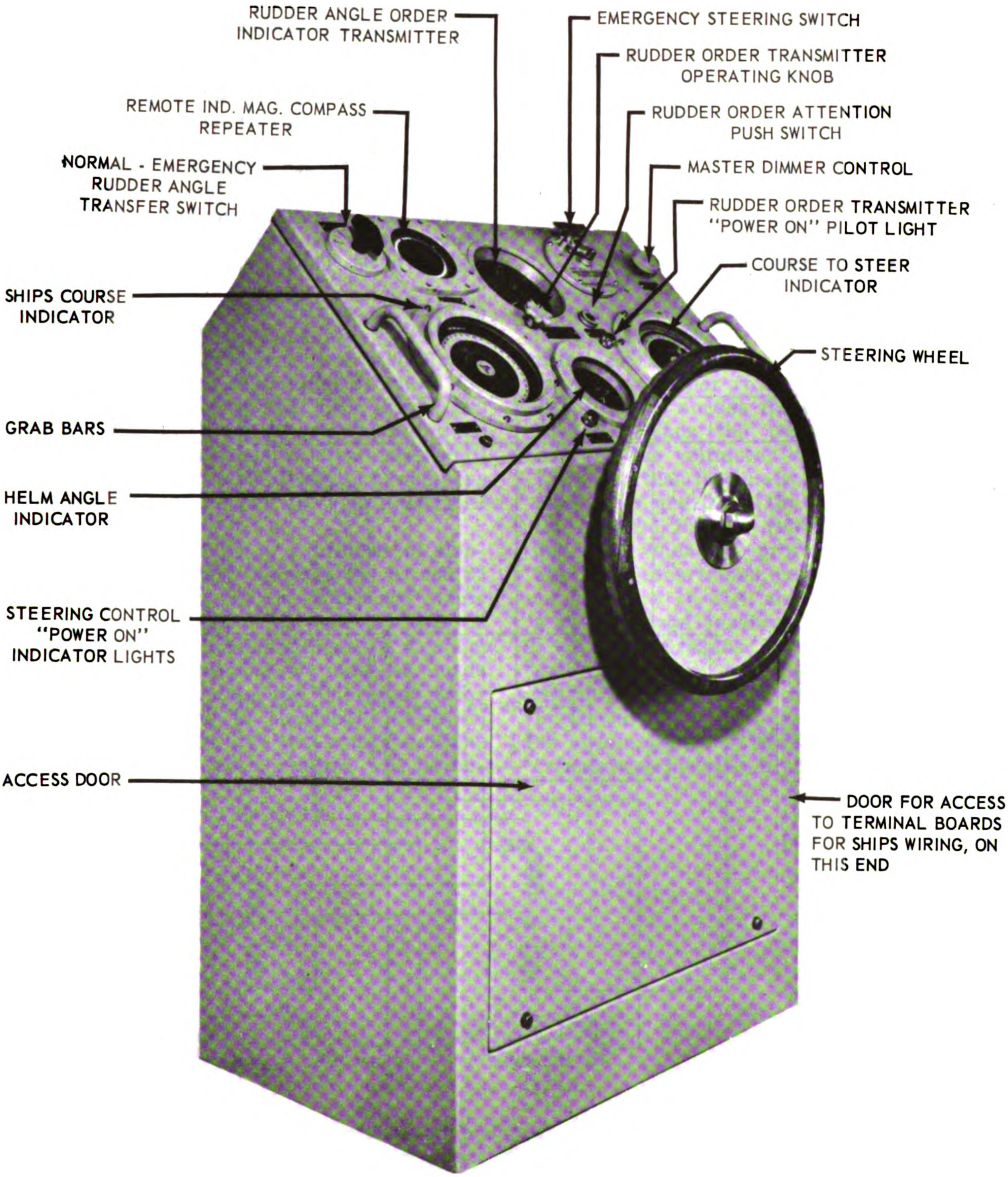
A dimmer is provided to control the intensity of illumination on all of the dials.

MAINTENANCE

If the ship control order and indicating equipment does not function properly and the cause is not immediately apparent, check for failure of the power supply, blown fuses, burned out dial illumination, and defective wiring, before starting a detailed examination of the circuit units and parts of the equipment. Some faults such as burned out lamps, rheostats, shorted transformers, or wiring can often be located by sight or smell. Check for smoke or odor of burned or overheated parts.

Troubleshooting of electrical circuits and components is readily accomplished by following standard procedures for circuit tracing to isolate the fault. Do not attempt to disassemble the unit until all signal and power sources have been checked and the trouble has been definitely located on the unit. As previously stated, the units comprising the ship control order and indicating systems operate on a standard synchro transmission system. Detailed information concerning the operation and maintenance of synchros is contained in the manufacturer's technical manual furnished with the equipment, Navy Ordnance Pamphlet No. 1303, and the training course Basic Electricity, NavPers 10086-A.

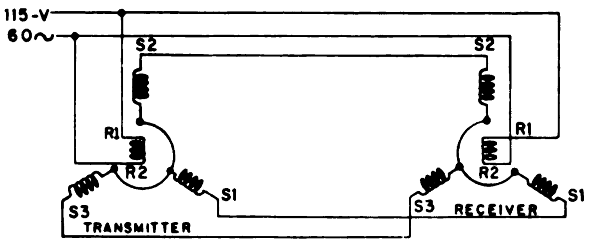
Digitized by Google



7.133

Figure 15-18.—Steering control console.

Digitized by Google

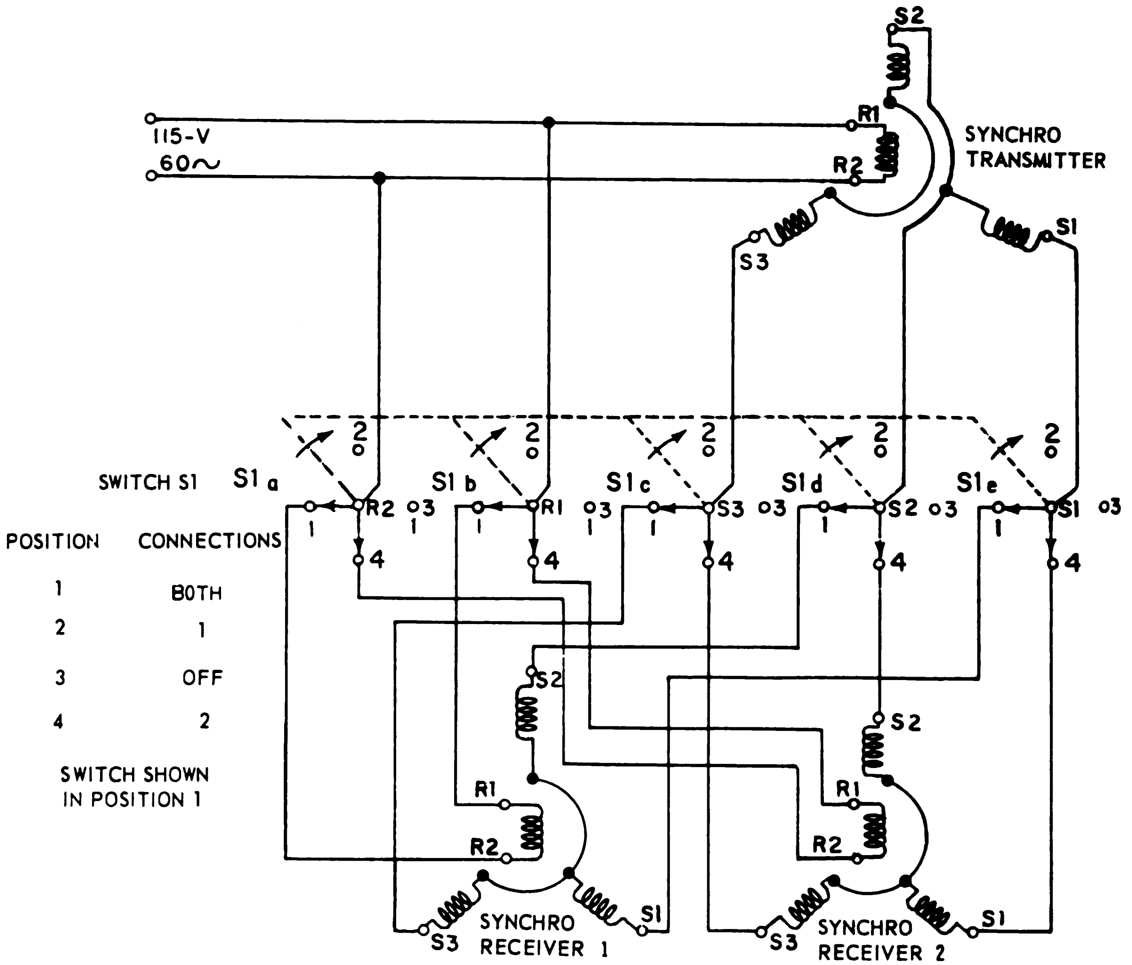


7. 134

Figure 15-19.—Simple synchro transmission system.

chros are installed in a system. The conventional connection is for counterclockwise rotation for an increasing reading.

The standard connections of a simple synchro transmission system consisting of a synchro transmitter and receiver are illustrated in figure 15-19. The R1 transmitter and receiver leads are connected to one side of the 115-volt a-c supply line, and the R2 transmitter and receiver leads are connected to the other side of the line. The stator leads of both the transmitter and receiver are connected lead for lead—that is, S1 is connected to S1, S2 to S2, and S3 to S3. Thus, when an increasing reading



7.135

Figure 15-20. —Connections of synchro transmitter and two independent synchro receivers through a rotary switch.

STANDARD SYNCHRO CONNECTIONS

Standard connections for synchros have been established to avoid confusion when many synchros are installed in a system. [continued above]

is sent over the transmission system, the rotor of the synchro receiver will turn in a counterclockwise direction.

Digitized by Google

When it is desired that the shaft of the synchro receiver turn clockwise for an increasing reading, the R1 and R2 transmitter and receiver leads are connected as before, and the S1 transmitter lead is connected to the S3 receiver lead, the S2 transmitter lead to the S2 receiver lead, and the S3 transmitter lead to the S1 receiver lead.

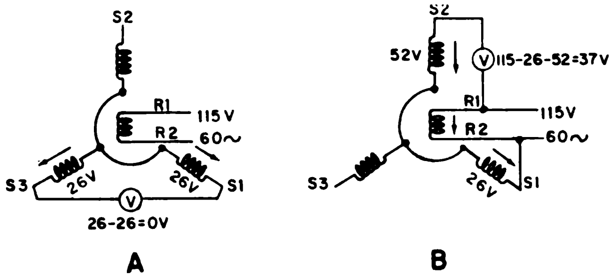
The standard connections of a synchro transmitter to two independent synchro receivers through a rotary switch is illustrated by the wiring diagram in figure 15-20.

SETTING SYNCHROS

In any synchro system that is expected to operate with any degree of accuracy, it is most important that the synchros are electrically zeroed. The methods of zeroing synchros include the use of a voltmeter, neon lamps, two lamps and a headset, and other synchros in the system. However, the most accurate method of setting both synchro transmitters and receivers is obtained by using a voltmeter as illustrated in figure 15-21.

For a synchro to be in a position of electrical zero, the voltage between the S1 and S3 leads must be zero and the rotor and stator voltages are subtractive between R1 and S2 when R2 and S1 are connected together. Connect a volt-meter across the S1 and S3 leads (fig. 15-21A) and rotate the energized rotor until a zero reading is obtained. However, remember that there are two rotor positions 180° apart where a zero reading will be obtained on the voltmeter. In order to locate the proper zero position, it is necessary to determine if the rotor and stator voltages are subtractive. To determine this phase relation, connect a jumper from S1 to the R2 leads and a voltmeter across the S2 and R1 leads (fig. 15-21B). When the polarity relationship is correct, the voltmeter will read LESS (115v - 78v = 37v) than the line voltage. If the voltmeter reading is greater (115v + 78v = 193v) than the line voltage, then the rotor must be rotated 180 degrees. When the proper phase relationship has been ascertained, connect the circuit again as in figure 15-21A, and readjust the rotor for a zero voltage reading across leads S1 and S3.

If for any reason, it is necessary to apply an external voltage to the stator windings for any length of time, some method of obtaining a maximum of 78 volts must be used. This can be accomplished by using a transformer, autotransformer, variac, or dropping resistor.



7.136

Figure 15-21.—Zeroing synchros.

Digitized by Google

CHAPTER 16

SHIP'S METERING AND INDICATING SYSTEMS

Ship's metering and indicating systems include the shaft propeller revolution indicator systems, wind direction and speed indicator system, salinity indicator system, underwater log system, and many others.

The units comprising the ship's metering and indicating systems are enclosed in splash proof metal cases designed for bulkhead or panel mounting, depending on the stations in which they are located. Windows are provided in the unit covers where required for viewing the dials and counters. The internal subassemblies can be withdrawn individually from the cases to facilitate troubleshooting and repairs.

The incoming ship's cables are brought through watertight terminal tubes into the cases and the leads are connected to terminal strips or female connectors. The leads for the synchros, backing signals, and other components are connected to corresponding terminal strips or male connectors within the cases.

FRICTION DISK AND ROLLER ASSEMBLIES

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.

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.

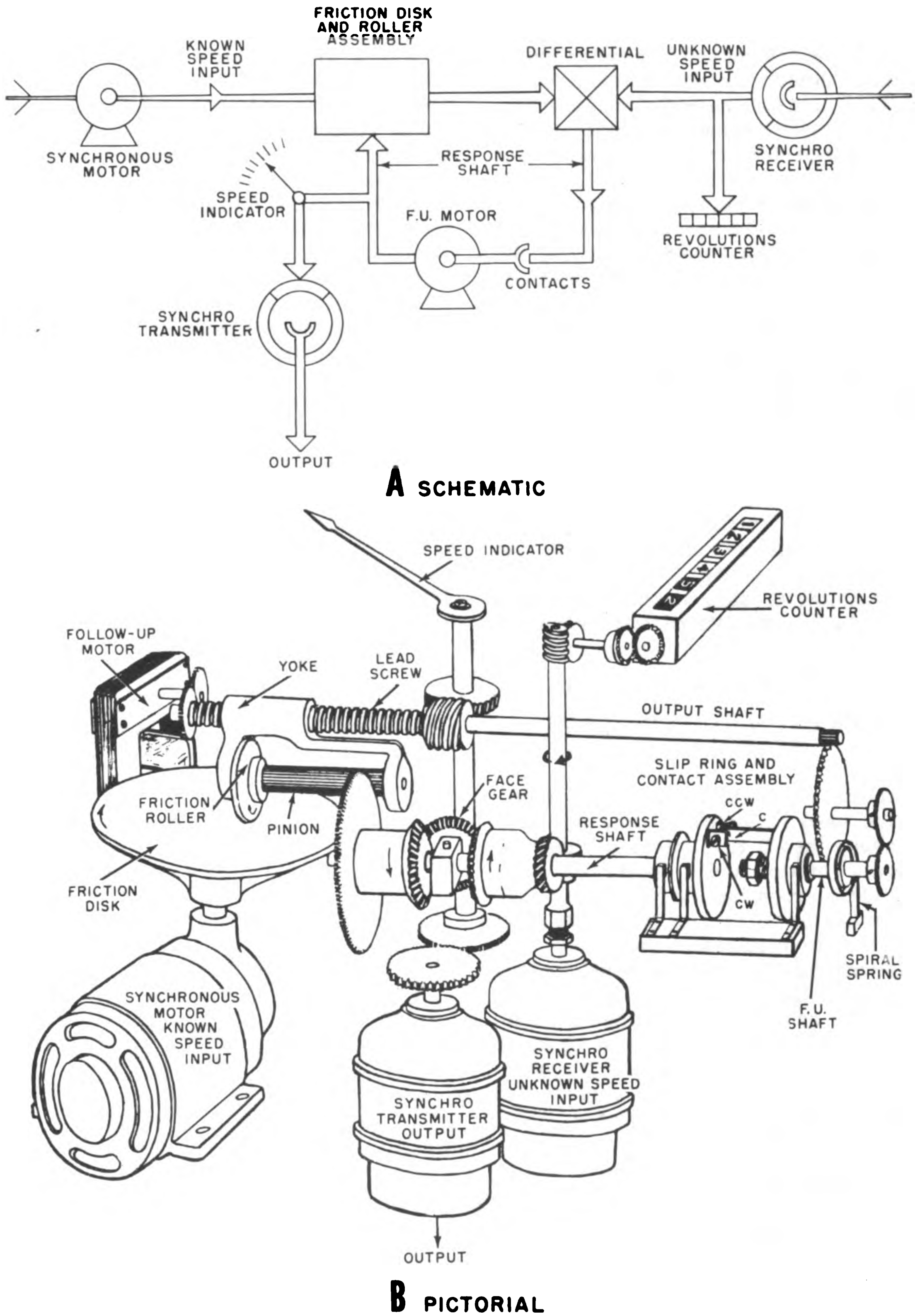
The friction disk and roller assembly is illustrated in figure 16-1. This device operates on the principle of comparing an unknown speed with a known speed through a differential and using the output of the differential to make these quantities approach equality. Electrical contacts operate in response to the differential output and control a followup motor that matches the two speeds (fig. 16-1A).

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 sycnhro rotor shaft drives the six-place odometer (fig. 16-1B).

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 CCW, each connected to a slip ring. These contacts do not normally make contact with the

Digitized by Google



140.59

Figure 16-1.—Friction disk and roller assembly.

Digitized by Google

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.

PROPELLER REVOLUTION INDICATOR SYSTEM

The propeller revolution indicator system, circuit K, is used to indicate instantaneously and continuously the (1) revolutions per minute, (2) direction of rotation, and (3) total revolutions of the individual propeller shafts. The information is indicated in the enginerooms, pilot house, and other required locations.

The system comprises the (1) synchro-type equipment and (2) magneto-voltmeter-type equipment. The synchro-type equipment is installed in large combatant ships and in many newly constructed small ships. The magneto-voltmeter-type equipment is less complicated and is installed in small ships, such as AMs, AMSs, and many others.

SYNCHRO-TYPE EQUIPMENT

A representative synchro-type propeller revolution indicator system installed in a large ship is illustrated by the block diagram in figure 16-2. The system consists of various transmitters, indicator-transmitters, and indicators. The transmitters for shafts 1 and 4 are installed in boiler operating station 3, and those for shafts 2 and 3 are installed in the after auxiliary machinery room. The transmitters are electrically connected to indicator-transmitters in their respective throttle stations. Indicators are also installed on the gage boards in the associated enginerooms and in the pilot houses as required by the types of ships. Each indicator is provided with a backing signal lamp which, when lighted, denotes astern rotation of the propeller shaft.

The rotary motions of the propeller shafts are transmitted by the shaft transmitters to the associated indicator-transmitters which convert the received rotary motions into stationary angular synchro displacements. The angular displacements, which are proportional to the speeds of the propeller shafts, are transmitted to indicators located at various stations. The indicators repeat the rpm readings received from the associated indicator-transmitters.

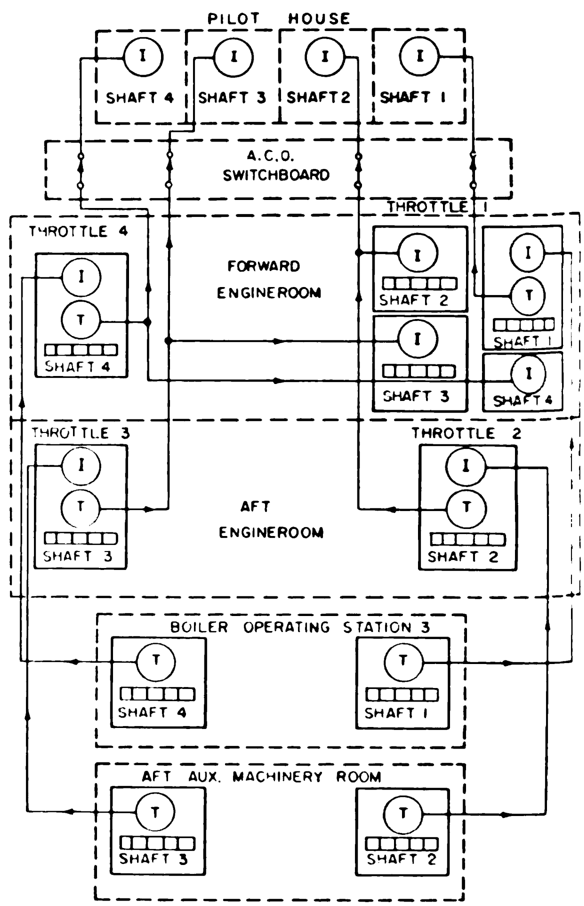


Figure 16-2.—Block diagram of propeller revolution indicator system.

Digitized by Google

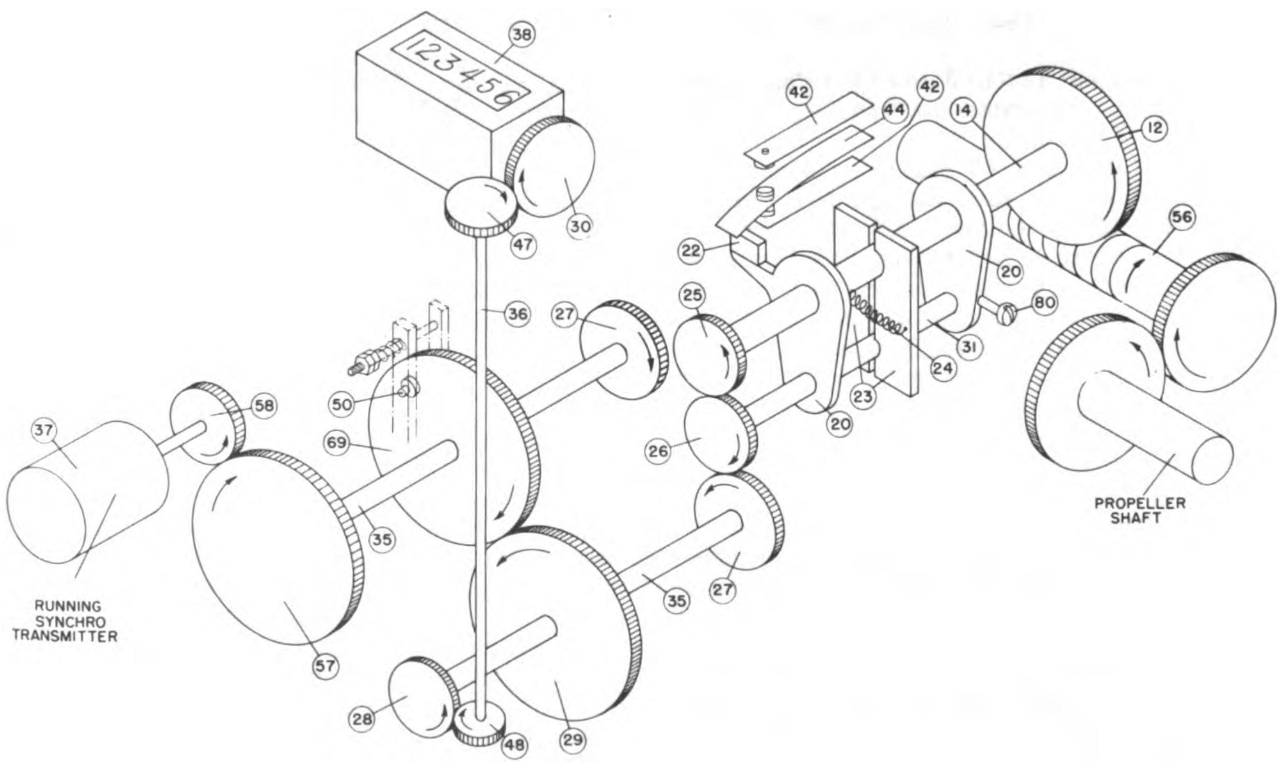
Transmitter

The transmitter, one for each propeller shaft (fig. 16-1), is used to indicate the revolutions of the propeller shaft and to transmit the speed and direction of rotation of the propeller shaft to the associated indicator-transmitter.

The unit consists of a running synchro transmitter, revolution counter, and contact assembly (fig. 16-3). These components, which are actuated by suitable gearing, are mounted in a watertight housing to form a complete transmitter subassembly. The transmitter is either gear driven from the propeller shaft, or is directly coupled to the end of a stub shaft of the propulsion machinery as required by the particular installation. The synchro transmitter is always driven at twice the propeller speed in a constant clockwise direction.

A drive worm, cut integral with the shaft 56, meshes with worm gear 12, which is secured to shaft 14. The ratio is such that shaft 14 is driven at exactly one-tenth the propeller speed. The gear 25 is attached to shaft 14 and the links 20 are free to swing on the shaft. The lower ends of links 20 support the swinging shaft 31. The gear 26 is attached to shaft 31. The friction blocks 23 are held in contact with the hubs of gears 25 and 26 by the spring 24. The friction blocks restrain the rotation of the gears 25 and 26 and swing the links assembly, including shaft 31 and gear 26 in the direction of rotation of gear 25. This action engages gear 26 with one of the two gears 27, the selection depending on the direction of rotation of gear 25. The screws 80 limit the angular swing of the links assembly.

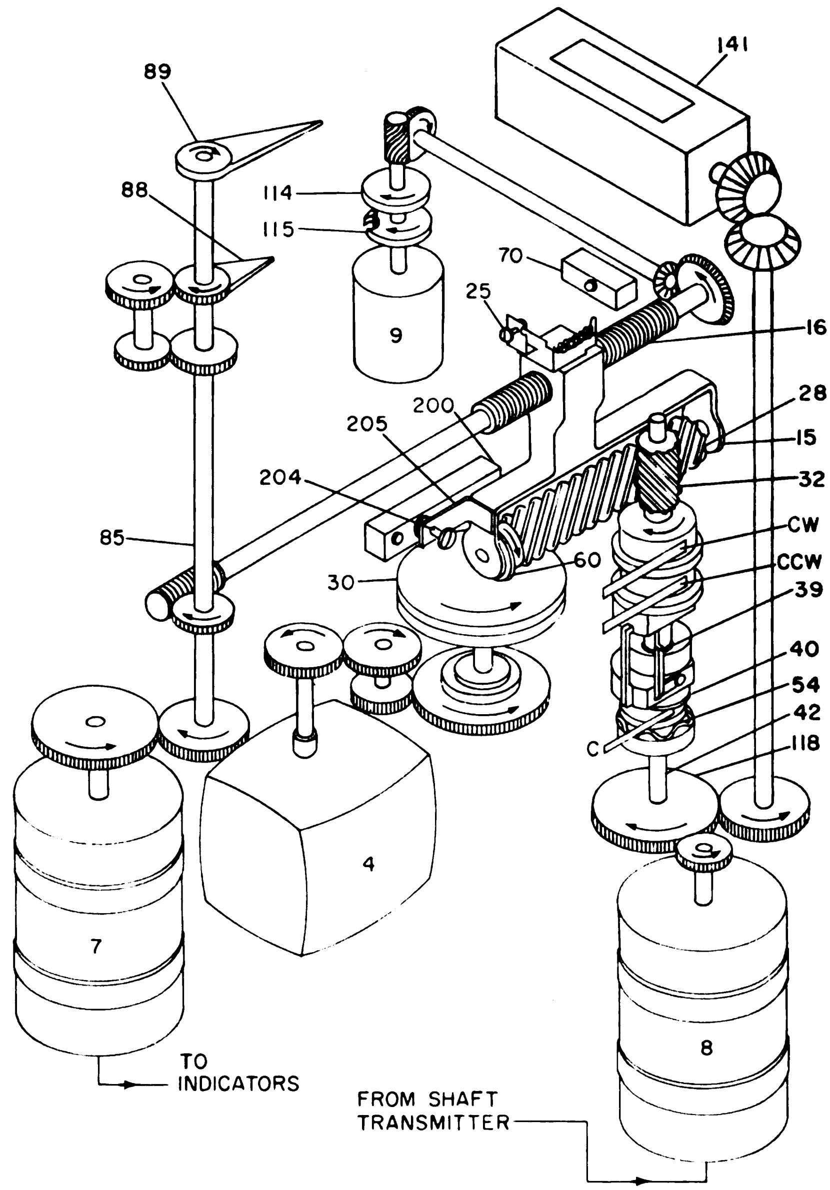
The gears 27 are secured to the respective side shafts 35, which also carry gears 29 and 69. These gears are meshed and drive each other alternately, depending on which one of the two gears 27 is engaged with the swinging idler gear 26. Gears 29 and 69 do not reverse when the propeller shaft reverses because idler gear 26 reverses rotation each time it swings from side to side. The same is true for gears 28 and 57, because they are mounted on the hubs of gears 29 and 69, respectively. Gear 57 engages gear 58 which is mounted directly on the shaft of the synchro transmitter 37. The overall gear



7.139

Figure 16-3.—Gearing diagram of transmitter.

Digitized by Google



LEGEND

4 – SYNCHRONOUS MOTOR
7 – POSITIONING SYNCHRO TRANSMITTER
8 – RUNNING SYNCHRO RECEIVER
9 – FOLLOWUP MOTOR
15 – TRAVELING YOKE
16 – LEAD SCREW
25 – SWITCH OPERATING SCREW
28 – HELICAL GEAR
30 – FRICTION DISK
32– HELICAL GEAR
39– SLIP RING AND CONTACT ASSEMBLY
40– HUB ASSEMBLY
42– INPUT SHAFT
54– SPRING WASHER
60– FRICTION ROLLER
70– LIMIT SWITCH
85– POINTER SHAFT
88– INNER POINTER
89–OUTER POINTER
114–DRIVEN DISK
115–DRIVE DISK
118–INPUT GEAR
141–MECHANICAL COUNTER
200–SPEED SIGNAL SWITCH
204–ACTUATOR SCREW
205–BRACKET

7.140

Figure 16-4.—Gearing diagram of indicator-transmitter.

Digitized by Google

ratio between the transmitter shaft 56, and the shaft of the synchro transmitter is such that the synchro shaft is always driven at twice the propeller speed in a constant clockwise direction.

The revolution counter 38 which is driven at one-tenth the propeller speed, is driven through helical gears 28, 48, 47, and 30. The reading is directly in terms of propeller revolutions because each revolution of the counter shaft registers a count of ten. The brake shoes 50 prevent the synchro transmitter 37 from driving the counter 38, backward during brief periods of rapid speed reduction.

The contact assembly is actuated by a small insulating block 22, attached to one of the swinging links 20. The block moves up and down as the link swings with reversals of driving rotation. This action moves the center spring contact 44 from the bottom to the top stationary contact 42, and vice versa. The center contact and one of the stationary contacts energize the signal lights in the remote indicator when the propeller shaft rotates in the astern direction.

Indicator-Transmitter

The indicator-transmitter installed in each throttle station (fig. 16-2) is used to convert the running speeds (received from the associated shaft transmitters) into angular synchro displacements which are transmitted to the various indicators.

The unit (fig. 16-4) consists of a running synchro receiver, a speed-measuring mechanism, a positioning synchro transmitter, revolution counter, two pointers, a dial, and a backing signal. These components and associated gears are mounted on a baseplate to form a complete indicator-transmitter subassembly enclosed in a watertight housing.

The two concentric revolving pointers indicate on a dual-marked fixed-dial the output in rpm of the speed-measuring mechanism. The inner scale, marked for each 100 rpm only, is indexed by the short pointer 88. The outer scale, calibrated from zero to 100 rpm with numerals for each 5 rpm, is indexed by the long pointer 89. The positioning synchro transmitter 7, and pointers 88 and 89 are geared to the friction roller 60, and followup motor 9. The long pointer 89 makes one complete revolution every 100 rpm and the short pointer 88 makes one complete revolution for full scale indication. The relative direction of the speed is indicated by the backing signal indicator which is lighted only when the propeller shaft rotates in the astern direction.

The running synchro receiver 8 is driven electrically by the associated shaft transmitter at a speed exactly one-tenth that of the propeller shaft. The running synchro drives the input shaft of the speed-measuring mechanism through gear 118. The speed-measuring mechanism converts the rotary motions into proportional angular displacements. The running synchro 8 also drives the revolution counter 141 through gears at a speed exactly one-tenth that of the propeller speed. The revolution counter registers the total propeller revolutions directly, irrespective of the direction of rotation.

The positioning synchro transmitter 7 receives the angular displacements from the speed-measuring mechanism and transmits these displacements to the remotely located indicators.

The speed measuring mechanism operates on the friction disk and roller assembly principle.

The unknown speed is the input of the running synchro receiver 8, which is geared to the input shaft 42 of the speed-measuring mechanism through gear 118 (fig. 16-4).

The known speed is provided by the synchronous motor 4, which drives the friction disk 30 through gears at a constant speed. The gearing is such that the disk speed is 16 2/3 rpm for 200 range units and 33 1/3 rpm for 400 range units. The friction disk is held in continuous contact with the friction roller 60, which is integral with the helical gear 28. The friction roller and helical gear are mounted on the traveling yoke 15, which has a total longitudinal motion of approximately 1.10 inches along the radius of the friction disk 30. The yoke is positioned along the disk radius by the lead screw 16, which is driven by the followup motor 9.

The friction roller 60, integral with helical gear 28, drives the helical gear 32, which is mounted on, but free to turn, through a limited range about the input shaft 42. Thus, the helical 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 radius of contact at any given point will determine the drive ratio and speed at which the roller 60, and gears 28 and 32 will rotate.

The speed of helical gear 32 is automatically adjusted to match the speed of the running synchro driven gear 118, by the slipring and contact assembly 39, the upper two sliprings of which

Digitized by Google

are mounted on the hub of gear 32 and are free to turn through a limited range about the input shaft 42. The assembly carries two outside brush contacts CW and CCW, each of which slides on a slipring. The center brush contact C slides on a slipring which is attached to the hub 40 and is secured to the input shaft 42 by the friction thrust washer 54. The contact assembly can be turned in either direction so that one or the other of the outside contacts can mate with the center contact. This action energizes the followup motor 9 and determines its direction of rotation.

When the input gear 118 and the helical gear 32 are running at exactly the same speed, the contacts are open, the followup motor 9 is deenergized, and the indicator pointers 88 and 89 are stationary. However, if the speed of gear 118 changes, the followup motor 9 is energized and drives the lead screw 16, which moves the yoke 15, in or out, depending on the direction of rotation. If the speed of gear 118 is faster than the original balanced speed, the CW contacts close, and if the speed is lower, the CCW contacts close. The contacts will remain closed to energize the followup motor in a correcting direction until the radius of disk contact with roller 60 reaches a new value where the speed of gear 32 is again equal to that of gear 118. At this point the contacts open to deenergize the followup motor.

At zero (rpm) input from the running synchro receiver 8, gear 118, is stationary and the contacts of the slipring assembly will cause the followup motor 9 to move the lead screw 16, and thus the friction roller 60, toward the center of the friction disk 30. At the exact center, the indicator pointers 88 and 89 should read zero rpm, and the positioning synchro transmitter 7 should be on electrical zero. However, the pointers will not reach the exact scale zero because a limiting switch (not shown in fig. 16-4) deenergizes the synchronous motor 4 at a pointer indication of approximately 1 rpm.

The full scale indication should occur when the point of roller contact is exactly 1 inch from the center of the disk 30. The indicators provide for an overspeed indication of about 10 percent above full scale (1.10 inches disk radius) before the limit switch 70 is actuated.

The indicator-transmitter can be provided with a speed signal switch 200 to continuously energize a remote light or other signal at propeller speeds below a specified value. The signal setting is adjustable from about one-quarter of full speed down to about 5 rpm. As the speed of the propeller shaft decreases from higher values above the switch operating point, the yoke 15, bracket 205, and actuator screw 204, are advanced along the lead screw 16, until the roller and arm of the stationary SPDT switch 200, are lifted by the actuator screw 204. The speed value at which the switch is operated is determined by the height of the actuator screw 204, above the bracket 205. The speed signal switch is adjusted by turning the actuator screw until the desired operating point is obtained. After the switch has been actuated in decreasing speed direction, it will remain actuated at lower speeds down to zero. Also, when the propeller speed increases, the OFF or release point of the switch will occur at a value slightly above the ON speed value in a decreasing direction because of the operating differential inherent in the microswitch 200.

Indicator with Revolution Counter

The indicator with revolution counter installed in the throttle stations (fig. 16-2) is used to indicate the rpm and total revolutions of the associated propeller shaft. The unit consists of a positioning synchro receiver and a running synchro receiver mounted on a baseplate. A revolving pointer indicates on a dial the rpm of the associated propeller shaft.

The positioning synchro receiver is driven by the positioning synchro transmitter in the associated indicator-transmitter unit (fig. 16-4), and positions the indicator pointer through gears. The running synchro receiver is driven by the associated running synchro transmitter and drives the revolution counter through gears. The entire subassembly is enclosed in a case to form a complete indicator unit. A backing signal light in the unit is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the astern direction.

Indicator

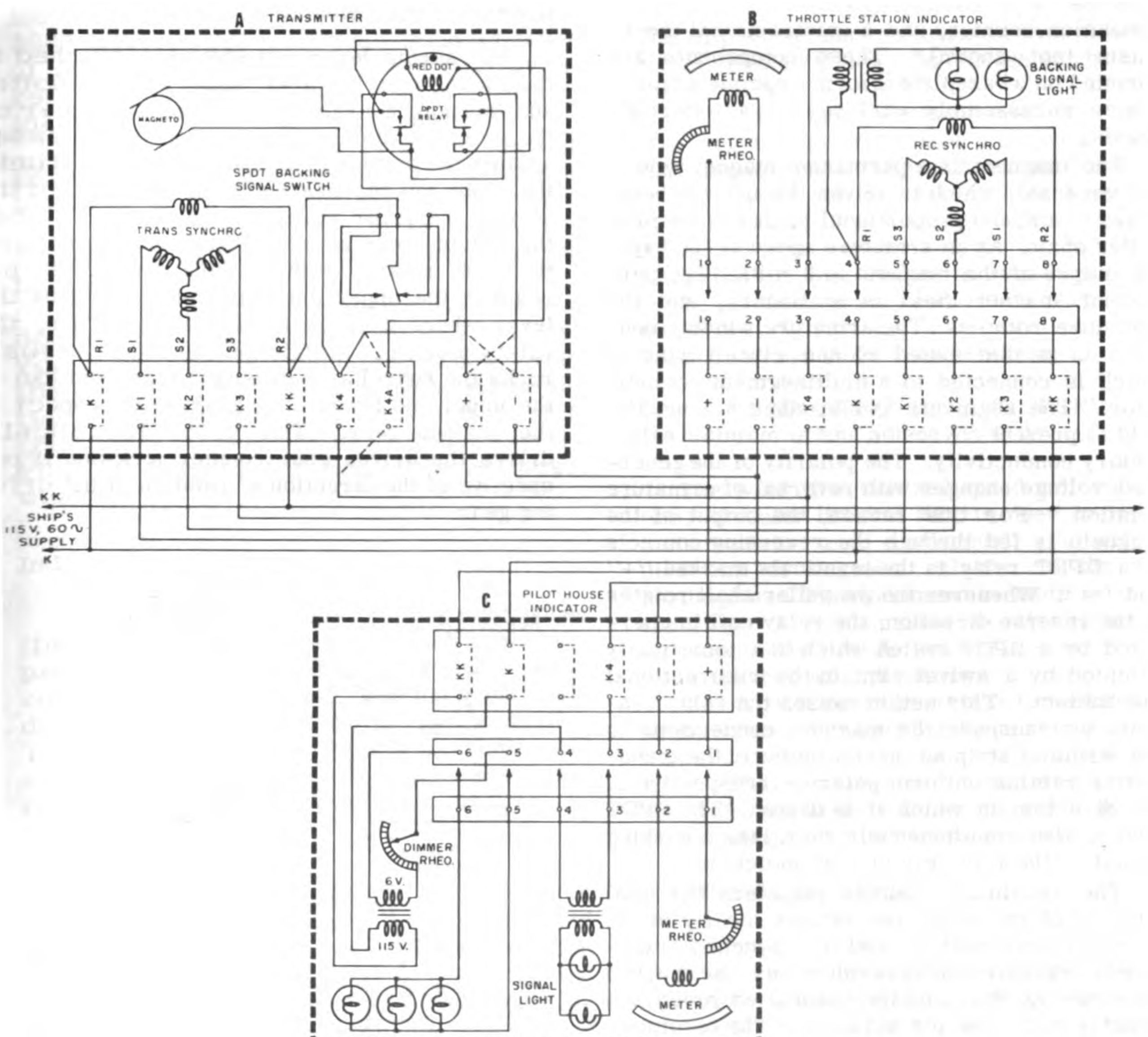
The indicator installed in the pilot house (fig. 16-2) is used to indicate the rpm of the associated propeller shaft. The unit consists of a positioning synchro receiver and a revolving pointer that indicates on a dial the rpm of the associated propeller shaft. The synchro receiver is driven by the positioning synchro transmitter in the associated indicator-transmitter unit (fig. 16-4). The indicator is

Digitized by Google

provided with a backing signal that is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the reverse direction.

MAGNETO-VOLTMETER-TYPE EQUIPMENT

The magneto-voltmeter propeller revolution indicating equipment consists of a transmitter of the magneto type geared to each propeller shaft and electrically connected to remotely located indicators of the voltmeter type. The wiring diagram of a representative magneto-voltmeter propeller revolution indicator system is illustrated in figure 16-5. The speed of the propeller shaft is converted by the magneto into a proportional d-c voltage. The indicators receive this voltage and indicate on the associated scales the rpm of the propeller shaft. The



7.141

Figure 16-5.—Wiring diagram of magneto-voltmeter propeller revolution indicator system.

Digitized by Google

magneto-voltmeter indicating equipment is self-energizing and does not require a separate power source for operation.

Transmitter

The magneto transmitter, coupled to the propeller shaft directly or through gears, is used to generate and transmit to the indicators speed, direction, and total number of revolutions of the propeller shaft. The unit (fig. 16-5A), consists of a magneto, synchro transmitter, revolution counter, and a unidirectional mechanism (not shown). These components are mounted on a baseplate to form a complete transmitter subassembly enclosed in a watertight housing.

The magneto is a permanent magnet type of d-c generator which is driven through two bevel gears at a speed proportional to that of the propeller shaft. At an armature speed of 1000 rpm the output of the magneto is 3 volts. The permanent magnet field is stationary, and the armature rotates. The armature winding consists of a distributed closed circuit winding which is connected to a multisegment commutator. The segments and brushes are usually gold to prevent corrosion and to maintain satisfactory conductivity. The polarity of the generated voltage changes with reversal of armature rotation. For this reason, the output of the magneto is fed through the reversing contacts of a DPDT relay to the terminals marked "+" and "-". Whenever the propeller shaft rotates in the reverse direction, the relay coil is energized by a SPDT switch which is automatically actuated by a swivel arm in the unidirectional mechanism. This action causes the relay contacts to transpose the magneto connections to the terminal strip so that the output of the transmitter retains uniform polarity irrespective of the direction in which it is driven. The SPDT switch also simultaneously energizes a backing signal in the remotely located indicators.

The revolution counter registers the total number of propeller revolutions locally at the magneto transmitter, and the synchro transmitter transmits these revolutions to the synchro receiver which drives the associated revolution counter in the remote indicator. The revolution counter and the synchro transmitter are mechanically driven at one-tenth the propeller speed through appropriate gearing by the input shaft.

The unidirectional mechanism (fig. 16-6), a gear changing device, is incorporated in the gear train that drives the revolution counter and the synchro transmitter in order to add the propeller revolutions in both the ahead and astern directions of the propeller shaft. The mechanism consists of a friction disk, two swivel-mounted idler gears, and a spring lever. The two swivel-mounted idler gears are located between the driving and driven gears so that the driven gear is alternately driven by either the upper or lower idler gear, as determined by the position of the swivel arm.

The spring lever (not shown), is attached to the swivel arm, the lower end of which is slotted and engages a crank pin located off-center on the friction disk. The friction disk presses against the driving gear and rotates with it until the crank pin reaches the lower extremity of the slot in the lever where it is restrained. When the driving gear reverses direction of rotation, the disk rotates with it until the crank pin reaches the upper extremity of the slot in the lever where it is again restrained. Thus, the rotary motion of the friction disk simultaneously rocks the swivel arm causing a transposition of the upper and lower idler gears with respect to the driven gear. This action automatically drives the driven gear counterclockwise irrespective of the direction of rotation of the driving gear.

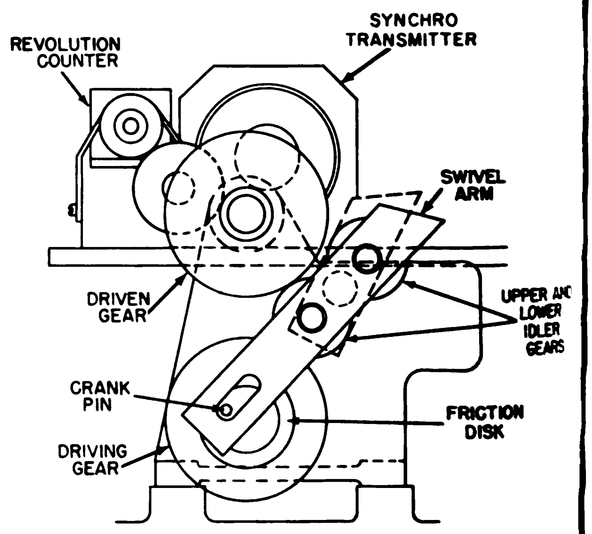


Figure 16-6.—Unidirectional mechanism.

Digitized by Google

Indicator with Revolution Counter

The indicator with revolution counter installed in the throttle station (fig. 16-5B) is used to indicate the rpm and total revolutions of the associated propeller shaft. The unit consists of a meter, synchro receiver, revolution counter, and backing signal lamp. A revolving pointer indicates on the dial the rpm of the associated propeller shaft.

The meter is essentially a d-c voltmeter calibrated in terms of propeller rpm so that an impressed terminal voltage of approximately 3600 millivolts will cause a full-scale deflection of the pointer. The meter is energized by the generated output voltage of the d-c magneto located in the shaft transmitter unit.

The revolution counter is driven through gears by the synchro receiver to indicate the total rpm of the propeller shaft. The synchro receiver is driven electrically by the synchro transmitter in the associated shaft magneto transmitter.

The backing signal indicator consists of a double lamp assembly provided with a 115/6-volt transformer and red target window. When the propeller shaft rotates in the astern direction, the unidirectional mechanism in the shaft transmitter actuates the SPDT switch to energize the lamps and illuminate the red target window.

Indicator

The indicator installed in the pilot house (fig. 16-5C) is used to indicate the rpm of the propeller shaft. It is similar in appearance and construction but smaller than the previously described unit installed in the throttle station. The unit is provided with dial illumination and a dimmer rheostat but does not include a revolution counter.

MAINTENANCE

Preventive maintenance for synchro and magneto-voltmeter types of propeller revolution indicating equipment consists of keeping the equipment clean, free running, and properly lubricated. The equipment should be deenergized during long periods of inactivity. This will cause lower internal temperatures in the instruments and reduce the tendency for the hot lubricants to drip out of the mechanisms.

Open all synchro-type transmitters and indicator-transmitters periodically, observe the condition of the gear teeth and remove any accumulation of dirt or hardened grease. Lubricate all running and worm gears according to the manufacturer's technical manual or the Planned Maintenance System manual. The main shaft bearings are usually sealed and require no lubrication.

Keep the slip ring assembly and contacts in the indicator-transmitter clean and free of any lubricant. Oil or grease on the slip rings will cause faulty operation of the followup motor. The slip rings may be cleaned with alcohol or a fine jeweler's file. Do not use sandpaper or emery cloth.

Synchro and magneto-voltmeter type indicators require no preventive maintenance other than inspections for cleanliness and freedom of motion of the moving parts. Use a wet cloth when cleaning the windows of the magneto-voltmeter type meters and let the window dry naturally. If the window is rubbed with a dry cloth, the friction may generate a static charge which will attract the instrument pointer and cause an error in the meter reading.

WIND DIRECTION AND SPEED INDICATOR SYSTEM

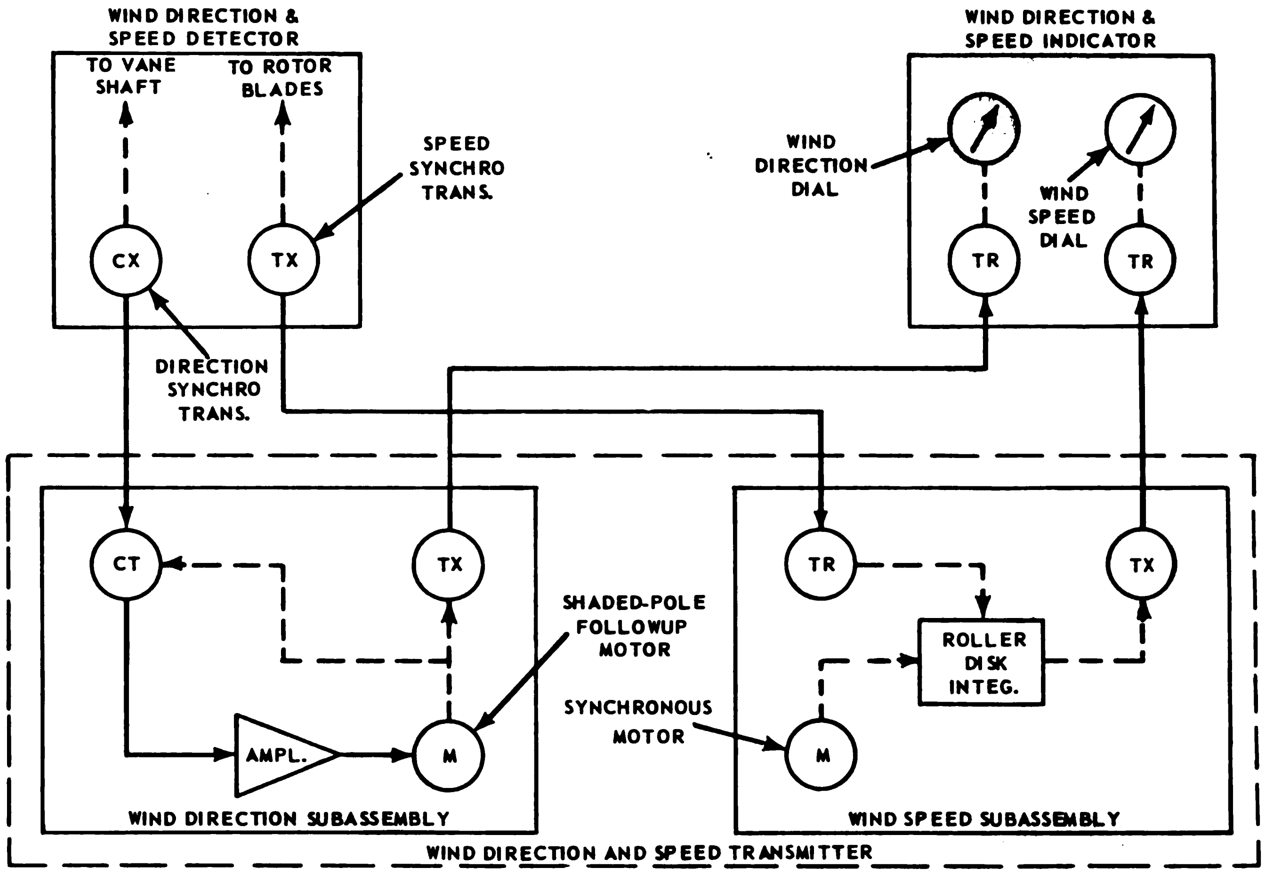
The wind direction and speed indicator system, circuits HD and HE, is used to indicate instantaneous and continuously the (1) wind direction in degrees relative to the ship's heading, and (2) wind speed in knots relative to the ship. A gyrocompass repeater is provided as an accessory to the system in order to determine the true wind direction.

The type-B wind direction and speed indicator system may be modified by adding a synchro signal converter and a synchro isolation amplifier. The converter and amplifier convert the 60-cycle signal to a 400-cycle signal for those ships using special weapons systems.

TYPE-B EQUIPMENT

Figure 16-7 shows a block diagram of a type-B wind direction and speed indicator system installed in a large ship. The system consists of a (1) wind direction and speed detector, (2) wind direction and speed transmitter, and (3) wind direction and speed indicator. Two wind direction and speed detectors are mounted on the foremast, one on the

Digitized by Google



140.60

Figure 16-7.—Block diagram of type-B wind direction and speed indicator system.

port side and one on the starboard side. The wind direction and speed transmitter is installed in the IC room. The wind direction and speed indicators are installed in various navigational spaces as required by the type of ship.

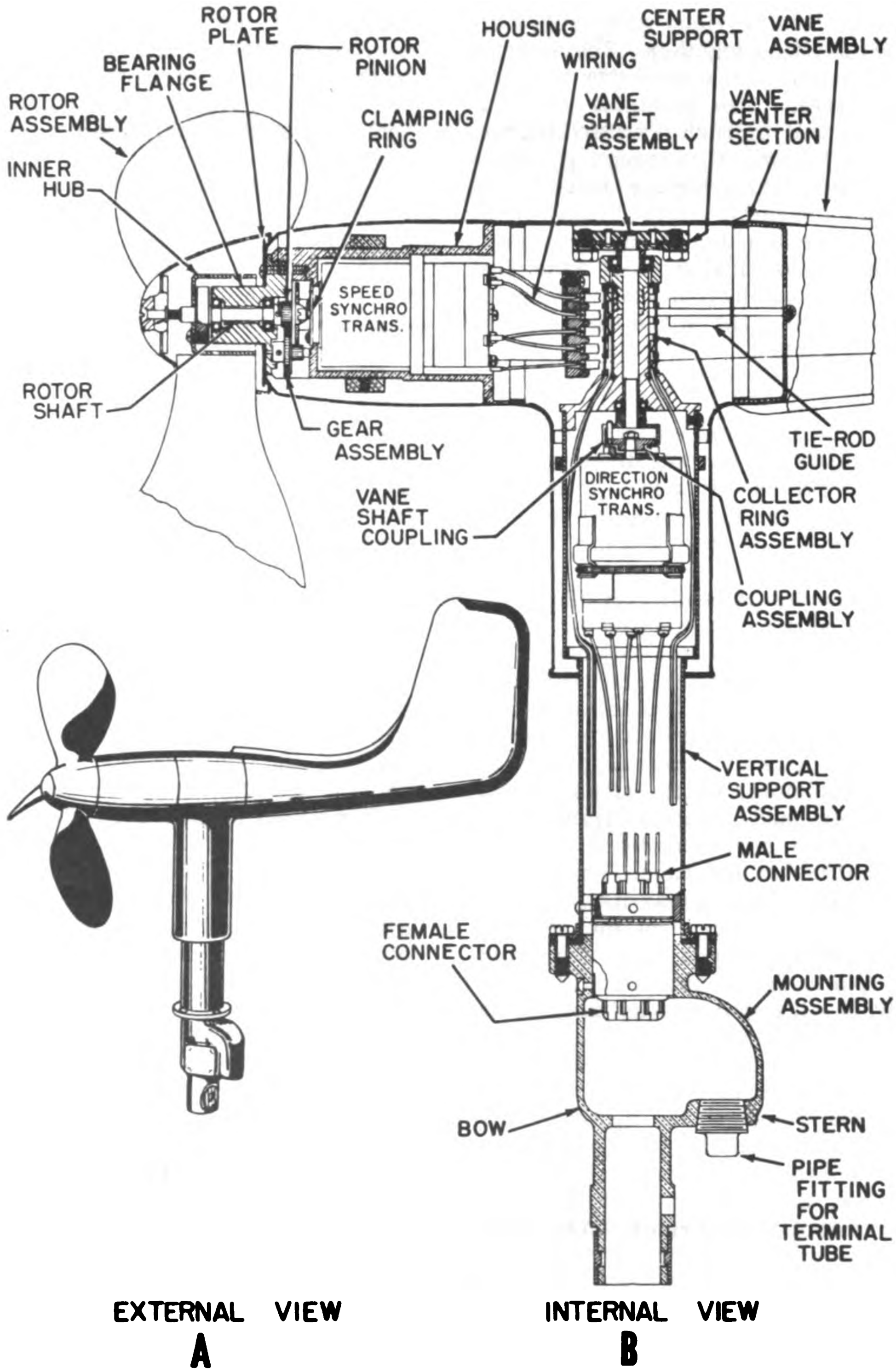
Detector

The wind direction and speed detector (fig. 16-8) consists of a thin-gage monel metal housing formed into a streamlined wind vane with a relatively large tail surface mounted on a vertical support assembly. The rotor assembly, attached to the head of the vane is held directly into the wind by the vane assembly and converts the wind speed into rotary motion. The speed of rotation of the rotor assembly is proportional to the velocity of the wind striking the rotor blades.

The direction synchro transmitter, mounted in the vertical support assembly, is directly coupled to the vane so that when the wind positions the vane, the synchro transmitter is displaced the same angular amount. The angular positions are transmitted electrically to a synchro control transformer in the wind direction subassembly of the transmitter (fig. 16-7). Because wind directions are indicated in relative bearings, the direction synchro transmitter is set to electrical zero when the rotor assembly of the detector unit points to the bow of the ship.

The speed synchro transmitter, mounted in the head of the vane, is coupled through gears to the rotor assembly so that the synchro rotates 1 revolution for each 12.5 revolutions of the propeller. The reduced rotary motions are transmitted electrically to a synchro receiver in the wind speed subassembly of the transmitter unit (fig. 16-7). Electrical connections to the speed synchro are provided through collector rings and brushes (fig. 16-8).

Digitized by Google



7.145

Figure 16-8.—Wind direction and speed detector.

Digitized by Google

The mounting assembly and the vertical support assembly are provided with flanges for bolting the two sections together. The detector is held in alignment by a mounting bolt that serves as a dowel. The incoming cable is brought into the unit through a watertight terminal tube in the bottom of the mounting assembly and is connected to a female connector in the top of this assembly. The leads for the synchros are connected to a male connector in the bottom of the vertical support assembly. Thus, the detector mechanism can be removed without disconnecting the incoming leads or disturbing the alignment.

Transmitter

The wind direction and speed transmitter (fig. 16-7) consists of a wind direction subassembly and a wind speed subassembly mounted on individual baseplates to form a complete unit enclosed in a metal case designed for bulkhead mounting.

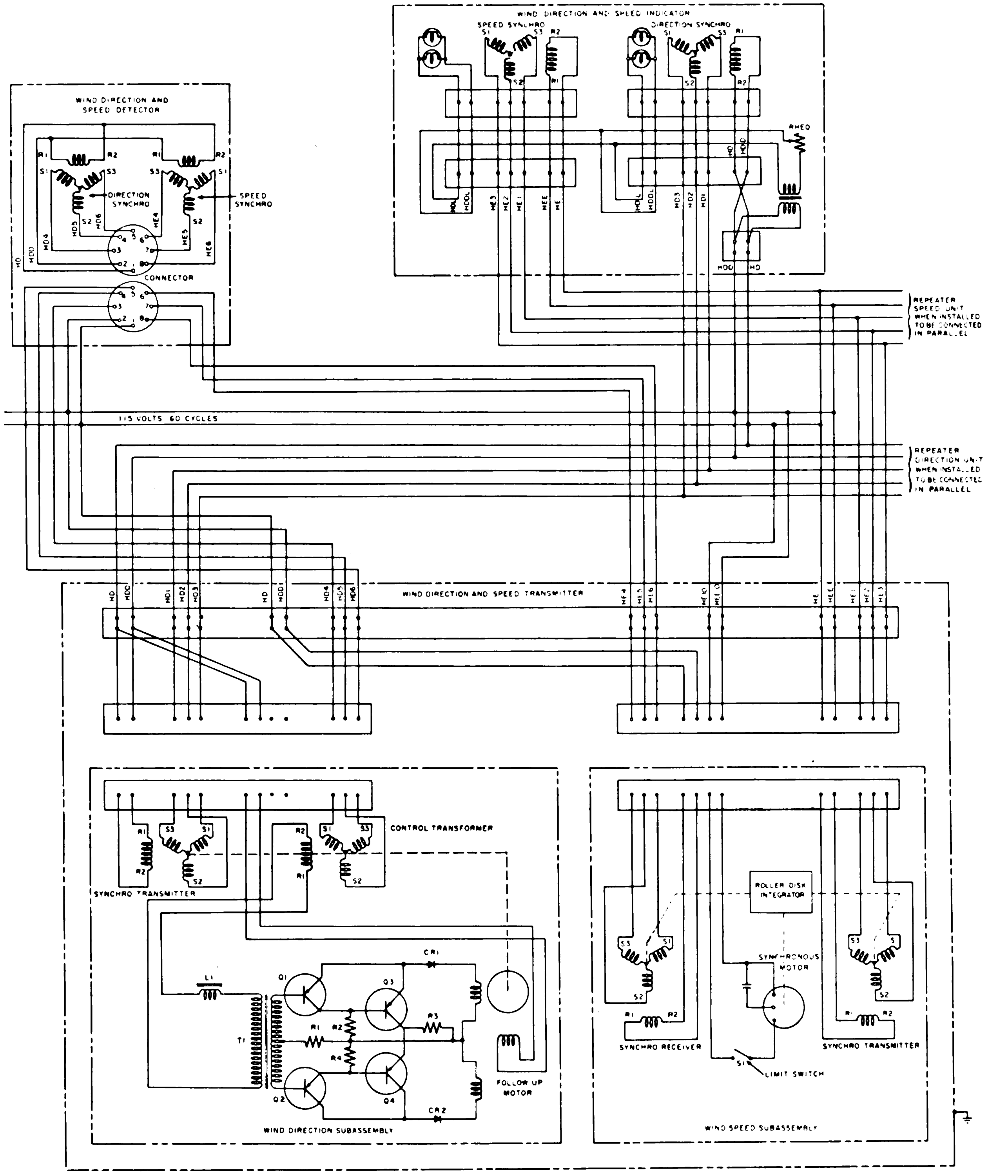
The wind direction subassembly (fig. 16-7) is essentially a servo unit comprising a synchro control transformer, followup motor, and synchro transmitter. The synchro control transformer receives the angular displacements from the direction synchro transmitter in the detector. These angular displacements are amplified and fed to the followup motor which drives the synchro transmitter and control transformer through gears into correspondence with the synchro transmitter in the vane. The synchro transmitter transmits the angular displacements (which are damped by means of the gear assembly), at a predetermined rate of approximately 1.25 rpm to the synchro receiver in the associated wind direction subassembly of the remotely located indicator.

When the vane direction transmitter and the synchro control transformer rotors are in correspondence, the output of the control transformer is zero. When the vane changes its position, the two rotors are no longer in correspondence and a voltage is induced in the rotor of the control transformer. The output voltage from the rotor of the control transformer is either in phase or 180 degrees out of phase with the source (reference) voltage, depending on the direction in which the vane has turned. Thus, the phase of the control transformer reverses with respect to the transmitter reference voltage as the direction of displacement reverses. The magnitude of the control transformer output voltage represents the amount by which the shafts of the control transformer and the vane transmitter are out of correspondence. The direction in which the transmitter shaft is turned represents the phase of the control transformer output voltage which determines the direction of rotation of the followup motor.

The signal from the control transformer (fig. 16-9) is fed to the input transformer T1 of the amplifier. The series inductor L1 in the primary of T1 compensates for the phase shift inherent in the control transformer so that the signal applied to the primary of T1 is exactly in phase or 180 degrees out of phase with the reference voltage. Transformer T1 also isolates any direct current in the circuit of the secondary winding from the synchro control transformer. The secondary of T1 is connected to the amplifier, consisting of the paralleled transistors Q1-Q2 and Q3-Q4 connected for push-pull operation. Transistors Q1 and Q2 are connected as emitter followers which offer a high impedance to T1, and thus prevent overloading of the synchro control transformer. The output of Q1-Q3 and Q2-Q4 is connected to the shading windings CCW and CW of the shaded-pole followup motor through rectifiers CR1 and CR2, respectively. When the vane changes its position, the upper section (Q1-Q3), or the lower section (Q2-Q4), conducts and applies the amplifier output to the CCW or CW winding to drive the followup motor in the direction corresponding to that in which the vane transmitter rotor is displaced. The followup motor positions the synchro transmitter and drives the rotor of the control transformer into correspondence with the vane transmitter rotor to null the signal and stop the motor.

The rectifiers CR1 and CR2 between the transistors and shading windings of the followup motor restrict the direction of current flow in the transistors and shading windings. The resistors R2 and R3 connected in the base circuits of transistors Q3 and Q4 serve to provide low resistance shunt paths for the collector leakage currents which may reach excessive values of high ambient temperatures. Resistor R1, connected in the common emitter return circuit provides degenerative bias to further stabilize the operating points of transistors Q3 and Q4. Resistor R1 also serves to drive the nonconducting transistor to cutoff when an error signal is present at the other transistor base, thereby improving the performance at all ambient temperatures.

Digitized by Google



7.144

Figure 16-9.—Schematic diagram of type-B wind direction and speed indicator system.

Digitized by Google

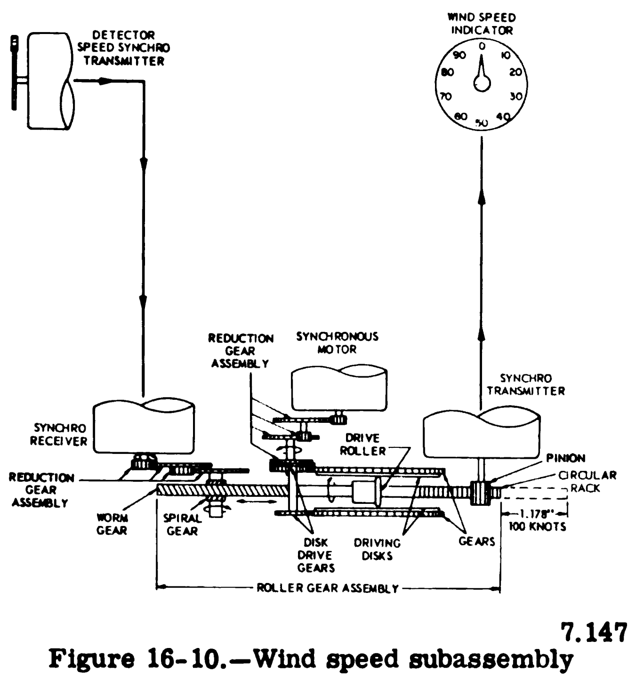
The wind speed subassembly (fig. 16-10), is essentially a roller disk integrator comprising a synchro receiver, a roller gear assembly with worm and circular rack, constant speed motor, and synchro transmitter. The synchro receives the rotary motions from the vane speed transmitter, the roller gear assembly converts the rate of these rotary motions into proportional angular displacements, and the synchro transmits these displacements to the synchro receiver in the associated wind speed subassembly of the remotely located indicator.

The synchro receiver, which rotates at the same speed as the synchro speed transmitter in the detector, transmits the rotary motion through reduction gears to the worm of the roller gear assembly. This gear reduction terminates with a spiral gear that engages the worm of the roller gear assembly. The action of the spiral gear against the worm of roller gear assembly is that of a pinion on a rack which drives the drive roller away from the center of the two driving disks in a linear motion. However, the drive roller with its integral worm and circular rack are rotated by the two driving disks, which turn in opposite directions, by a constant speed (synchronous) motor through reduction gears and the two disk drive gears.

The speed of the circular motion of the drive roller depends on the position of the roller with respect to the center of the driving disks. The speed of the drive roller increases as the roller approaches the edge of the disk. Hence, the drive roller receives circular motion and linear motion simultaneously. Although the driving action of the spiral gear against the worm tends to drive the roller away from the center of the two disks, the motion resulting from the revolving of the worm engaging the spiral gear is toward the center of the disks. When the circular motion and the linear motion balance each other, the drive roller assumes a position of displacement from the center of the disks that is proportional to the rotor speed of the speed transmitter in the detector.

The drive roller is attached to the roller gear assembly shaft and positions this shaft laterally. The circular rack of the roller gear assembly engages a pinion on the shaft of the synchro transmitter, thereby transforming linear motion into angular motion. The angular motion is transmitted to the wind speed subassembly in the remotely located indicator. The speed synchro transmitter is set to electrical zero when the wind speed is zero.

A low-limit switch, S1, (fig. 16-9) is provided to open the circuit to the synchronous motor when the drive roller is at the center of the driving disks at zero wind speed. As the roller nears the center of the disks, the end of the worm gear forces a bellcrank (not shown) to open switch, S1, and deenergize the circuit to the synchronous motor. This switch saves needless wear on the disks and roller when there is no wind speed to be indicated.



7.147

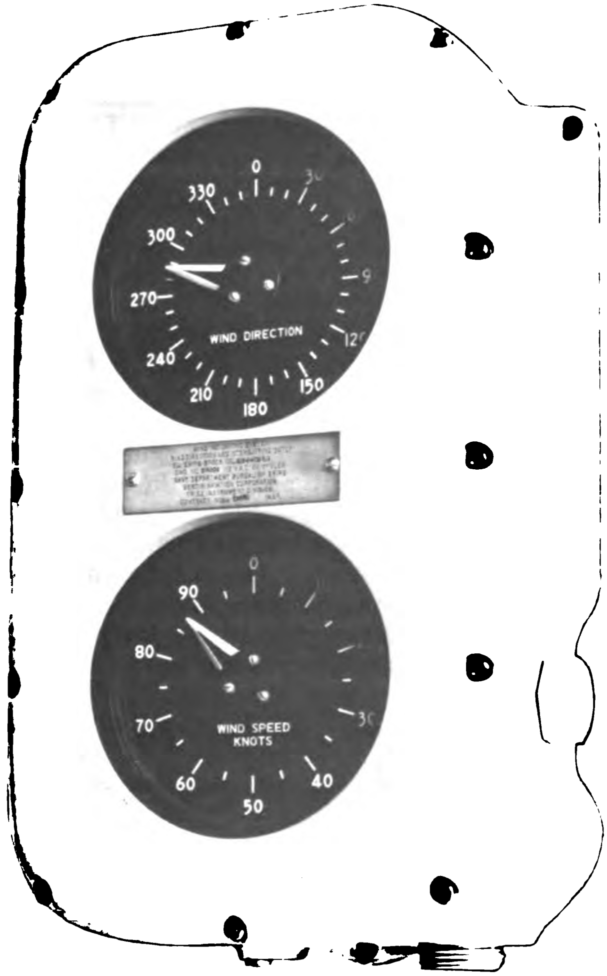
Figure 16-10.—Wind speed subassembly

Indicator

The wind direction and speed indicator (fig. 16-11), is a dual unit consisting of a wind direction subassembly and a wind speed subassembly. The two subassemblies are identical except for the dials. Each consists of a synchro receiver indicating on a fixed dial by means of a revolving pointer directly attached to its shaft. The subassemblies are mounted on individual baseplates and enclosed in a metal housing to form a complete wind direction and speed indicator unit.

The direction synchro receiver receives the angular displacements from the synchro transmitter in the direction subassembly of the transmitter unit, and indicates these displacements on the direction dial. The direction dial is graduated in 10° intervals from 0° to 360°.

Digitized by Google



7.148
Figure 16-11.—Wind direction and speed indicator.

The speed synchro receiver receives the angular displacements from the synchro transmitter in the speed subassembly of the transmitter unit, and indicates these displacements on the speed dial. The speed dial is graduated in 5-knot intervals from 0 to 100 knots.

The dials and pointers are red illuminated. Dial illumination for each subassembly is provided by two lamps in parallel supplied from a 115/6-volt transformer inside the housing. A knob on the side of the case controls a rheostat for varying the intensity of the illumination.

MAINTENANCE

Preventive maintenance for the type-B wind direction and speed indicator system consists of periodic inspections, cleaning, and lubricating. Observe the indicators periodically; uneven movement of the pointers indicates possible trouble. By comparing the pointer movement of one indicator with another you can determine if the trouble is in a single indicator or in the system.

Periodically and after exposure to high winds, inspect the detector mounting and tighten the mounting bolts if necessary. Turn the rotor by hand to ensure that it turns freely. Rotate the vane through 360° in both directions to ensure it rotates freely.

Every six months, or as specified by the Planned Maintenance System Manual, clean and lubricate the detector and transmitter. The indicators require no lubrication.

SALINITY INDICATOR SYSTEM

The salinity indicator system, circuit SB, is used to indicate the amount of salinity in water systems aboard ship. The system is a necessity aboard ship because all fresh water, particularly when underway, is made from sea water. Excessive salinity in the boiler feed water causes pitting of the tubes and rapid deterioration due to electrolysis. Salinity indicators are usually provided in the enginerooms and the firerooms for checking the condensate from the main and auxiliary condensers. They are also provided for the evaporator plants to indicate the degree of purity of the fresh water and condensate at various selected points in the distilling system.

The operation of the salinity indicator system is based on the principle that an increase of the electrolytic impurities (principally salt) in water increases the electrical conductivity of the water and conversely, that a decrease in the impurities increases the electrical resistance of the water. If two electrodes are immersed in the water being tested and a constant alternating voltage is applied across the electrodes, a constant alternating current will flow, provided the impurity content and the temperature of the water remain unchanged.

The amount of current flow is indicated on a meter, the scale of which is graduated in equivalent parts per million. If the saline content of the water increases because salt water leaks into the system or because the operation of the distilling plant becomes faulty, the conductivity between the electrodes increases and the meter

Digitized by Google

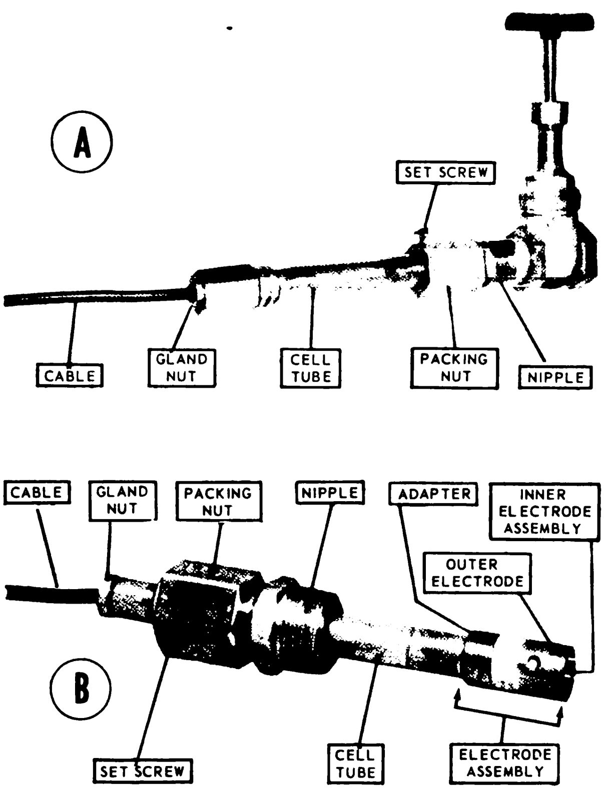
reading increases an amount that is proportional to the increase in salinity.

A complete salinity indicator system consists of one or more salinity cells and an indicator panel. The salinity cells measure the conductivity of the water and transmit the measurements of the salinity indicator panel. The salinity indicating meter provided on the panel has a pointer which moves over a logarithmic scale calibrated in parts per million (PPM) of chloride. Each salinity cell including the associated circuits, indicators, and switches constitute one salinity channel.

SALINITY CELL AND VALVE ASSEMBLY

The salinity cell and valve assembly are illustrated in figure 16-12.

The valve is a standard 1 1/4-inch cast-bronze wedge-seated valve with an externally threaded stem (fig. 16-12A). It is rated at 125 psi for steam pressure and is hydrostatically tested to 200 psi. The valve is fitted into the water system piping by means of a standard approved tee and provides a means of shutting off the water when withdrawing the salinity cell for cleaning and inspection.



7.150

Figure 16-12.—Salinity cell and valve assembly.

The salinity cell is a self-contained unit consisting of a nipple, packing nut, cell tube, and electrode assembly (fig. 16-12B). The cell tube provides a means of extending the electrode assembly through the valve and is connected to the tee through the nipple and packing nut to form a watertight seal. The packing nut has a set screw that screws into a groove in the cell tube to prevent axial displacement of the tube by the hydrostatic pressure. A steel ring stop on the cell tube, between the packing nut and nipple, locates the cell properly in the piping.

A 6-foot, 3-conductor cable connects the cell to the salinity indicating panel through the ship's 115-volt 60-cycle power. The cable is secured to the cell by means of a gland nut.

The electrode assembly comprises the inner electrode, adapter, automatic temperature compensator, and the outer electrode. The inner electrode is a hollow platinum-coated brass cylinder closed at the forward end. It is held in the adapter by means of a spring-loaded nut on the end of the inner electrode holder. A solder lug under this nut connects the white conductor of the incoming cable.

The outer electrode is a hollow brass cylinder the inside of which is coated with a thin layer of platinum. This electrode screws onto the adapter which in turn screws onto the cell tube. It is pierced with holes to vent the gases trapped in the space between the electrodes and to allow for free circulation of the water. The connection for the outer electrode is made by soldering the green conductor of the incoming cable into the hole provided in the cell tube.

The automatic temperature compensator is a small circular disk located within the inner electrode to automatically compensate for changes in temperature through a range of 40° F to 250° F. It consists of a material having a negative temperature coefficient of resistance. The material has the same resistance temperature characteristics as dilute solutions of sea water. The conductance between the inner and outer electrodes is balanced by the conductance of the temperature in an electrical ratio circuit in such a way that the alarm point signal is independent of changes in water temperature. One side of the compensator disk is soldered to the closed end of the inner electrode and the

Digitized by Google

ther side has a lead brought out through the nner electrode holder to the black conductor f the incoming cable.

ALINITY INDICATOR PANEL

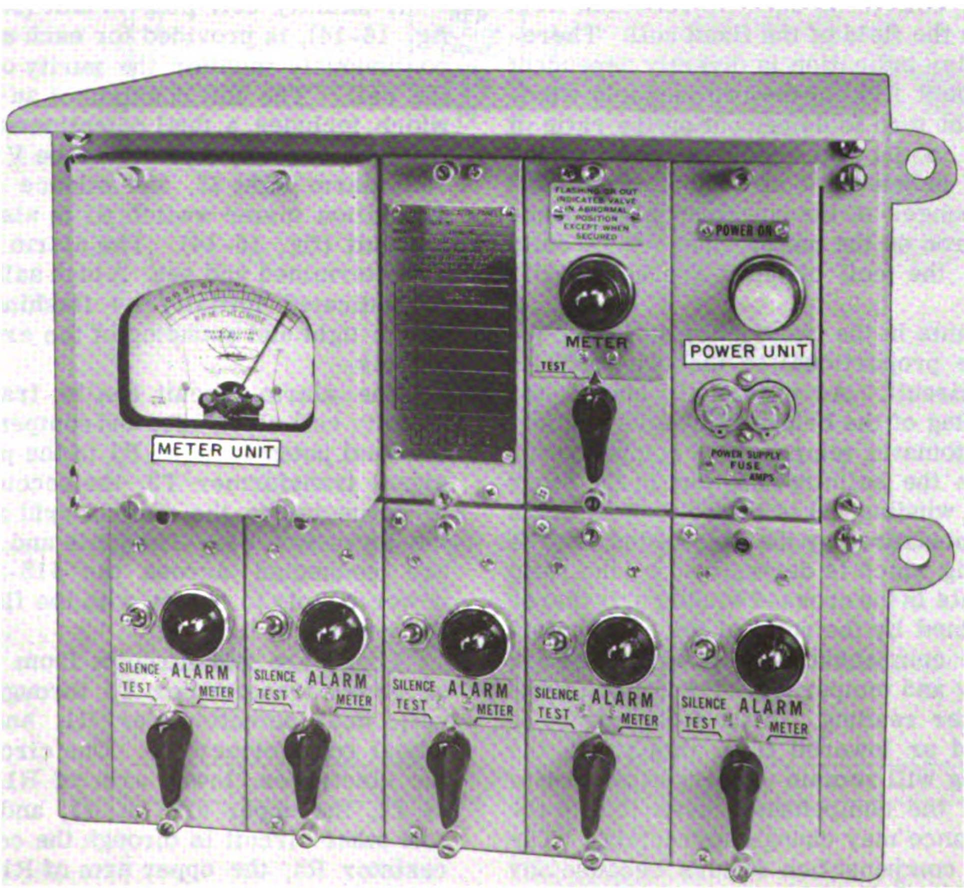
The salinity indicator panel (fig. 16-13) is esigned to function in a system having five alinity cells, external alarm bells, and two olenoid trip valves. The panel contains a power nit, meter unit, five salinity cells, valve posiion and meter test unit, and a relay unit. The nits are of the plug-in type to facilitate removal or inspection and repairs.

'ower Unit

The ship's 115-volt 60-cycle power is aplied to the salinity indicator panel through the power unit (fig. 16-13). The power unit is not a plug-in type, but is wired directly onto the panel. It is provided with a white power-on indicator lamp, two fuse holders, and two blown-fuse indicators. The two fuses protect only the salinity cell and the alarm circuit wiring. The power circuits to the solenoid-operated control valves are not fused.

Meter Unit

The meter unit (fig. 16-13) measures the specific electrical conductivity of the water. The conductivity values are then converted by meter scale calibration into equivalent concentrations of sea water. The meter is connected to the cell circuits by individual switches on each salinity cell. The specific electrical conductivity is measured by means of a bridge



7.151

Figure 16-13.—Salinity indicator panel.

Digitized by Google

circuit which employs a special power-factor type meter. The meter measures the ratio of currents in the two separate arms of the bridge. One arm of the bridge is the dilute solution of sea water to be measured. The other arm of the bridge is an automatic temperature compensating resistor which has the same resistance-temperature characteristics as dilute solutions of sea water.

The power-factor-type meter (fig. 16-14), employs a fixed coil and a movable coil. The movable coil consists of two windings, A and B, at right angles to each other. It is free to rotate within the fixed coil. The movable coil is energized from the secondary of power transformer, T1. Hence, the currents in windings A and B are in phase with each other and the circuits are resistive because of the series limiting resistor, R6. The fixed coil is energized from the ship's 115-volt 60-cycle power supply in series with the voltage dropping resistor, R12. The movable coil turns until its resultant field lines up with the field of the fixed coil. Therefore, the meter indication is directly dependent on the resultant field of the two movable windings, which in turn is dependent on the ratio of the currents in the two windings. The meter indication is independent of minor voltage and frequency changes of the power supply because there is no iron on the meter magnetic circuits and because the coil circuits are essentially resistive.

The currents in the two windings of the movable coil are proportional to the two loads in the bridge circuit. As previously stated, the load in one leg of the bridge (movable winding, A) is the automatic temperature compensator, C, located in the salinity cell, and in the other leg (movable winding, B) is the resistance of the water being measured by the electrodes, E. The meter reading which is determined by the ratio of the currents in the crossed windings, is therefore determined by the ratio of the cell resistance and the compensator resistance. At any given salinity and temperature there is only one possible meter reading. If the temperature is either raised or lowered from this point, the meter reading will remain unchanged because of the action of the compensator even though the water resistance may change appreciably. The temperature compensation occurs because any thermal change of the water being measured by the cell is immediately transferred to the automatic temperature compensator. The resistance of the compensator is inversely proportional to its temperature so that the thermal change transmitted to the compensator causes its resistance to change accordingly.

The resistance-temperature characteristics of the compensator are the same as those of dilute solutions of sea water. Therefore, the thermal change in the compensator, which is exactly the same as the thermal change of the sea water, causes sufficient resistive change in the compensator to compensate for the resistive change occurring in the cell. Although the absolute values of current in the windings have changed, their ratio has not changed and consequently the meter reading is unchanged. Because the temperature compensation is equally effective at all salinities, the only change that can vary the meter reading is a change in the current ratio caused by a change in salinity.

Salinity Cell Unit

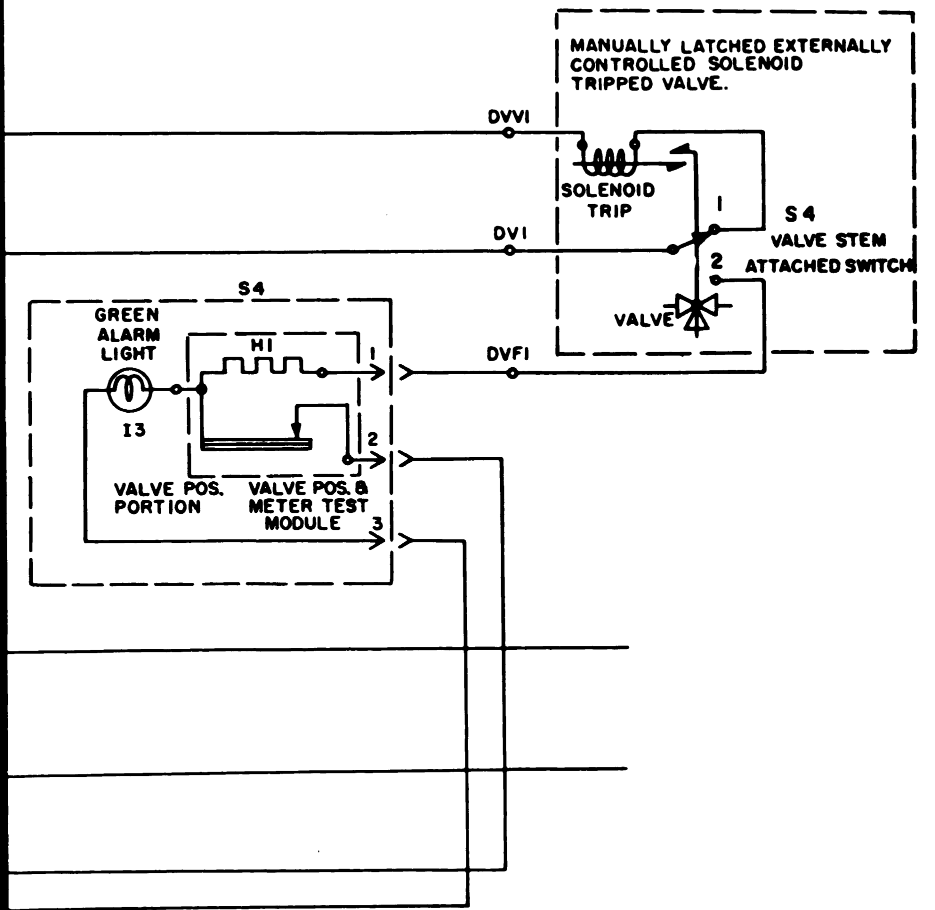
A salinity cell plug-in unit (salinity module fig. 16-14), is provided for each salinity cell to continuously monitor the purity of the water of the cell. The unit consists of an alarm circuit which includes a dual potentiometer R1, signal transformer T2, thyratron tube V1, flasher H2, red alarm light I2, and silence switch S2. A 3-position meter switch S1 is also provided on the unit (fig. 16-14). The alarm point value is predetermined and set. A high salinity condition is indicated initially by flashing of the red alarm light and sounding of the external audible alarms.

The alarm circuit can be traced from the salinity cell electrodes and compensator through the dual potentiometer R1 to the primary of the signal transformer T2, the secondary of which is connected to the control grid and cathode of the thyratron V1. The plate and cathode of V1 are connected across the 115-volt 60-cycle power supply in series with the flasher H2, and the red alarm light, I2.

There are two circuits from the secondary of power transformer T1 through the salinity cell, dual potentiometer R1, and primary of signal transformer T2. One circuit is through the electrodes, lower arm of R1, the primary of T2, the upper arm of R1, and resistor R6. The other circuit is through the compensator C, resistor R5, the upper arm of R1, the primary of T2, the lower arm of R1, and resistor R6. The conductance values of the salinity cell electrodes and compensator which are applied to the secondary of T1 and to the two arms of

Digitized by Google

Digitized by Google



Digitized by Google

potentiometer, R1 determine the grid to cathode voltage of V1. The current flow through the two arms is in opposite directions or 180 degrees out-of-phase and the resultant voltage is impressed across the primary of T2.

For Thyratron V1 to conduct, the voltage between the control grid and cathode (from the secondary of T2), must be in phase with the plate to cathode voltage.

When the salinity condition of the cell is higher than the alarm setting, the resistance across the two electrodes is decreased and more current flows through the lower arm of R1, the primary of T2, the upper arm of R1, and resistor R6. The resultant voltage is impressed across the grid and cathode of V1 through transformer T2. This voltage is of the proper phase to cause V1 to conduct during the half cycles when the grid and plate voltages of V1 are positive. The circuit is completed from one side of the line SB through the cathode and plate of V1, silence switch S2, rectifier CR4, flasher H2, rectifier CR3, red alarm light I2, to the other side of the line SBB.

The silencing switch S2, when placed in the SILENT (down) position, clears the external alarm circuit for other incoming alarms and causes the red alarm light to light steadily. When the high salinity condition is corrected, the red alarm light again flashes to remind the operator to place the switch S2 in the NORMAL (up) position to extinguish the red alarm light and clear the unit for future alarm signals.

The meter switch S1 (fig. 16-12) is a 3-position, spring-loaded switch having a NORMAL (center) position, TEST position, and METER position. The meter switch S1, when placed in the TEST position, disconnects resistor R5B, in the salinity cell circuit resulting in an unbalanced condition which causes the cell to behave as though a high salinity condition exists. This action energizes the alarm circuit causing the red alarm light to flash and the alarm relay to sound the external alarm. The meter switch, S1, when placed in the METER position, connects the meter unit in the circuit of the associated salinity cell and a salinity reading is indicated on the meter.

Relay Unit

The relay module (fig. 16-12) consists of an alarm relay K2 and two 2-second delay flashers. For simplicity, only one flasher is shown. The flasher is used to delay the tripping time of the solenoid-operated valves. Normally, the current through the delay flasher contact circuit is not sufficient to open the flasher contacts. However, if terminal 5 of the relay unit is energized from an associated salinity cell, the flasher contact will open deenergizing control power relay K1-1 causing contacts K1-1 to open. This action deenergizes the valve control circuit causing the valve to actuate.

The rectifier CR2 allows a current to flow through the operating coil of alarm relay K2, from the plate of V1, through switch S2, in the NORMAL (up) position and back to the other side of the line SBB. Rectifier CR5, across the coil of K2, maintains the current flow through the coil during the nonconducting half cycles of V1. The contacts of relay K2 close to energize the external alarm circuit.

The silencing switch S2, when placed in the SILENT (down) position, opens the circuit to the audible alarm and connects the plate of V1 to one side of the alarm light through CR2. As long as the salinity is higher than the alarm setting, CR2 allows a current to flow directly through the red alarm light I2, which is lighted steadily. During this condition, CR3 prevents a large current flow through the heater of flasher, H2. When the salinity decreases to a value at which V1 ceases to conduct, the flasher heater voltage causes the red indicator light to flash as a reminder for the operator to place the silencing switch S2 in the NORMAL (up) position.

Normally, the current flows through the relay module from the line terminal, SBB, the bimetallic arm of the delay flasher, the coil of the power control relay K1-1, to the line terminal SB. This current maintains power relay K1-1, operated so that its contacts are closed. For simplicity, only one solenoid-operated valve is shown.

Valve Position and Meter Test Unit

The valve position and meter test module (fig. 16-14) is provided with a green valve position indicator lamp and a meter test switch. The dual purpose of the unit is to indicate when the control valve is in the NORMAL or ABNORMAL position and to provide a means of testing the meter unit.

When the solenoid trip valve is in the NORMAL position as shown, the green indicator lamp is lighted steadily; when the control valve disk is in the ABNORMAL position the green alarm light flashes; and when the control valve

Digitized by Google

is reset manually the green alarm light is again lighted steadily.

The meter test switch, when placed in the TEST position, connects the meter unit in a circuit simulating a known salinity condition (1.7 PPM) to check the calibration of the meter.

The valve position portion of the unit consists of the green indicator lamp I3 and the flasher H1, interconnected with the solenoid-operated valve. During normal operating conditions the solenoid is energized from line terminal SSB through the contacts of the power control relay K1-1, terminal 1 of the SPDT switch, S4 (on the control valve), to line terminal SB. The green indicator lamp I3 is lighted steadily during this condition from line terminal SB, the contact arm of flasher H1, to line terminal SBB.

When an abnormal condition occurs, the power control relay K1-1 is deenergized and its contact opens the circuit to the solenoid coil which actuates switch S4. This action connects the heater and contact arm of flasher H1 from line terminal SB, through terminal 2 of switch S4, to line terminal SBB causing the green indicator light to flash.

The meter test portion of the unit (fig. 16-14), consists of the meter test switch S3, resistor R10, and potentiometer R11. Normally, the meter unit is not connected to any salinity cell. The meter test switch S3 is a 2-position, spring-loaded rotary switch having a NORMAL (center) position and a TEST position. The rotary switch S3 when placed in the TEST position, connects the movable windings A and B of the power-factor-type meter in a circuit comprising resistor R10 and potentiometer R11, the resistances of which duplicates the resistances of the electrodes and compensator. There are two circuits through the movable windings. One circuit is from line terminal SB, the right arm of potentiometer R11, terminal 4 of switch S3, resistor R10 to line terminal SBB. The other circuit is from line terminal SB, the left arm of potentiometer R11, terminal 5 of switch S3, movable winding B, terminal 6 of switch S3, resistor R10, to line terminal SBB. With the meter test switch in the TEST position, the meter should read 1.7 PPM.

MAINTENANCE

The salinity cells should be inspected for mechanical damage and cleaned at least once a month. To remove a cell for inspection while the power is on and the system under pressure, proceed as follows: Loosen the setscrew in the packing nut (fig. 16-12A) and slowly loosen the packing nut about one turn. Grasp the cable gland nut and pull the cell tube through the packing nut until a red groove on the cell tube can be seen, then close the gate valve. Remove the packing nut and cell tube from the nipple, and inspect the electrodes. Do not allow the electrodes to touch your body. If the electrodes show scale deposits, they must be cleaned.

To clean the electrodes, turn off the power and unscrew the outer electrode (fig. 16-12B) to permit cleaning the platinum surfaces. Use absorbent cotton and pure grain alcohol to clean the electrodes, then rinse them in distilled water. If this does not remove the deposits, soak the electrodes in a 50% solution of hydrochloric acid then rinse them thoroughly in distilled water. Do not use abrasives of any kind to clean the electrodes.

To reinstall the salinity cell, replace the outer electrode and push the cell tube through the packing nut until the red groove on the cell tube is just visible at the end of the packing nut. Screw the packing nut on the nipple using the cell tube as an alignment guide. When the packing nut compresses the packing against the outside wall of the cell tube, the gate valve may be opened cautiously. When the valve is open about one turn and full pressure applied to the electrodes, carefully tighten the packing nut to stop any small leaks. Do not overtighten the packing nut. When the small leaks are stopped, open the gate valve fully and push the cell tube inward until the setscrew can be set firmly in the groove on the cell tube.

Inspect the salinity indicator panel and its associated wiring frequently and remove any dust or dirt with clean rags or a vacuum cleaner. Check all electrical connections and mechanical fastenings for tightness. Replace any burned-out indicator lights. When one bulb burns out in a dual bulb indicator light, replace both bulbs.

Turn off and tag the main supply switch for the system when working inside the panel. Removing the fuses on the panel will not cut off the power to the control relay circuits. Normally you will not be required to make extensive repairs to the modules. If a module fails, insert a spare of the same type in the panel and turn the faulty module in to a repair facility or the manufacturer as directed.

Digitized by Google

UNDERWATER LOG SYSTEM

The underwater log system, circuit Y, meas-ıres and indicates the speed of the ship and the listance traveled through the water. It also ransmits these indications to the various weap-ıns and navigational systems as required.

The general types of underwater log equip-nents installed in Navy ships are the pitot-static hydraulic) type, the propeller (electromechan-cal) type, and the electromagnetic type. In all hree types, a rodmeter protruding through the ıull of the ship below the keel furnishes the speed signal to a mechanism within the ship which con-erts the signal into speed and distance traveled.

In the pitot-static type, a pressure signal rom the rodmeter acts on a bellows which oper-ates contacts to indirectly control the speed of a pump drive motor. The pump drive motor is made to run at a speed where the pressure out-put of the pump equals the pressure signal from the rodmeter. The pump drive motor also drives a synchro transmitter which furnishes an indi-cation of distance traveled, and supplies the un-known speed input to a friction disk and roller assembly to indicate instantaneous speed.

In the propeller type equipment, the rodmeter contains a four-bladed propeller which drives a small a-c generator housed within the hub of the propeller. The output from the a-c generator supplies a synchronous motor in the speed and distance indicating mechanism.

The electromagnetic type underwater log (fig. 16-15) is rapidly replacing the other two types. The major components of the system are the sea valve, rodmeter, and indicator-transmitter.

SEA VALVE AND RODMETER

The sea valve (fig. 16-16), is mounted to the hull of the ship and houses the rodmeter. The rodmeter passes through the open valve. The valve must be closed when the rodmeter is removed.

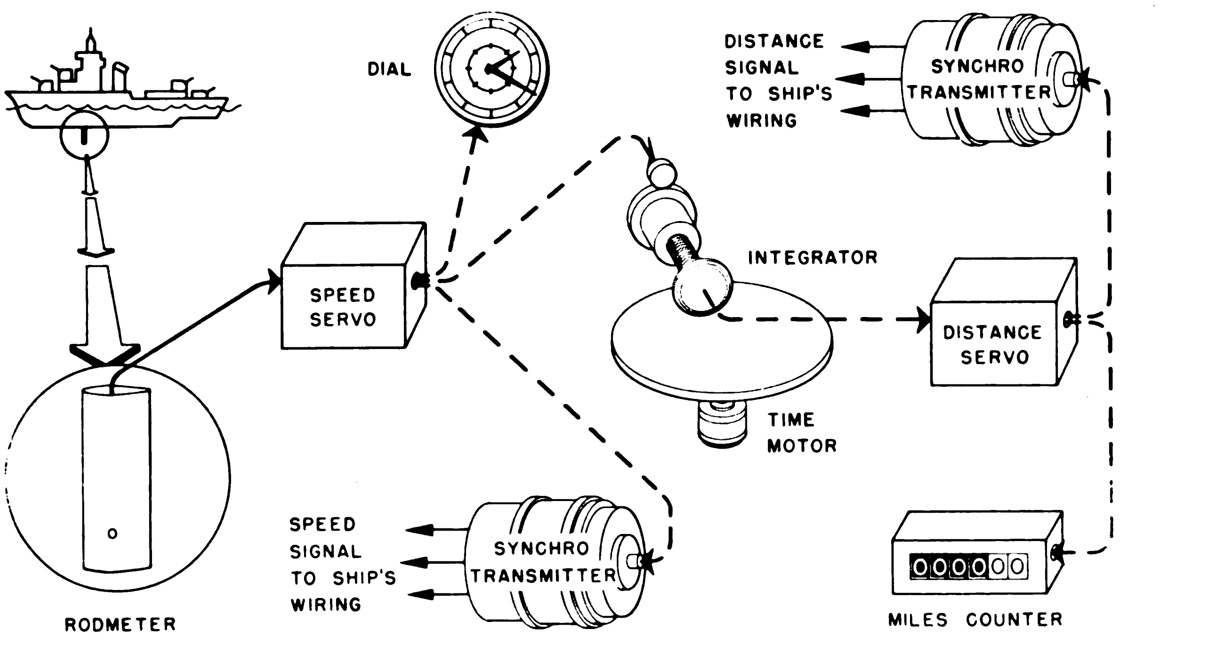
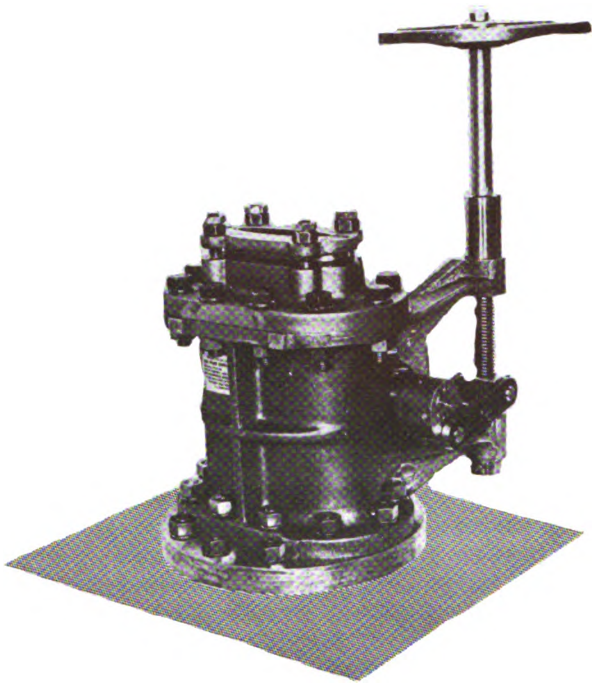


Figure 16-15.—Block diagram of electromagnetic-type underwater log system.

The rodmeter is a sword-like structure of corrosion resistant monel approximately six feet in length. The main components are the rod weldment, the junction box, and the sensing unit (fig. 16-17).

The rod weldment makes up most of the length of the rodmeter. It is a hydrofoil cross section, nickel-copper, watertight tube. The sensing unit is cemented to the lower end of the

Digitized by Google



27.271
Figure 16-16.—Sea valve.

rod weldment, and the junction box is bolted to the upper end. Two shielded electrical cables connected to the sensing unit pass through the rod weldment and terminate in the twinax connectors.

Sensing Unit

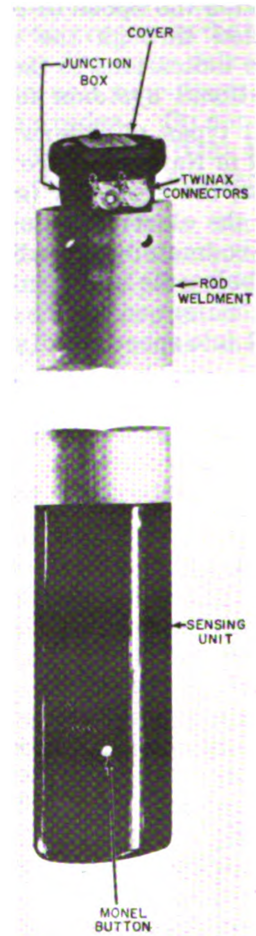
The sensing unit is a plastic moulding containing an electromagnet which produces the speed signal voltage, and two monel buttons which pick up the signal voltage (fig. 16-18).

The sensing unit operates on the principle of electromagnetic induction. As you recall from Basic Electricity, NavPers 10086-A, when a conductor is made to move in a magnetic field so as to cut the lines of field flux, an EMF is induced in the conductor. The EMF induced is equal to the product of the flux density in which the conductor is moving, the length of the conductor, and the velocity of the conductor.

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 16-19.

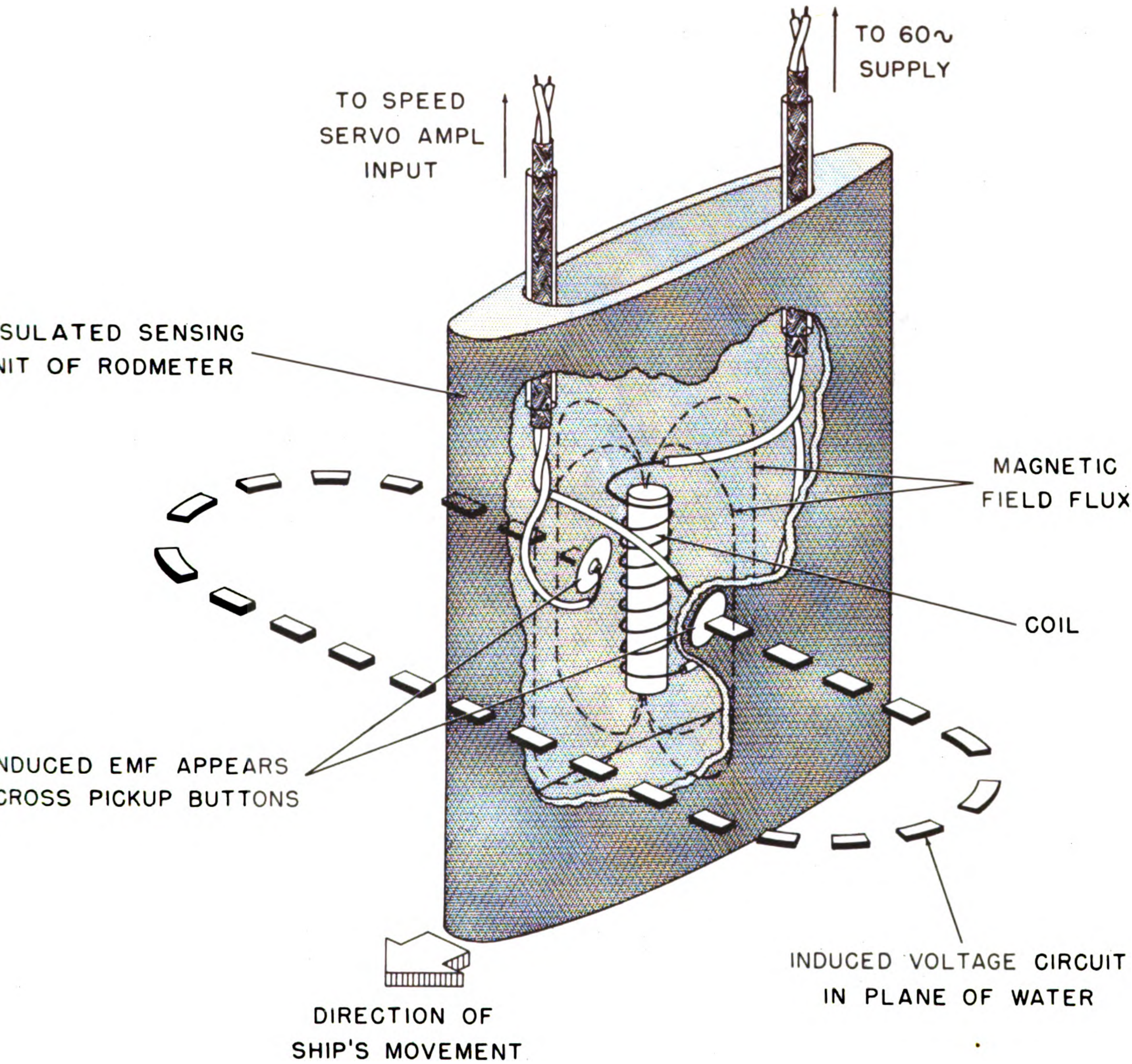
Using the second method, close the conductor upon itself outside the magnetic field, as shown by the dotted lines in figure 16-20. Then cut the conductor by a nonconducting plane parallel to the direction of motion and to the lines of flux, and by means of suitable contacts on each side of the plane 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 induced in the conductor on both sides of the plane.

If the conductor shown in figures 16-19 and 16-20 is replaced by a sheet of conductive material, as shown in figure 16-21, a voltage will be induced in the conductive sheet in a manner similar to that shown in figure 16-19. If a plane could be passed through the conductive sheet



27.272
Figure 16-17.—Rodmeter.

Digitized by Google



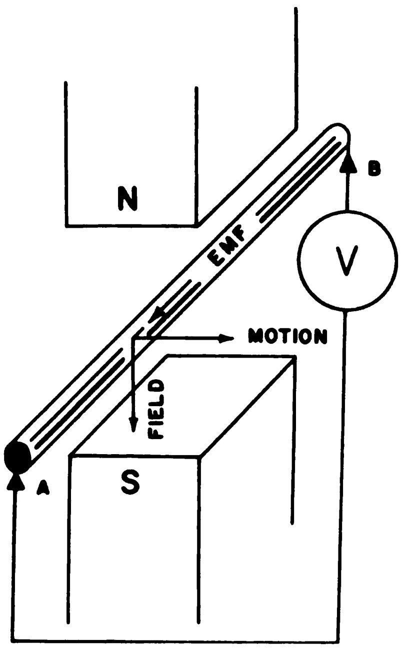
27.273

Figure 16-18.—Sensing unit.

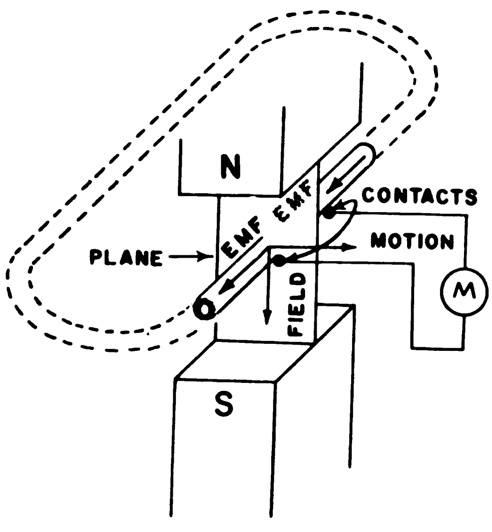
ig. 16-21), the magnitude of the voltage induced the sheet could be measured, as shown in gure 16-20. The portion of the sheet that lies itside of the magnetic field acts as a closed op around the insulating plane. Therefore, the tal voltage induced in the conductive sheet ould be measured across the plane.

The operation of the rodmeter is based on ie principles just described. An a-c voltage exites 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 coil current reverses each half cycle. Therefore the induced voltage is an alternating voltage. The magnitude of the a-c voltage generated in

Digitized by Google



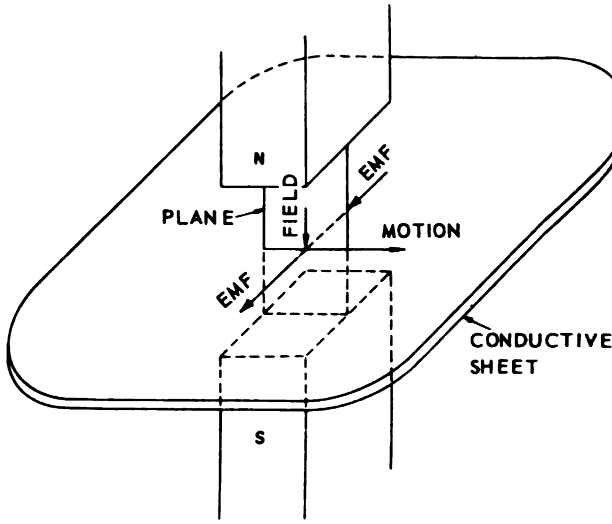
27.274
Figure 16-19.—Voltage induced in a conductor.



27.275
Figure 16-20.—Measurement of induced voltage.

the conductor is proportional to both the flux density and the velocity, as stated previously.

The water, which is a conductor, creates a closed path in its natural flow about the rodmeter.



27.276
Figure 16-21.—Measurement of voltage in a conductive sheet.

The water is cut by the nonconducting plane, which is the plastic shell of the rodmeter. As the magnetic field moves through water, the 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. 16-18), located on each side of the rodmeter make contact with the water and pick up the voltage being generated in the water. This a-c voltage (approximately 450 microvolts per knot) is fed to the servo amplifier in the speed servo (fig. 16-15).

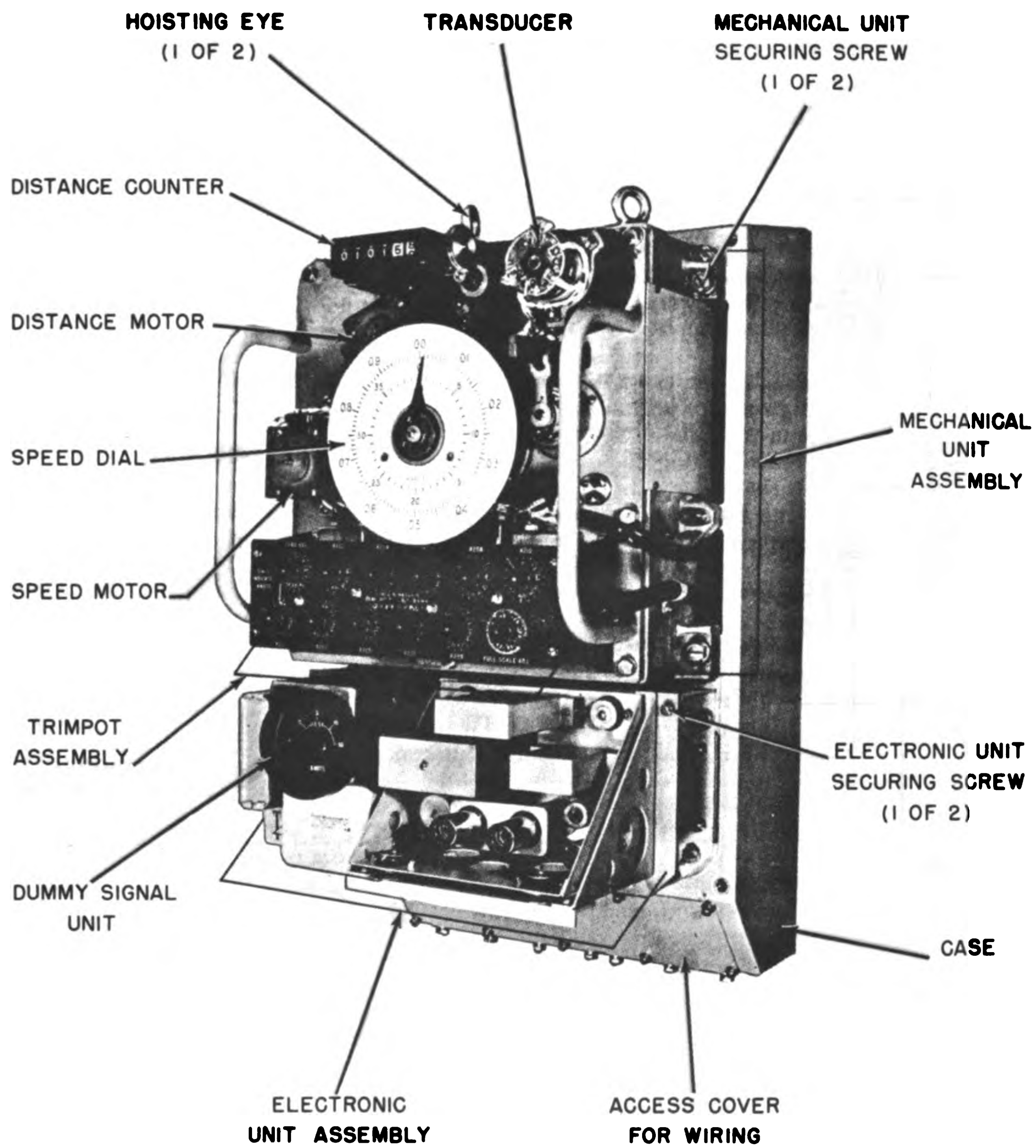
INDICATOR-TRANSMITTER

The indicator-transmitter (fig. 16-22), contains all the electrical and electromechanical components of the log equipment except the components contained in the rodmeter. The unit is electrically connected to the rodmeter by two 2-conductor cables which terminate in connectors that fit receptacles in the lower part of the case. The principal components of the indicator-transmitter are the (1) speed servo, (2) integrator, and (3) distance servo.

Speed Servo

The speed servo (fig. 16-23), functions to translate the signal voltage generated by the rodmeter into a mechanical angular output which

Digitized by Google



7.153

Figure 16-22.—Indicator-transmitter (cover removed).

drives the speed dial, speed synchro transmitter, and the input to the integrator.

The input transformer T2 functions as an error detector. It receives the speed voltage generated by the rodmeter and a response signal which is an indication of the positions of the load. When an error exists between the position of the load and the position called for by the speed signal, an error signal is generated, by the input transformer. The error signal is fed to the amplifier which produces the power necessary to drive the speed servomotor in accordance with the error signal. When the load is correctly positioned in accordance with the speed signal, the error voltage is zero. The response signal is initially produced by the voltage drop across resistor R9 in the rodmeter coil supply. The magnitude of the response signal is adjusted by the response potentiometer R10 which is driven through gears by the speed servomotor B1.

Digitized by Google

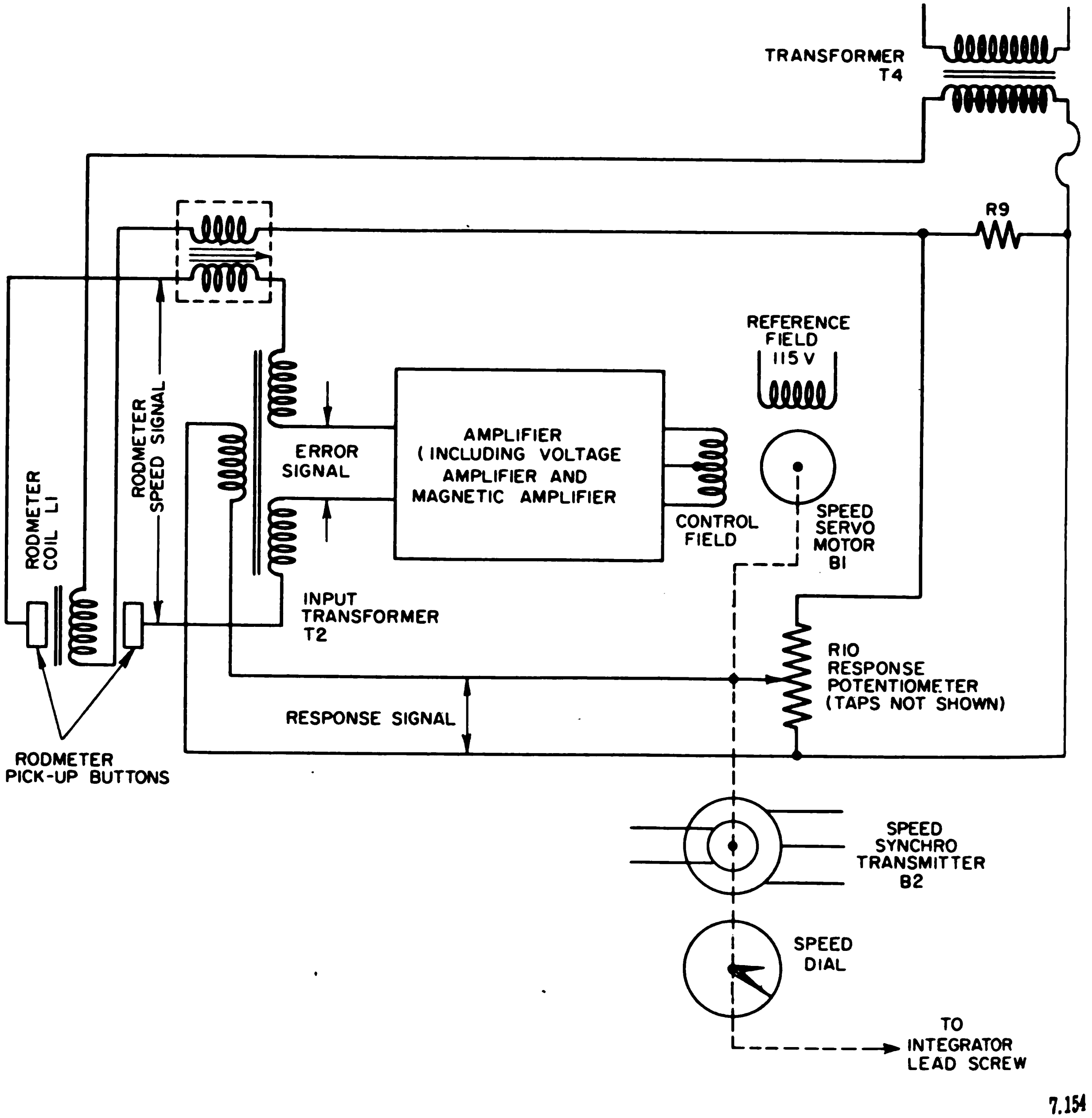


Figure 16-23.—Schematic diagram of speed servo.

AMPLIFIER.—The amplifier (fig. 16-23), consists of the input transformer, a 4-stage vacuum-tube voltage amplifier with its power supply and a 2-stage self-saturating magnetic power amplifier that drives the speed servomotor B1. Each stage of the 4-stage voltage amplifier is a separate interchangeable plug-in unit equipped with twin triode tube.

SERVO MOTOR.—The speed servo is driven by a small two-phase squirrel-cage induction motor B1, of the capacitor type. Its field consists of two sets of windings as shown in figure 16-24. One is a single reference winding. The other, the control winding, actually consists of two separate coils. The reference and control windings are arranged at an angle of 90 degrees with respect to each other.

Digitized by Google

The amplifiers output at inputs other than zero is a pulsating d-c (pulses at 60 cps) through either one control winding coil or the other. This develops a 60-cps a-c in the resonant tuned circuit which includes the two control field coils and capacitor C4. When one of the coils is excited by the amplifier output, the a-c in the field is in phase with the reference (power) supply; when the other coil is excited, the a-c in the field is 180 degrees out-of-phase with the reference supply. This phase relationship is ultimately determined by the input received from the voltage amplifier.

The reference winding is fed from the a-c reference supply. Capacitor C5, in series with this winding displaces its current through 90 degrees. Thus, since the control winding is either in phase with the reference supply or 180 degrees out, the direction in which the rotor turns depends on whether the control field flux leads or lags the reference field flux.

The motor drives the speed dial, speed synchro transmitter B2, and response potentiometer R10 (fig. 16-23).

DIAL AND SPEED SYNCHRO TRANSMITTER.—Ship speed as transmitted by the speed servo is indicated on a dial on the face of the indicator-transmitter. The dial is a clock-type indicator with the short hand making one complete revolution for change in speed of 40 knots, and the long hand making one complete revolution for a change in speed of 1 knot. The hands are driven through gearing by the speed servo motor. The servo motor also positions the rotor in the speed synchro transmitter.

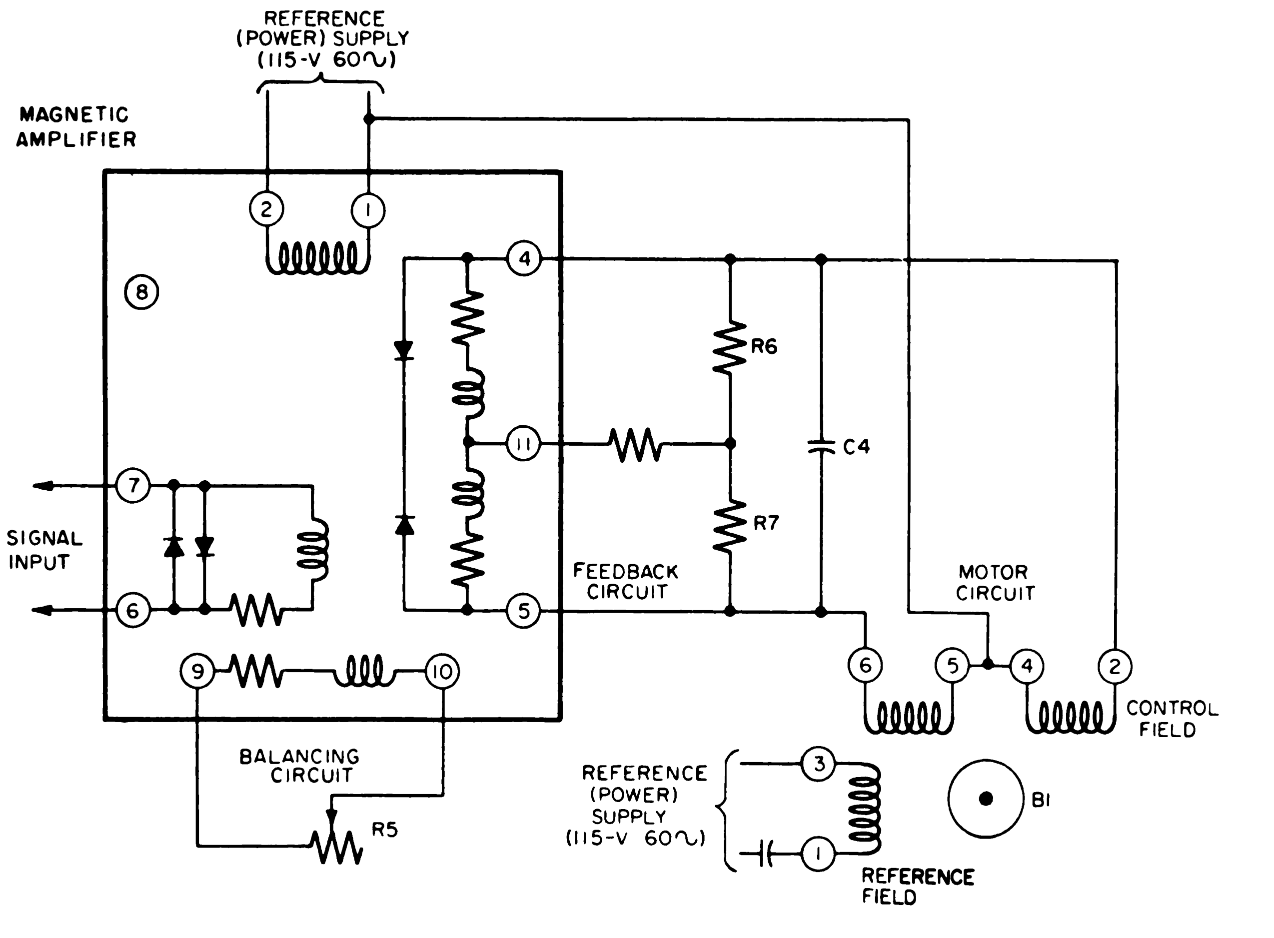


Figure 16-24.—Schematic diagram of magnetic amplifier, speed servo motor and balance circuit.

Digitized by Google

Integrator

The integrator (fig. 16-15), uses the speed servo output to develop a continuous shaft rotation proportional to ship speed. The integrator consists of:

1. A smooth disk rotated at constant speed by a synchronous time rotor.
2. A wheel or roller driven by friction contact with the surface of the disk.
3. A nonrotating lead screw which can position the wheel at any required distance, within limits, from the center of the disk.
4. A threaded bushing, driven by the speed servo motor, which engages the lead screw and translates it longitudinally when it rotates.

The wheel's rate of rotation depends on (1) the rotational rate of the disk, which is constant, and (2) the wheel's distance from the center of the disk, which is regulated by the position of the screw. The screw, when translated by the rotation of the speed servo-driven bushing, moves the wheel toward the disk's center as the speed goes down, or toward the disk's periphery as speed increases. The number of rotations made by the wheel is thus proportional to the distance the ship travels through the water. To keep the wheel from causing excessive wear on the disk at zero speed, the zero position of the wheel is at a radius of 0.5 inch from the center of the disk. Thus, the wheel is always in rolling contact with the disk, and it rotates even when the ship's speed is zero. At zero knots the wheel rotates at 200 rpm.

The function of the differential is to cancel out this continuous wheel rotation at zero speed. Wheel rotation drives one end gear of the differential. The time motor drives the other end gear. At zero ship's speed (wheel at minimum distance from the center of the disk) the inputs to the two end gears of the differential are equal, and opposite in direction.

Since the minimum distance from disk center permitted for the wheel corresponds to zero speed output from the speed servo, the equipment can register only positive (forward) increments of distance.

Distance Servo

The integrator output is a continuous rotation at a rate proportional to ship's speed. This output is used to drive a miles counter and a synchro transmitter which transmits a corresponding synchro signal to remote receivers. However, because a direct load on the integrator output is likely to cause slippage, wear, and inaccuracy a distance servo (fig. 16-25) receives the integrator output. The distance servo in turn drives the counter and synchro transmitter.

The main components of the distance servo are:

1. Mechanical differential
2. Transducer
3. Demodulator
4. Saturable transformer
5. Servo motor
6. Counter
7. Distance synchro transmitter

DIFFERENTIAL.—The mechanical differential functions as an error-detecting device. It receives two inputs—the speed signal output from the differential in the integrator, and the mechanical response from the servo motor. Its output is an error signal which turns the shaft of the transducer.

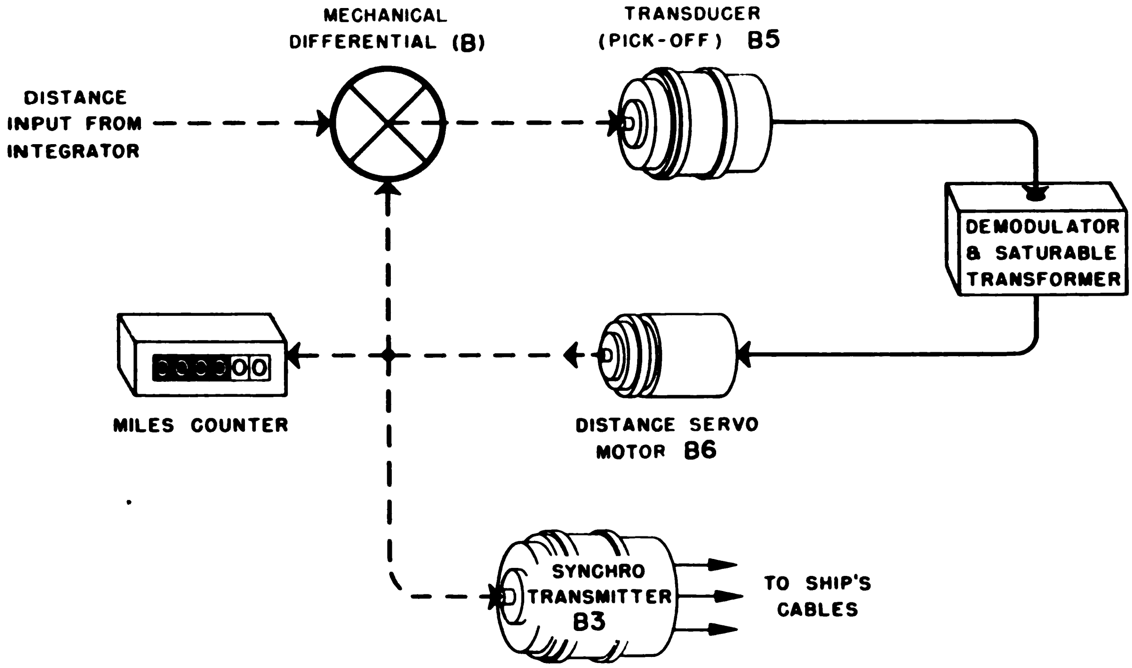
TRANSDUCER.—The transducer (fig. 16-25), pick-off unit is a rotary device that functions like a variable transformer. It is actually a standard 115-volt 60-cps synchro transmitter. Rotor leads R1 and R2 are excited by the 115-volt reference supply. The voltage output from the stator depends upon the rotor position and the output voltage is tapped from terminals S1 and S2 (S3 is not used). This voltage is then amplified. Thus, the transducer converts the mechanical motion received from the differential into a voltage which it transmits to the demodulator and saturable transformer. Its output thus controls the distance servo motor.

DEMODULATOR AND SATURABLE TRANSFORMER.—The output from the transducer (fig. 16-25) is an a-c signal whose phase relationship with respect to the reference supply depends on the angular position of the rotor (excited by the reference supply) and the stator. The saturable transformer functions like a single-stage magnetic amplifier.

The saturable transformer requires a d-c control signal. The function of the demodulator is to furnish such a signal.

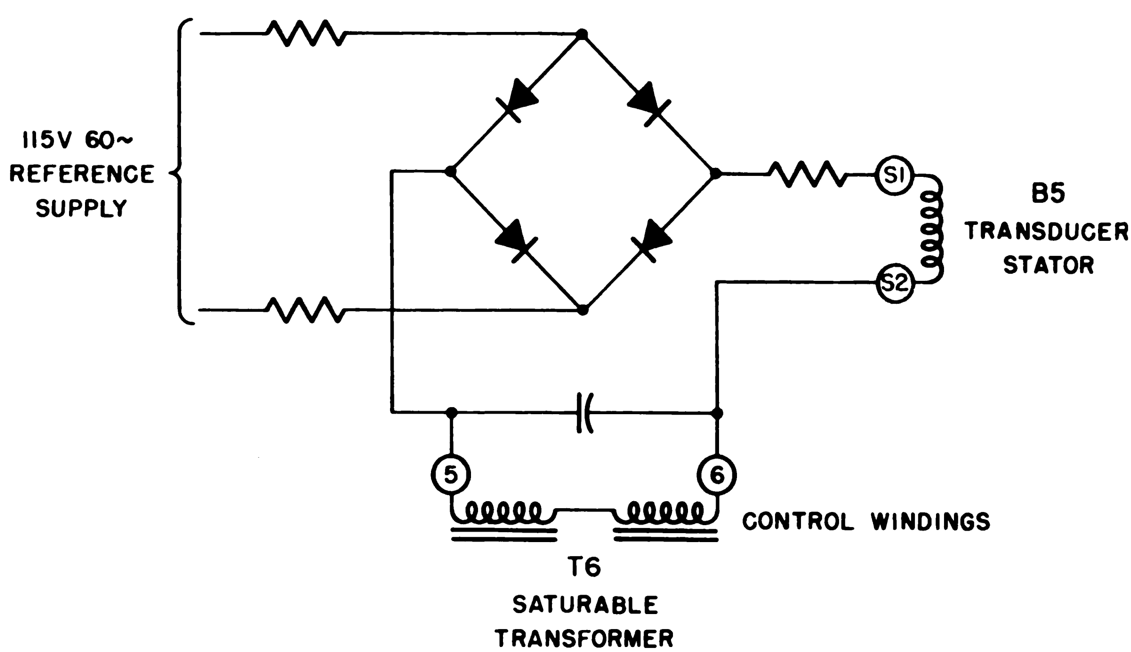
The demodulator is a phase sensitive rectifier device. Figure 16-26 is a schematic diagram of the demodulator, the signal source (the transducer secondary), the reference supply

Digitized by Google



7.158

Figure 16-25.—Functional diagram of distance servo.



7.159

Figure 16-26.—Schematic diagram of demodulator.

Digitized by Google

(115-volt 60-cps), and the output to the control windings of the saturable transformer.

As the diagram shows, the demodulator is fundamentally a bridge-type rectifier circuit consisting of four rectifiers. The a-c signal input comes from the transducer. The reference supply allows the rectifiers to pass current during one-half of its cycle, and causes them to block current flow during the other half.

The transducer, as mentioned, functions like a rotary variable transformer. Depending on rotor position with respect to the stator, the input it supplies is either in phase with the reference supply or 180 degrees out. If the transducer signal is in phase all rectifiers will conduct during one-half the cycle and signal current will flow in one direction. However, during the other half of the cycle no current would flow.

If the transducer output reverses phase (as it would if its shaft were driven in the opposite direction), then current would flow in the control windings in the reverse direction during that part of the reference supply cycle when current is permitted to flow in the demodulator.

The saturable transformer is a variable-impedance transformer. The impedance is varied by a d-c control current from the demodulator. The assembly contains two transformer cores of the shell type (fig. 16-27). Each core is wound similarly, with four windings: d-c bias, d-c control, a-c primary, and a-c secondary. The a-c windings are distributed on the outer legs of the core; the d-c windings are on the center legs of the core. This arrangement minimizes transformer coupling from the a-c to the d-c windings. The secondaries on the two cores are connected so that the output voltage of one is in phase opposition to that of the other. When the impedances of the cores are equal, secondary output voltage is zero.

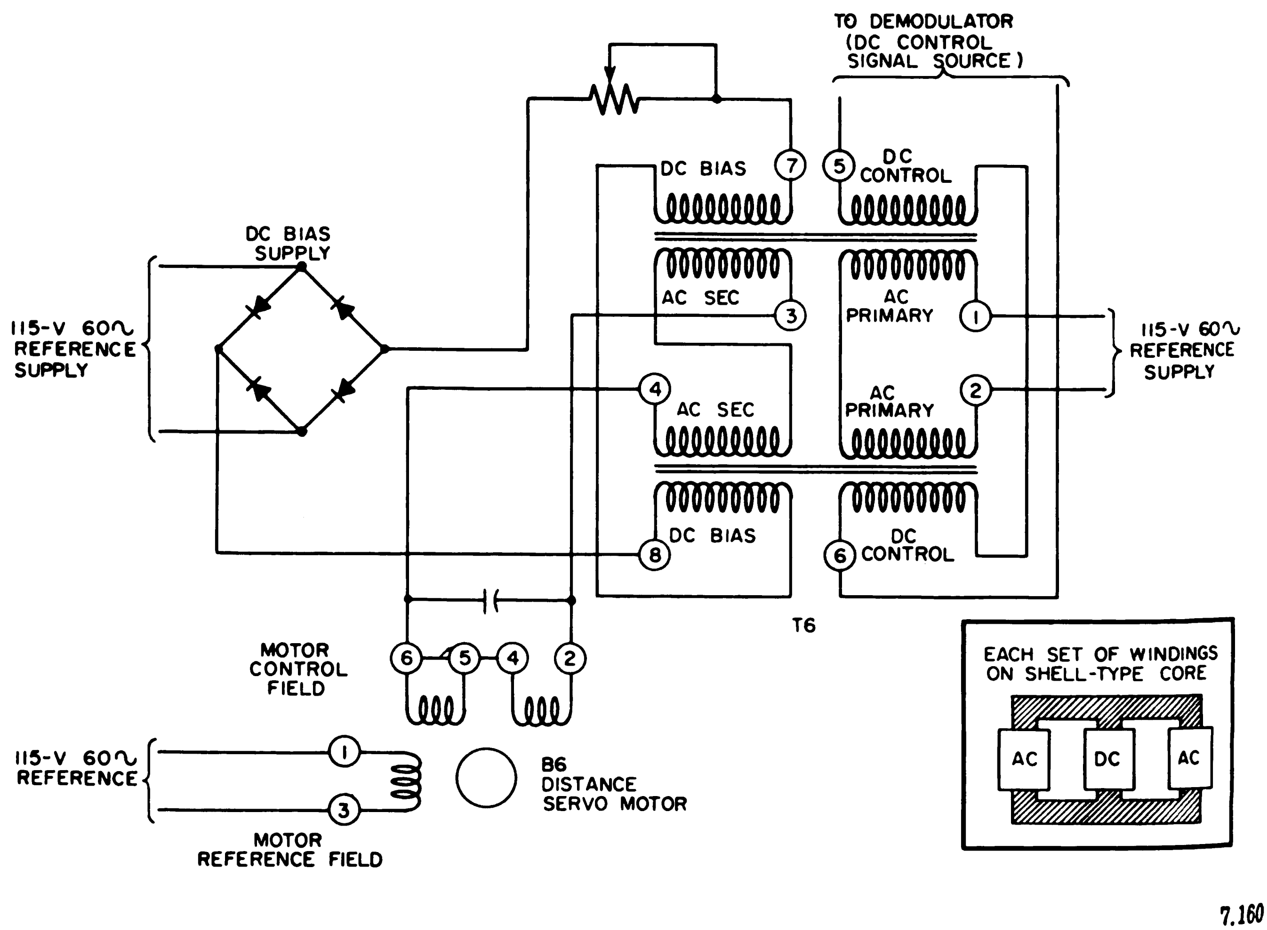


Figure 16-27.—Schematic diagram of saturable transformer.

Digitized by Google

The saturable transformer receives two d-c inputs—the variable signal from the demodulator and the fixed bias current from a full-wave rectifier. The bias current establishes an initial d-c magnetization level in each core.

The bias and control windings are so interconnected that when current flows in the control winding, the flux generated by the current adds to the bias flux in one core and opposes the bias flux in the other. Thus, a control current in either direction drives one core further into saturation, and drives the other out of saturation. The greater the control current, the greater is the difference in saturation of the cores. The greater the saturation, the lesser is the amount of flux available in the core to cause induction in the secondary by transformer action, and the lesser is the output voltage. Thus, the less saturated core produces the higher output voltage.

The output of the saturable transformer is substantially the difference between the output voltages of the two secondary windings (one on each core), and is the same phase as the voltage across the winding but has a higher output. The transformer output is always phase shifted about 90 degrees from the reference supply, but may either lag or lead, depending on the direction of the control current.

DUMMY SIGNAL CIRCUIT

The function of the dummy signal circuit is to produce voltage signals which simulate speed outputs from the rodmeter. Such signals can be used to check the performance of the distance servo. The dummy signal circuit provides a simulated response signal that causes the speed servo to stabilize at any of four dial readings (0, 5, 15, or 30 knots), and permits measurement of the accuracy of distance servo and integrator functioning. Dummy signals are not intended for calibration purposes, but only to check functioning of the equipment.

MAINTENANCE

Make a visual inspection of the rodmeter each time it is retracted, and clean off any marine growth. Look for scratches or scars particularly around the sensing unit. Smooth down any scratches or scars with emery paper or crocus cloth. Scratches, scars, or burs will not affect the functioning of the rodmeter but may damage the valve packing. If the sensing unit is cracked, replace the rodmeter. Check the connections in the Twinax connectors for tightness. The Twinax plug connections at the rodmeter junction box are under strain when the rodmeter is raised or lowered, and are likely to work loose or break.

When the rodmeter is out of the sea valve, inspect the sea valve packing. Replace the packing if it is damaged or eroded.

Every six months, or as directed, open and inspect the electrical and mechanical parts of the indicator-transmitter. When inspecting the electrical parts, look for signs of overheating and leakage of potted compound from sealed parts. Remove and test all electron tubes. Replace defective tubes, and any that test weak. Tighten all connections.

When inspecting the mechanical parts, look for signs of abrasion, loose parts, and noisy or worn gears. Check the integrator disk for signs of scoring. Clean any accumulation of oil or grease drippings with a lint-free cloth. Grain alcohol may be used to clean off the excess oil or grease. An approved solvent may also be used if adequate ventilation is provided. Do not use solvent on any rubber parts. Lubricate all components according to the manufacturer's technical manual or as specified by the Planned Maintenance System Manual.

Digitized by Google

CHAPTER 17

MAINTENANCE

The purpose of maintenance is to ensure that the equipment is ready for service at all times. In maintaining the ship's IC equipment you will be required periodically to test, inspect, and make minor adjustment and repairs. In addition you may be required to maintain certain records and reports concerning the performance and maintenance of IC equipments as specified by the Standard Navy Maintenance and Material Management System.

Maintenance information for various IC equipments has been presented throughout this training course. This chapter presents additional maintenance information relating to cleaning and painting IC equipment, and material concerning the maintenance of portable power tools, batteries, motors and generators, and transistorized and printed circuits. Also included is a brief discussion of the Standard Navy Maintenance and Material Management System.

CLEANING IC EQUIPMENT

Loose dust, dirt, or lint can be best removed by a vacuum cleaner, or by wiping with clean rags. Low pressure air may be used provided that the air is free from foreign particles and moisture, and that the air pressure is sufficiently reduced to preclude damage to the equipment. Compressed air should be used with caution if abrasive or metal particles are present as the particles may be driven into the insulation and air gaps.

Oil and hard deposits of dirt or other foreign matter can be removed with a cloth dampened with an approved cleaning solvent. Inhibited methyl chloroform and trichloroethylene are approved solvents for applications in which carbon tetrachloride was previously used. Carbon tetrachloride is no longer used as a cleaning solvent due to its high toxicity. Trichloroethylene should not be used to clean insulation because of its strong solvent action. Inhibited methyl chloroform may be used to clean insulation and parts painted with insulating varnish if it is used sparingly. Inhibited methyl chloroform will dissolve most insulating varnishes if allowed to stand on the varnish.

To clean insulation or parts painted with insulating varnish, slightly dampen a lintless cloth or piece of surgical gauze with inhibited methyl chloroform and lightly rub the surfaces to be cleaned. Allow the surfaces to dry and repeat the process as necessary. After cleaning, wipe the surfaces with a clean dry cloth.

When using either inhibited methyl chloroform or trichloroethylene, ensure that the space you are working in is well ventilated. Avoid prolonged breathing of the vapor, and prolonged or repeated contact with the skin.

Type II dry-cleaning solvent is an approved nontoxic solvent for cleaning electrical and electronic equipments. The efficiency of this solvent however, is somewhat less than inhibited methyl chloroform or trichloroethylene. Type II dry-cleaning solvent is also injurious to some types of insulation and insulating varnishes. Before using it to clean insulation or parts painted with insulating varnish, make a test by applying the solvent to a small spot on the surface to be cleaned to determine how it is affected by the solvent.

Do not use gasoline or benzine for cleaning IC equipments. Pure grain alcohol is recommended for cleaning some IC components, but must not be used on energized equipment or near any equipment where a spark is likely to occur.

PAINTING AND VARNISHING

Repainting IC equipment should be done only when necessary to prevent corrosion due to lack

Digitized by Google

of paint. General repainting in lieu of cleaning should not be done.

When IC equipment must be painted to combat corrosion, deenergize it first and paint only the area affected by the corrosion. Exercise caution in the use of scraping and chipping tools to avoid damage to the equipment. After the old paint has been removed, the equipment should be thoroughly cleaned with a vacuum cleaner.

Electrical insulating varnish should be applied to IC equipment only as necessary. Frequent applications of insulating varnish builds up a heavy coating which may interfere with heat dissipation and develop surface cracks. Do not apply insulating varnish to dirty or moist insulation, as the varnish will seal in the dirt and moisture and make future cleaning impossible.

Shellac and lacquer are forms of varnish but must not be used for insulating purposes. The two types of insulating varnishes commonly used in the Navy are clear baking varnish (grade CB), and clear air-drying varnish (grade CA). Grade CB is the preferred grade, however if it is not possible to bake the part to be insulated, grade CA is used.

Do not use grade CA or CB insulating varnish on insulating material other than class O or class A material. The classes of insulating materials used in shipboard electrical equipments are listed below:

- Class O insulation consists of cotton, silk, paper, and similar organic materials when neither impregnated nor immersed in a liquid dielectric. Class O insulation is seldom used by itself in electrical equipment.
- Class A insulation consists of (1) cotton, paper, and similar organic materials when they are impregnated or immersed in a liquid dielectric; (2) molded and laminated materials with cellulose filler, phenolic resins and other resins of similar properties; (3) films and sheets of cellulose acetate and other cellulose derivatives of similar properties; and (4) varnish (enamel) as applied to conductors.
- Class B insulation consists of mica, asbestos, fiber glass, and similar inorganic materials in built-up form with organic binding substances. A small portion of class A materials may be used for structural purposes.
- Class H insulation consists of (1) mica, asbestos, fiber glass and similar inorganic materials in built-up form with binding substances composed of silicone compounds or materials with equivalent properties; and (2) silicone compounds in the rubbery or resinous forms, or materials with equivalent properties. A small proportion of class A materials may be used where essential for structural purposes.
- Class C insulation consists entirely of mica, glass, quartz, and similar inorganic material. Class C insulation, like class O, is seldom used alone in electrical equipment.
- Class E insulation is an extended silicone rubber dielectric used in reduced diameter types of electric cables in sizes 3, 4 and 9.
- Class T insulation is a silicone rubber-treated glass tape used in reduced diameter cables in sizes 14 through 800.

PORTABLE ELECTRIC POWER TOOLS

Navy specifications for portable electric power tools require the electric power cord for the tool to be provided with a distinctively marked grounding conductor in addition to the conductors supplying power to the tool. Past practice was to use the red conductor for the grounding conductor in three-conductor cords, and the green conductor in four-conductor cords. Current specifications require that the green conductor be used for the grounding conductor in power cords for all portable electric equipment.

The end of the grounding conductor which is within the portable electric power tool is connected to the tool's metal housing. The other end of the grounding conductor must be grounded, (connected to the metal structure of the ship), when the tool is being used. Standard type plugs and receptacles automatically make this ground connection when the plug is inserted into the receptacle.

If a power tool is used in a nongrounding type receptacle, the metal housing of the tool must be grounded to the ship's metal structure by a separate grounding conductor. The grounding conductor must be at least as large in cross-sectional area as the power conductors. Care must be taken to ensure a clean, tight electrical contact to the ship's metal structure. Securing the grounding conductor under a screw or bolt is preferred over the use of alligator or similar type clamps. Make the ground connection before inserting the plug into the receptacle, and remove the plug from the receptacle before removing the grounding conductor.

Digitized by Google

INSPECTING AND TESTING

Before using portable electric power tools for the first time, and periodically thereafter as directed, they should be inspected and tested as follows:

- Visually inspect the plug and power cord. Ensure that the conductors are tightly secured under the plug terminal screws, and that the plug contacts are clean. Pay particular attention to the ground contact. Clean the contacts with fine sandpaper if necessary.

- If the plug shell is made of brass, measure the insulation resistance between the brass shell and each plug contact with a megger. Move the cord with a push-pull, bending, and twisting motion while taking the reading. If the reading changes while the cord is being moved, or if the reading is below one megohm, the cord should be cut back and the plug rewired. Replace the brass shell with a nylon shell if available.
- Measure the resistance from the ground contact on the plug to the metal housing of the tool with an ohmmeter. Move the cord while taking the reading as before. A change in the resistance reading while moving the cord usually indicates broken strands in the grounding conductor, and requires rewiring the plug or replacing the power cord. The reading must be below one ohm to be satisfactory.
- Inspect the power cord for physical damage such as cuts, cracks, tears, chafing, and exposed bare conductors. Replace defective power cords rather than repairing them with tape.
- Visually inspect the power tool for any mechanical defects, or signs of dampness. Ensure that mechanical parts are not jammed.

- Measure the insulation resistance between each power line contact on the plug and the metal housing of the tool with a megger. Take readings with the tool switch in the ON and OFF positions. An insulation resistance reading of one megohm or above is satisfactory. If the reading is below one megohm the tool should not be used. Low insulation resistance readings may be caused by foreign matter such as dirt, carbon dust, and grease inside the electric motor for the tool. If this is the case, cleaning the motor will bring the readings up to a satisfactory value. Moisture inside the motor is also a frequent cause of low insulation resistance. If this is suspected, the moisture may be removed by drying the tool in an oven.

When replacing plugs and power cords for portable electric power tools, make all connections securely and in a workmanship like manner. There must be no loose strands of wire protruding from under terminal screws. Use standard crimp or solder type wiring terminals, or form the conductor ends into an eyelet or hook, and coat them with solder to bond the strands together.

BATTERIES

A cell is a device that transforms chemical energy into electrical energy. A battery may consist of one cell or two or more cells connected together and assembled in a common container. Batteries may be made up of either primary (dry) or secondary (wet) cells, the operating principles of which are discussed in Basic Electricity, NavPers 10086-A.

DRY BATTERIES

One or more dry cells constitute a dry battery. A dry battery is not completely reversible, and therefore cannot be recharged economically after it has been discharged. Dry batteries are manufactured in a wide variety of sizes and weights, and are used to supply circuits that require a low and intermittent current. Dry cells are of the (1) Leclanche; (2) mercury; and (3) low-temperature types.

LECLANCHE CELL.—The Leclanche cell has a nominal open-circuit voltage of 1.5 volts. The positive electrode is a mixture of manganese dioxide and powdered carbon in contact with a carbon rod. The negative electrode is zinc and usually comprises the container. The electrolyte is a paste consisting of ammonium chloride (sal ammoniac), a small amount of zinc chloride and mercury chloride, water, and starch. The electrical energy is obtained from reactions between the zinc, sal ammoniac, and maganese dioxide.

MERCURY CELL.—The mercury cell has a nominal open-circuit voltage of 1.3 volts. The positive electrode is a mixture of mercury oxide and carbon. The negative electrode is a zinc plate or compressed zinc powder. The electrolyte is a watery solution of potassium hydroxide. The electrical energy is obtained from the reduction of mercury oxide to metallic mercury, and the oxidation of zinc to zinc oxide.

Digitized by Google

LOW-TEMPERATURE CELL.—The low-nperature cell is composed of the same ma-:ials as the Leclanche cell except that the ectrolyte is modified to give better low nperature (below zero degrees Fahrenheit) rformance. The positive electrode is made highly active manganese dioxide; consequent-, low-temperature cells do not store as well normal cells. Their use is not recom-ended unless they can be shipped, stored, d used at temperatures below 35 degrees ihrenheit.

The low-temperature cell and the mercury ll have superior characteristics for special plications, but are not used as extensively the Leclanche cell because of the greater st.

LABEL.—All dry batteries are labeled to ovide installation and replacement data. This ta includes the type designation, order number, de number, and manufacturer's name and ad-ress, (fig. 17-1). The type designation com-ises the battery component, battery type imber, and installation indicator.

The battery component denoted by the symbol, A, identifies a dry battery. The battery type imber, 236, following the component symbol, lentifies the basic design of the battery and e kind of cell or cells that make up the bat-ery. Battery type numbers 1 through 999 in-icate Leclanche cells; 1000 through 1999 in-icate mercury cells; and 2000 through 2999 dicate low-temperature cells.

The installation indicator denoted by the ymbol U, (fig. 17-1), indicates general utility ervice. The code number 034 indicates the ate the battery was manufactured. The first wo digits, 03, indicate the third month (March) nd the 4 indicates the year 1964.

TERMINAL MARKINGS.—The terminals of dry battery are indicated with the proper polarity markings, which appear on the top or side of the battery as close as possible to the applicable terminal. The location of the polarity markings will vary depending upon the type of battery.

MIL BATTERY BA-236/U

1958-PHILA.-51-7
034
J & J MFG. CO.
PLAINFIELD, N. J.

77.86

Figure 17-1.—Dry battery label.

CHARACTERISTICS.—Dry batteries are rated in volts and hours for various conditions of operation. The capacity of a dry battery is determined by the length of time required for the terminal voltage to drop to a specified end value when the battery is discharged continuously through a fixed resistance. The operating conditions that determine the discharge characteristics of a dry battery are the initial capacity, delayed capacity, initial arctic capacity, and delayed arctic capacity.

INITIAL CAPACITY.—The initial capacity is the time required at normal temperature for the battery voltage to fall below the specified test end voltage, or to show evidence of electrolyte leakage, or swelling of the case when discharging through a specified load.

DELAYED CAPACITY.—The delayed capacity is the time required at normal temperature for the battery voltage to fall below the specified end voltage, or to show evidence of electrolyte leakage, or swelling of the case after the battery has been stored for a period of time.

INITIAL ARCTIC CAPACITY.—The initial arctic capacity is the time required at 40° below zero F, for the battery voltage to fall below the specified end voltage, or show evidence of electrolyte leakage, or swelling of the case.

DELAYED ARCTIC CAPACITY.—The delayed arctic capacity is the time required at 40° below zero F, for the battery voltage to fall below the specified end voltage, or show evidence of electrolyte leakage, or swelling of the case after the battery has been stored for 48 hours at this temperature.

An example of the capacity ratings for battery BA-2039/U are: Initial capacity—36 hrs.; delayed capacity—31 hrs.; initial arctic capacity—3.6 hrs.; and delayed arctic capacity—3.1 hrs.

INSTALLATION.—Applicable installation practices and safety precautions must be followed when installing dry batteries. Fresh batteries of the proper type, size, and shape should be installed initially, or as a replacement for a specified installation. They must be connected in accordance with the instructions furnished with the equipment, and all

Digitized by Google

electrical connections should be clean, tight, and well insulated.

If equipment is idle for two weeks or more, remove the batteries. If the batteries are fairly fresh, return them to storage with a record showing how long they have been used. Remove and scrap batteries that have had long, hard use.

STORAGE.—Dry batteries are perishable and will deteriorate when not in use. They should be stored in a cool dry space. Do not store them in the equipment in which they are to be used, as they may become discharged by internal chemical reaction, or by leakage current across normally open contacts. These conditions generate water within the cells, and the electrolyte may leak out and corrode the equipment.

SHELF LIFE.—The shelf life of dry batteries is the length of storage time beyond which a group of batteries will contain so many dead cells that the entire group is considered unusable. Shelf life varies, depending upon the type of battery and its use. Shelf life tables are issued by supply offices. These tables are based on general use requirements and indicate a longer shelf life than is tolerable for some applications. Test the usability of an individual battery by trying it out in the equipment for which it is to be used, or by connecting it to an equivalent load and measuring the closed-circuit voltage. If the closed-circuit voltage is above that required for satisfactory equipment operation, the battery is suitable for use. Always survey batteries when they have reached the end of their shelf life.

SAFETY PRECAUTIONS.—Certain types of dry batteries generate hydrogen, which is very explosive. When working with these batteries, interrupt the current at a remote point before disconnecting them from the equipment.

When a battery is disconnected from operating equipment, the terminal leads of the battery should be insulated to prevent the possibility of short-circuiting the battery, which might generate sufficient heat to cause a fire. Also the discharge caused by a short circuit usually produces excessive water in the cells, thereby causing them to burst and spill the electrolyte on the equipment.

Multicell dry batteries should not be used after the closed-circuit voltage has dropped below 0.9 volt per cell. If the battery is further discharged, current will be forced through some cells that may be completely discharged. This action will generate hydrogen and oxygen due to the electrolysis of the water with the consequent danger of a hydrogen explosion.

STORAGE BATTERIES

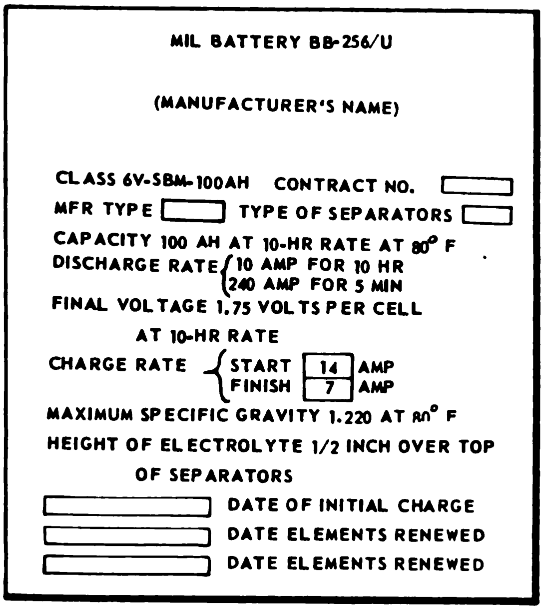
Storage batteries are made up of secondary (wet) cells. One cell, one tray of cells, or a number of trays of cells connected in series, parallel, or series-parallel constitute a storage battery. A storage battery is reversible because the active materials consumed during discharge can be restored by passing a charging current through the battery. Storage batteries in general use in the Navy are the lead-acid and nickel-cadmium types. Storage batteries are classified as class ER, electrolyte-retaining, and class FE, free electrolyte batteries. Class ER batteries have separators and plates that absorb and retain within the cell at least 80 percent of the electrolyte, and operate with not more than 20 percent of the electrolyte in a free condition. Class FE batteries operate with at least 50 percent of the electrolyte in a free condition.

NAMEPLATE.—All storage batteries are provided with nameplates that contain installation and replacement data (fig. 17-2). The type designation on the nameplate is the same form as that previously described for dry batteries. The battery component denoted by the symbol, BB, identifies a lead-acid storage battery. The battery type number, 256, identifies the basic design of the battery. Batteries designed for low temperature operation are identified by increasing the established battery type number by 2000. For example, a low temperature battery is identified if the established battery type number, 256, is increased to 2256.

Prior to Military Specification For Lead-acid Storage Batteries, (MIL-B-15072A), storage batteries were identified according to voltage, use, and rating. This former type designation Class 6V-SBM-100AH, also appears on the nameplate (fig. 17-2). The 6V identifies a six-volt battery, and the symbol SBM identifies a monobloc storage battery. The symbol 100AH identifies a battery with a 100 ampere-hour rating.

TERMINAL MARKINGS.—The positive and negative terminals of storage batteries are marked POS or P and NEG or N respectively. These polarity markings are raised or depressed characters placed on, or as close to the

Digitized by Google



77.87

Figure 17-2.—Storage battery nameplate.

applicable terminal as possible. For further polarity identification, portions of the positive and negative terminals that are not contact surfaces may be painted red and black respectively.

CAPACITY.—The capacity of a storage battery is the constant current that the battery can supply continuously at a definite rate of discharge before the voltage drops to a specified (final) voltage. This capacity varies with the rate of discharge; that is the lower the rate of discharge the greater the capacity.

DISCHARGE RATE.—Navy storage batteries are rated at the 10-hour discharge rate, which is the constant current in amperes that the battery can supply continuously for 10 hours before the voltage drops to the low-voltage limit or final voltage.

FINAL VOLTAGE.—The final voltage, or low-voltage limit is that voltage set by the manufacturer beyond which very little useful energy can be obtained from the battery. The final voltage will vary depending upon the type of battery. For most lead-acid storage batteries it is 1.75 volts per cell.

Lead-acid Batteries

The lead-acid storage battery is the storage battery most used in the Navy. Lead-acid storage batteries may be shipped charged and wet or dry. When shipped to Navy ships they are usually in the charged and wet condition. When shipped to naval shipyards or other shore establishments, or to repair ships and tenders, they are usually in the dry condition.

CHARGED AND WET.—When batteries are received in the charged condition, the height of the electrolyte should be checked, and the specific gravity and temperature readings should be taken of all cells to determine the state of charge. Unless otherwise specified, the height of the electrolyte should be three-eighths of an inch above the separators. If the electrolyte has been spilled during shipment, it should be replaced with electrolyte of 1.215 specific gravity corrected to 80° F. If water or electrolyte is added, the battery should be charged at the finishing rate until the specific gravity readings, corrected for temperature, are constant for a period of five hours. If the battery is not to be placed in service immediately, an equalizing charge should be given at one month intervals, or sooner if the specific gravity drops to 1.180.

UNCHARGED AND DRY.—When batteries are received in the dry condition, and are not to be placed in service, the vent plugs must be kept tightly in place and the batteries stored in a clean dry place until they are required.

If the battery is to be placed in service, follow the instructions furnished with the battery. These instructions specify the specific gravity of the electrolyte to be used in filling the cells, and instructions for conducting the initial charge.

PLACING IN SERVICE.—When connecting batteries for service and the terminals are not marked or cannot be read, the polarity can be determined with a d-c voltmeter. If a d-c voltmeter is not available, immerse the terminal leads in salt water holding them about one-half inch apart. Bubbles will collect on the negative lead. Do not allow the leads to touch each other when conducting this test.

The contact surfaces of battery terminals are usually covered with a thin film of acid which should be neutralized and removed to prevent corrosion before making the connections. Diluted ammonia or a solution of bicarbonate of soda can be used for this purpose. Do not allow the solution to enter the cells. After the contact surfaces have been neutralized and cleaned, they should be

Digitized by Google

brightened with a wire brush or fine sandpaper. After the connections are made, coat the terminals with petrolatum.

STORAGE.—Storage batteries, like dry batteries, deteriorate when not in use. Batteries in a wet condition should not be stored for any great length of time. When they are to be stored temporarily, they should be placed in a clean dry space at an average temperature of about 75° F. Give them an equalizing charge before placing in storage and coat all exposed terminals with petrolatum to prevent corrosion. Batteries in wet storage must be inspected at frequent intervals, and the electrolyte level maintained above the tops of the separators. They should be given an equalizing charge each month, or more often if the specific gravity falls below 1.180.

MAINTENANCE.—Lead-acid storage batteries will deteriorate rapidly if not maintained properly. The actual life of these batteries is indeterminate, but when properly cared for they should give service for four or more years.

The service for which a battery is used primarily determines the nature of the care and maintenance that will ensure maximum life of the battery.

For batteries subject to heavy use, frequent charging is necessary. Batteries used as emergency power supplies, such as gyrocompass batteries, are usually kept on a floating charge and must be inspected frequently to prevent overcharging. Batteries that are seldom used must also be checked periodically, as a normal battery on open circuit will discharge 50 percent or more of its capacity in three or four months. This is a normal condition known as local action or self-discharge. The lead sulphate formed during self-discharge is more difficult to reduce by charging than the lead sulphate formed during a regular discharge. Batteries that are seldom used, therefore, should be given an equalizing charge approximately once a month.

SAFETY PRECAUTIONS.—Battery charging stations must be provided with adequate ventilation to remove the explosive mixture of hydrogen and air. When batteries are being charged, hydrogen gas is liberated; if the surrounding air contains from 4 to 8 percent hydrogen, a mixture is formed that will burn if ignited; if the mixture contains more than 8 percent hydrogen, it will explode. Thus, ample ventilation is necessary to keep the hydrogen concentration below the safe limit of 3 percent. The ventilating system, in addition to preventing the formation of an unsafe hydrogen concentration, provides a means of keeping the temperature of the battery charging station down to 95° F, or lower. The temperature of the electrolyte for batteries on charge must not exceed 125° F.

All batteries must be kept clean and free from acid and dirt; otherwise corrosion will occur and lead to troublesome grounds. Grounds are formed by the collection of dirt and acid on the cell tops and sides of the battery, and will cause the battery to discharge. A battery ground can also cause a spark that could ignite a fire, or cause an explosion.

Acid that has collected on a battery can be removed with a cloth moistened in a dilute solution of ammonia or bicarbonate of soda.

Never charge a battery at a higher finishing rate than that indicated on the battery nameplate. When charging more than one battery at the same time, the voltage of the charging line must exceed the total voltage of all the batteries being charged in series. Also the charging rate in amperes must not exceed the maximum charging rate of the battery having the lowest ampere-hour capacity in the charging line. The charging rate must be lowered as soon as the battery begins to gas, or the temperature of the battery reaches 125° F. Except in an emergency, do not discharge a battery below the low-voltage limit. Do not allow a battery to stand in a completely discharged condition for more than 24 hours.

Only tools with insulated handles should be used while servicing a battery, and care should be exercised not to shortcircuit the terminals. Do not make repairs to battery connections while the current is flowing. When batteries are used with one terminal grounded, connect the grounded terminal last when connecting the battery in a circuit, and disconnect it first when disconnecting the battery.

When mixing electrolyte, always pour the acid into the water, not the water into the acid. Add the acid slowly to prevent excessive heating. Do not allow it to splash. Stir the solution continually while mixing, to prevent the acid (which is heavier than water) from flowing to the bottom of the container. Wear a rubber apron, rubber boots, rubber gloves, and goggles when mixing electrolyte.

Digitized by Google

Nickel-Cadmium Batteries

The nickel-cadmium battery is composed of alkaline storage cells. The construction and general arrangement of the cell are similar to that of the lead-acid cell. The negative plate assembly is a cadmium-oxide compound; the positive plate assembly is a nickel-oxide compound; and the electrolyte is a 30 percent solution of potassium hydroxide. Separators between the positive and negative groups prevent internal shortcircuits. The cell components are assembled in a single plastic jar. The battery is of fabricated steel. A six-volt battery contains five series connected cells. When fully charged, the cell voltage ranges from 1.39 to 1.45 volts.

CHARGING.—The effect of the charging current is to change the active material of the negative plate (cadmium-oxide) to metallic cadmium (CdO to Cd). The active material of the positive plate (nickel-oxide) is changed to a higher state of oxidation, (NiO to Ni_2O_3). As long as the charging current continues, this action occurs until both materials are completely converted. Toward the end of the charging process, and during overcharge, the cell will gas due to the electrolysis of the water in the electrolyte. The amount of gas liberated depends upon the charging rate.

The electrolyte does not enter into any chemical reaction with the positive or negative plates. It acts simply as a conductor of current between the plates, and its specific gravity does not vary appreciably with the amount of charge. The effect of the reactions during charge is a transfer of oxygen from the negative to the positive plates. In this respect the nickel-cadmium battery is similar to the lead-acid battery. Unlike the lead-acid battery however, the specific gravity of the electrolyte remains constant, except at the end of a charge, or on overcharge, when it increases because of the electrolysis of the water. The proper specific gravity can be obtained by adding distilled water.

There is no simple practical way of measuring the state of charge of a nickel-cadmium battery. When in doubt about the state of charge, the best procedure is to give the battery a charge. Nickel-cadmium batteries can be charged by the constant voltage, constant current, or stepped constant current methods.

DISCHARGING.—When the battery is being discharged, the chemical action that occurs is the reverse of that of the action on charge. The negative plates gradually regain oxygen (Cd to CdO), and the positive plates gradually lose oxygen (Ni_2O_3 to NiO). There is no gassing on discharge due to the interchange of oxygen.

MOTORS AND GENERATORS

Preventive maintenance of motors and generators consists mainly of cleaning, lubricating, and inspecting and servicing bearings, collector rings, and brushes.

CLEANING

Motors and generators are cleaned by using wiping cloths, suction, compressed air, and solvents.

Wiping with a clean lint-free cloth (such as cheesecloth), 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, collector ring insulation, and connecting leads.

The use of suction is preferred over the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine. 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. Exhaust the blower to a suitable sump or overboard when used for this purpose.

Compressed air must be clean and dry when used for cleaning. Air pressure up to 30 pounds per square inch may be used on motors and generators up to 50 hp and 50 kw respectively. Pressures up to 75 pounds per square inch may be used on machines over 50 hp or kw.

The use of solvents for cleaning should be avoided whenever possible. Solvents must be used however, for removing grease and pasty substances consisting of oil and carbon or dirt. Exercise caution in using solvents to clean insulation as stated previously.

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

Digitized by Google

most in motors and generators. This bearing is further divided into three types depending upon the load it is designed to bear as shown in figure 17-3.

The rotating element of a 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.

Preventive maintenance for ball bearings requires periodic checks for bearing wear, and adequate lubrication.

Wear

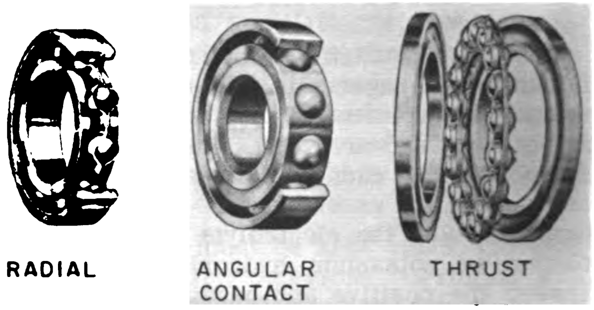
Measuring air gaps to determine bearing wear is not necessary on machines equipped with ball bearings. Ball bearing wear of sufficient magnitude as to be detected by air gap measurements would be more than enough to cause unsatisfactory operation of the machine.

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

When checking for overheating, the normal running temperature of the bearing must be known before the check can be reliable. Rapid heating of a bearing is an indication of danger. A bearing temperature that is uncomfortable to the hand may not be a sign of danger 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 upon the experience of the person making the test. He must be thoroughly familiar with the normal vibration of the machine to be able to correctly detect and interpret any unusual vibrations. Vibration is easily telegraphed, and a thorough search may be required to locate its source and to determine its cause.

A good method for testing for abnormal noise in a ball bearing is to place one end of a screwdriver or a steel rod against the bearing housing and the other end against the



77.66

Figure 17-3.—Typical ball bearings.

ear. If a loud, irregular grinding, clicking, or scraping noise is heard, trouble is indicated. The one sure method of checking ball bearings is also the most difficult. In this method, 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 approximately every two years. The condition of the lubricant in the bearing may be checked at this time.

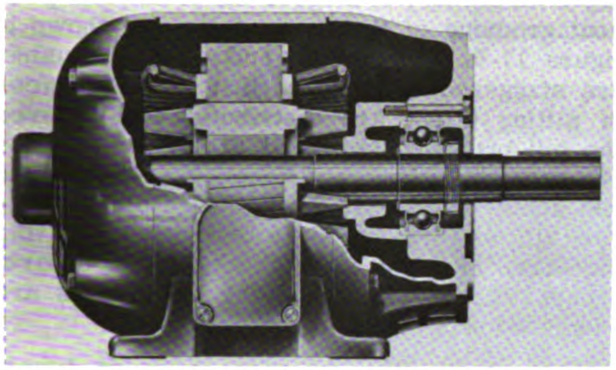
Lubrication

Many motors and generators are equipped with permanently lubricated ball bearings, and require no additional lubrication throughout their life. A permanently lubricated ball bearing is shown in figure 17-4. Note the absence of grease fittings on the motor.

Ball bearings other than the permanently lubricated type require periodic lubrication with grease or oil. Machines using grease-lubricated bearings are provided with grease cups attached to the bearing housing which provide a means for adding grease to the bearing. The parts of a grease-lubricated ball bearing are shown in figure 17-5. Whenever feasible, it is recommended that grease cups be attached to machines only when grease is being added to the bearings. When the grease cup is removed however, it must be replaced with a suitable pipe plug to prevent dirt or other foreign matter from entering the bearing. This procedure prevents unauthorized personnel from adding grease to the bearing.

The frequency with which grease must be added to ball bearings depends upon the service the machine performs. Usually the addition of grease will not be necessary more often than

Digitized by Google



77.67
Figure 17-4.—Motor equipped with permanently lubricated ball bearings.

once every six months. Overgreasing has been a major cause of bearing failure. In a bearing housing too full of grease, 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 and heat 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 instrument. 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, then replace the drain plug.

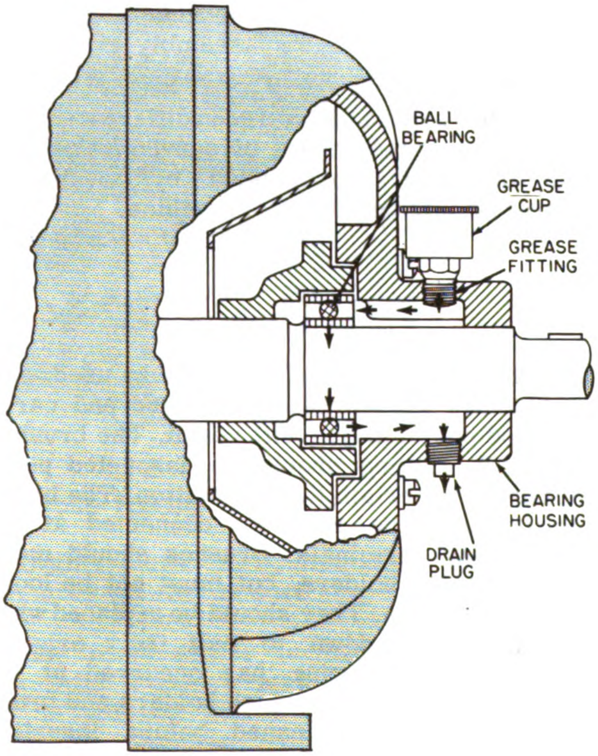
A grease gun should not be used to lubricate ball bearings unless there are no other means available. If used, remove the drain plug and apply just enough pressure to the gun to get the grease into the housing. Grease gun fittings must be removed from the machine after use and replaced with a pipe plug.

Some motors and generators are equipped with oil-lubricated ball bearings. Lubrication charts or special instructions are usually furnished for this type of bearing and should be carefully followed. In the absence of instructions, the oil level inside the bearing housing should be maintained approximately level with the lowest point of the bearing inner ring.

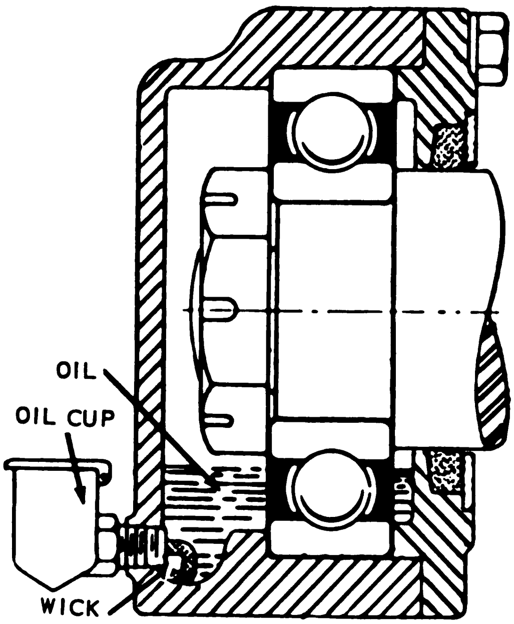
A common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick. The wick also filters the oil and prevents leakage through the cup in the event a pressure is built up within the housing. A wick-fed oil-lubricated ball bearing is shown in figure 17-6.

BRUSHES

The brushes used in motors and generators are usually made of carbon and bear against a commutator or collector ring to provide a sliding contact for passage of current to an external circuit. An adjustable spring is usually provided to maintain proper pressure of the



77.68
Figure 17-5.—Grease-lubricated ball bearing.



77.69

Figure 17-6.—Wick-fed ball bearing.

brush on the commutator or collector ring. Constant-pressure brush holders are used in some small machines. A d-c generator brush holder and brush-rigging assembly are shown in figure 17-7.

Brushes are manufactured in different grades to meet the varied types of service. Only the grade of brush recommended by the manufacturer should be used in a machine.

Care

If the correct grade of brush is used, and the brushes are correctly adjusted and cared for, good commutation will result. The brushes and brush rigging should be inspected periodically to ascertain their condition. The brush pigtails must be securely connected at the brushes and terminals. Brushes should move freely in their 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. The brush holders and brush rigging should be cleaned before inserting the new brushes.

The pitting effect on the commutator differs under the positive and negative brushes, making it necessary to stagger the brushes to prevent grooving of the commutator, as shown in figure 17-8. 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. 17-8A). In a machine having an odd number of pairs, it is impossible to stagger all the brushes in this manner. In this machine, the brushes are staggered as before, except that the brushes of the odd pairs are staggered separately (fig. 17-8B).

Except for the constant pressure types, as the brushes wear, the brush spring tension must be changed to keep the brush pressure approximately constant. Brush pressure should be as specified in the manufacturer's technical manual for the machine concerned. Pressures as low as 1 1/2 pounds per square inch of contact area may be specified for large machines, and as high as 8 pounds per square inch for small machines. Where manufacturer's technical manuals are not available, a pressure of 2 to 2 1/2 pounds per square inch of contact area is recommended for integral horsepower and kilowatt machines, and about twice that pressure for fractional horsepower and kilowatt machines.

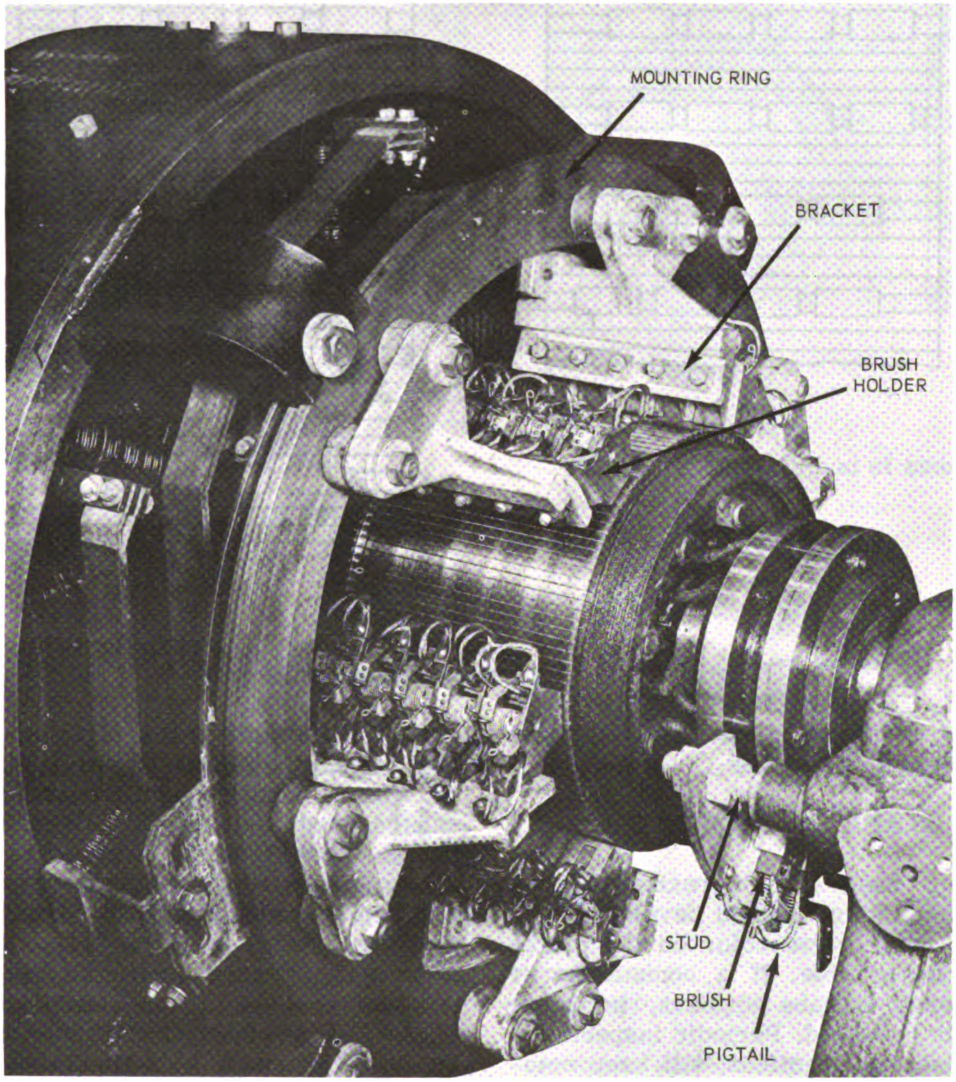
To measure brush pressure, attach a small spring balance to the pigtail end of the brush, insert one end of a strip of paper between the brush and the commutator, then exert a pull on the spring balance in the direction of the brush holder axis (fig. 17-9). Note the reading of the spring balance when the pull is barely sufficient to release the paper so that it can be pulled from between the brush and the commutator without resistance. Divide this reading by the contact area of the brush to obtain the brush pressure.

Seating

Accurate seating of the brushes must be assured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools for seating.

Disconnect all power from the machine, and exercise caution to ensure that the machine will not be inadvertently started, before using sandpaper to seat the brushes. The brushes to be seated are lifted and a strip of fine sandpaper approximately the width of the

Digitized by Google



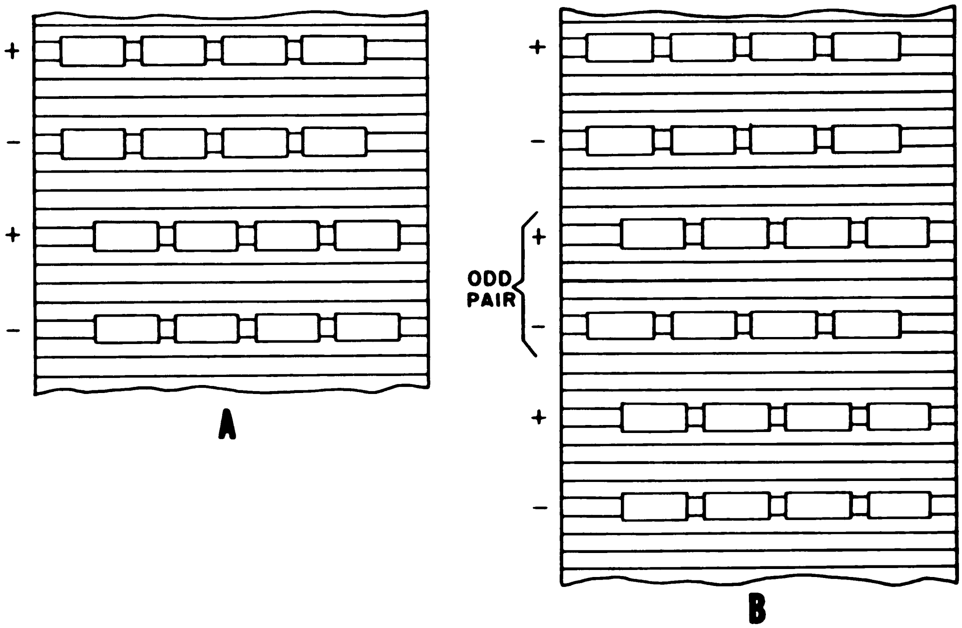
77.70

Figure 17-7.—Brush holder and brush-rigging assembly.

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 tension, pull the sandpaper in the direction of normal rotation of the machine (fig. 17-10). When returning the sandpaper for another pull, the brushes must be lifted. This operation is repeated until the brushes are accurately seated. Use a finer grade of sandpaper when finishing. Use a vacuum cleaner to remove dust while sanding. After the brushes are seated, thoroughly clean the commutator and windings to remove all carbon dust.

The brush seater is made of a compound of a mild abrasive material loosely bonded, and is formed into a stick about 5 inches in length. To use the brush seater, touch it lightly for a second or two at the heel of the brush while the machine is running (fig. 17-11). 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. After using the

Digitized by Google



77.71

Figure 17-8.—Method of staggering brushes.

brush seater, clean the machine in the same manner as for sanding brushes.

COMMUTATORS AND COLLECTOR RINGS

After being used for approximately two weeks, the commutator should develop a uniform, glazed, dark brown color on the places where the brushes ride. If a nonuniform or a bluish colored surface appears, improper commutation is indicated. Periodic inspections, and proper cleaning practices will keep commutator and collector troubles to a minimum.

Cleaning

One of the most effective ways of cleaning a 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-eights inch thick (fig. 17-12). The canvas may be secured with rivets if they 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. When using the wiper, exercise caution to keep it from getting caught in the moving parts of the machine. The methods of applying the wiper to the commutator are shown in figure 17-13.

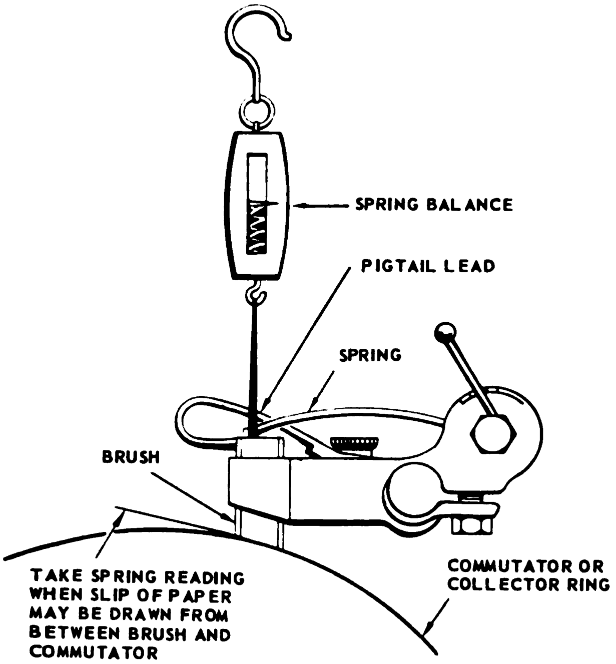
When machines are secured, a toothbrush can be used to clean out the commutator slots, and a clean lintless cloth may be used for wiping the commutator and adjacent parts. In addition to being cleaned by wiping, the commutator should be cleaned periodically with a vacuum cleaner or blown out with clean, 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. Sandpaper 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 back and forth across the surface of the commutator while the machine is running at a moderate speed. Do not use emery cloth, emery paper, or an emery stone on a commutator or collector ring.

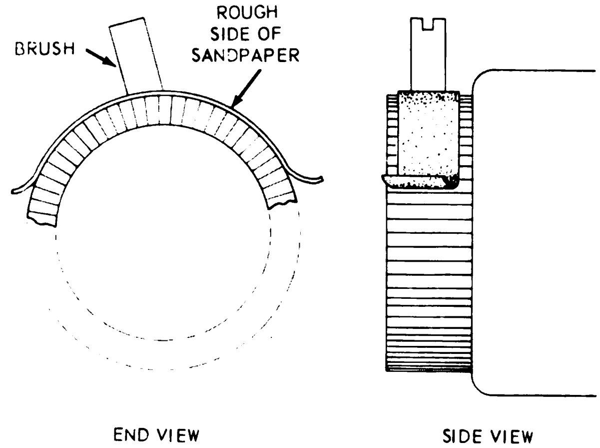
Care of Commutators

Commutators must be true within close limits. For satisfactory operation, eccentricity (out-of-roundness) of the commutator surface should not exceed 0.002 inch. Hand stoning, grinding with a rigidly supported stone, and

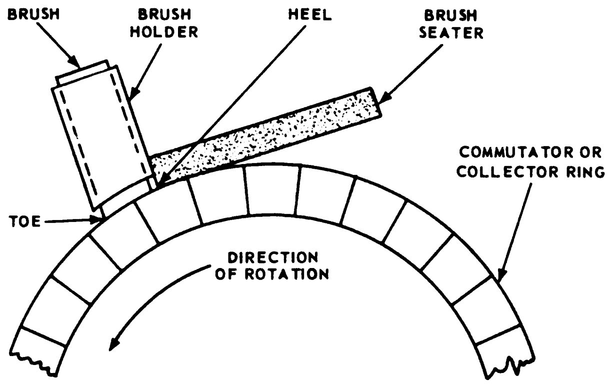
Digitized by Google



77.72
Figure 17-9.—Measuring brush pressure.



1.52
Figure 17-10.—Method of sanding brushes.



1.53
Figure 17-11.—Using the brush seater.

turning the commutator in a lathe are measures that will correct out-of-roundness in commutators.

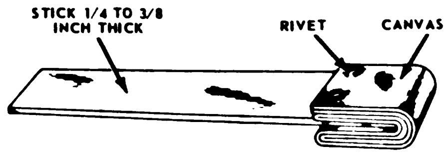
For hand stoning, the machine should be running at, or slightly below rated speed. For motors, remove all brushes except enough to keep the armature turning at the proper speed. The stone to be used should fit the curvature of the commutator, and have a surface larger than the largest flat spot to be 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. 17-14). Crowding the stone will roughen the surface. Exercise care to avoid electric shock, and to prevent jamming the stone between moving parts of the machine.

Either a rotating or a nonrotating stone can be used when grinding the commutator with a rigidly supported stone. Regardless of which stone is used, or whether the grinding is done with the commutator in the machine or in a lathe, extreme care must be taken to align the supports so that the motion of the stone is parallel to the axis of the commutator.

For turning, the armature is supported in a lathe (fig. 17-15). A cutting tool that is rounded sufficiently so that the cuts will overlap must be used to make the cut. The proper cutting speed is about 100 feet per minute, with the feed about 0.010 inch per revolution. The depth of the cut should not exceed 0.010 inch.

When the oxide film (dark brown color) of the commutator has been removed by truing operations, it can be replaced by burnishing the commutator with a hardwood block. The block is shaped to fit the curvature of the commutator, and is pressed hard against the surface of the commutator while the machine is running. A commercial burnishing stone may be used for this purpose. Less pressure is required when applying the commercial

Digitized by Google



1.54.1
Figure 17-12.—Canvas wiper.

burnishing stone because the friction is greater, and the heat developed is high. Do not raise the temperature of the commutator above its normal operating level.

Commutator mica that has become carbonized looses its insulating value. The carbonized portion should be scraped out and replaced with an insulating cement. Poor commutation will result if the commutator bars are worn down to or below the level of the mica. In this case, the mica should be undercut to a depth of between three sixty-fourths and one sixteenth inch below the level of the commutator bars.

Care of Collector Rings

Collector rings require the same careful attention as the commutator. Out-of-round conditions of the rings may be corrected in the same manner as for commutators. Crocus cloth may be used to apply a mirror-like finish following any turning, grinding, or sanding.

Pitting sometimes develops on the surface of collector rings due to electrolytic action. It may occur on only one ring, but will cover the whole ring area. This condition can be corrected by reversing the polarity of the rings periodically. Reversing the polarity of the d-c field of a three-phase generator will not affect the phase rotation of the generator. Do not leave the field current on while a generator is secured as it will cause spot pitting and burning of the collector rings under the brushes.

TRANSISTORIZED AND PRINTED CIRCUITS

The use of transistors and other semiconductors in IC equipment is constantly increasing. Because of its versatility, the transistor is used in many circuit applications. Its miniature dimensions make the transistor particularly suitable for use in unitized and modular constructed equipment. For the same reason (miniaturization and compactness), troubleshooting equipment containing transistors is made more difficult.

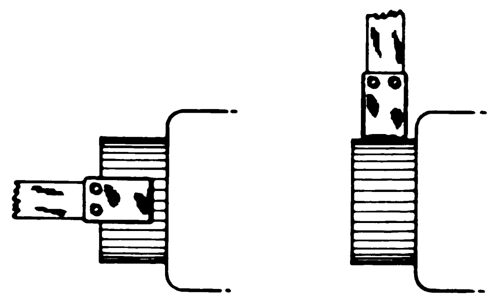
The maintenance and repair of equipment using transistors has raised many questions concerning proper servicing procedures and troubleshooting practices that have been used previously in electron-tube circuitry.

Like electron tubes, transistors come in various shapes and sizes and often are classified according to their use and application. The characteristcs of transistors are presented in specification sheets, or they may be included in transistor manuals.

It should be noted that the primary difference between the operation of a transistor and an electron tube is that the electron tube is voltage operated, and the transistor is current operated.

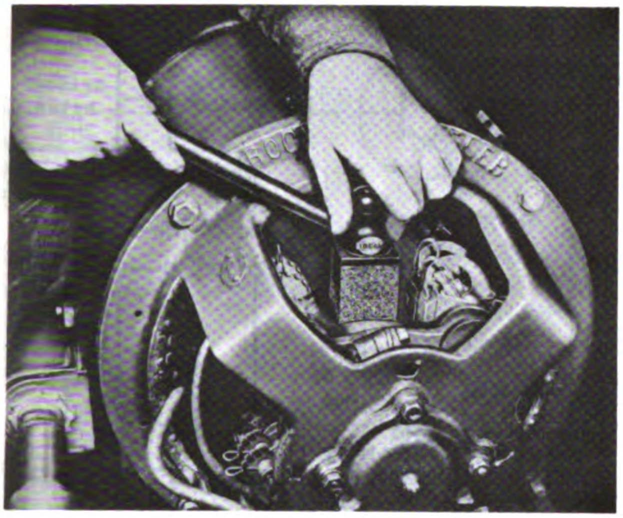
Comparison of a given transistor and an electron tube shows that there is a great similarity in their functions. Therefore any knowledge you have gained on electron tube equipment will be useful in the serving of transistorized circuits. There are many differences however, between a transistor and an electron tube from the standpoint of servicing. For instance, the reliance placed on the senses of sight, touch, and smell in the inspection of electron tube circuits is not feasible in transistor circuits. Many transistors develop so little heat that nothing can be learned by feeling them. High frequency transistors hardly get warm. Usually if a transistor (except a high-power transistor) is hot enough to be noticeable, it has been damaged beyond use.

In electron tube circuits, a quick test is often made by the tube substitution method; that is by replacing the tube suspected of being bad with one known to be good. In transistorized



154.2
Figure 17-13.—Using the canvas wiper on a commutator.

Digitized by Google



73.161
Figure 17-14.—Handstoning the commutator.

circuits, the transistors are frequently soldered in and the substitution method is impractical. Furthermore, indiscriminate substitution of transistors and other semiconductors should be avoided. It is preferable to test transitors using a transistor test set as discussed later.

TROUBLESHOOTING TRANSISTOR CIRCUITS

The first step in troubleshooting transistor circuits, as in the troubleshooting of electron tube circuits, is a visual inspection of the entire equipment. Loose connections, broken leads, and any other visible damage should be repaired before undertaking the next step of the troubleshooting procedure. A careful visual inspection will frequently shorten what could otherwise be a lengthy troubleshooting job.

When the visible defects have been corrected, and if the equipment is still inoperative, the next step is to determine the defective stage by means of a signal-substitution or signal-tracing method, and then analyze that stage for the defective component. Use a signal generator to locate the defective stage, then use a voltmeter and ohmmeter to determine the defective part or parts.

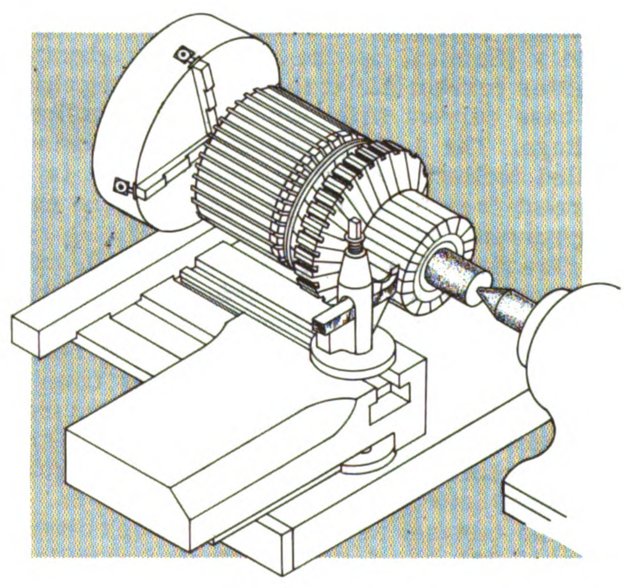
Most good quality test equipment used for electron tube circuit troubleshooting may also be used for transistor circuit troubleshooting. Signal generators, both r-f and a-f, may be used if the power supply in these equipments is isolated from the power line by a transformer. Before any tests are made with a signal generator, a common ground wire should be connected from the chassis of the equipment to be tested to the chassis of the signal generator before any other connections are made.

Signal tracers may be used on transistor circuits if the precautions concerning the power supplies are observed. Many signal tracers use transformerless power supplies; therefore to prevent damage to the transistor, an isolation transformer must be used.

Multimeters used for voltage measurements in transistor circuits should have a high ohms-per-volt sensitivity to ensure an accurate reading. A 20,000 ohms-per-volt meter or an electronic voltmeter (VTVM) with an input resistance of 11 megohms or higher on all voltage ranges is preferred.

Ohmmeter circuits which pass a current of more than one milliampere through the circuit under test cannot be used safely in testing transistor circuits. Before using an ohmmeter on a transistor circuit, check the current it passes on all ranges. To check the current passed by the ohmmeter, set the meter up for resistance measurements and connect a milliammeter in series with the test leads. Observe the milliammeter reading on all ranges. Do not use any range for testing that passes more than one milliampere.

Conventional test prods, when used in the closely confined areas of transistor circuits,



77.74
Figure 17-15.—Truing commutator by turning.

Digitized by Google

often are the cause of accidental shorts between adjacent terminals. In electron tube circuits the momentary short caused by test prods rarely results in damage, but in transistor circuits this short can ruin a transistor. Also, as transistors are very sensitive to improper bias voltages, the practice of troubleshooting by shorting various points to ground and listening for a click must be avoided. The sensitivity of a transistor to surge currents should always be borne in mind when testing transistor circuits.

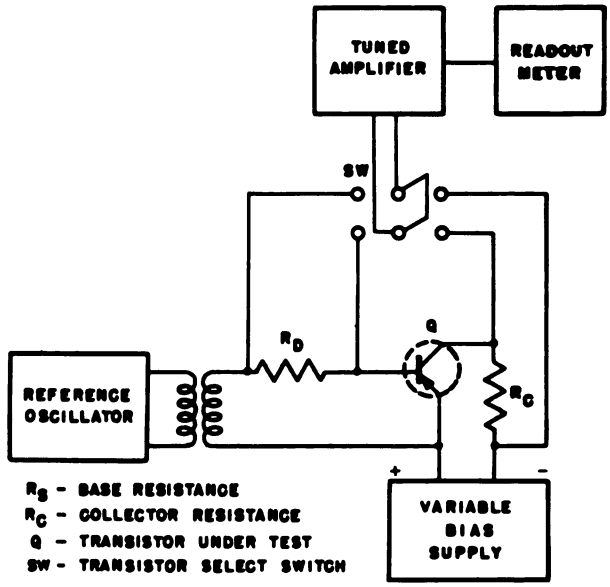
Another change from conventional troubleshooting procedure that is required by transistor circuits is the use of a small, low-wattage soldering iron with a narrow point or wedge. Wattage ratings on the order of 35 to 40 watts are satisfactory. The common type of soldering gun or iron used on electron tube circuits should not be used on transistor circuits.

TESTING TRANSISTORS

As discussed in Introduction To Electronics, NavPers 10084, in the common base transistor circuit, current gain α (Alpha) is the ratio of the change in collector current (ΔIc) to the corresponding change in emitter current (ΔIe) for a constant collector voltage. In the common emitter transistor circuit, current gain β (Beta) is the ratio of the change in collector current (ΔIc) to the corresponding change in base current (ΔIb) for a constant collector voltage. In the common collector transistor circuit, current gain γ (Gamma) is the ratio of the change in emitter current (ΔIe) to the corresponding change in base current (ΔIb) for a constant collector voltage. The leakage current of a transistor, called collector current cutoff (Ico), is the current from collector to base when no emitter current flows.

Transistor test set TS-1100/U is designed to measure the current gain of a transistor when the transistor is connected in the circuit, and to measure the current gain and leakage current with the transistor removed from the circuit. A table is included in the manufacturer's technical manual for the tester which gives a numerical listing of the transistors capable of being tested.

The test set as shown in the block diagram (fig. 17-16), consists of a reference oscillator, tuned amplifier, and a variable bias supply. The transistor to be tested is shown in the dashed circle. The oscillator is used to generate



124.223

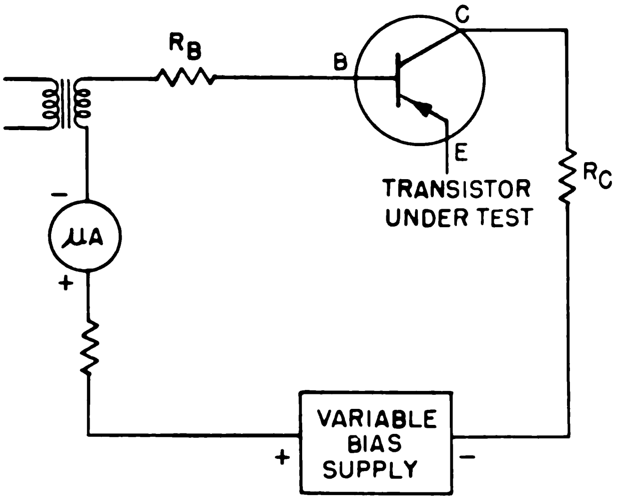
Figure 17-16.—Measuring beta using transistor test set TS-1100/U.

a test signal; the tuned amplifier provides a means for measuring the second harmonic component of the transistor under test; and the bias circuit furnishes the required voltages for testing the transistor.

The many types of transistor base connection arrangements require that the leads be properly identified before connecting them to the tester. Transistor lead identification is discussed in Introduction To Electronics, NavPers 10084. The TS-1100/U test socket arrangement will accommodate most transistor types. If the leads are long enough, it is usually possible to effect proper hookup by bending them. If the leads are too short, it is necessary to use the test cable and alligator clips provided with the tester. In all cases however, the transistor leads should be identified, and then matched up with the tester connections.

The circuit arrangement for measuring beta is shown in figure 17-16. When the proper adjustments are made according to the manufacturer's technical manual, the value of beta will be indicated directly on the meter. The circuit arrangement for measuring Ico is shown in figure 17-17. The manufacturer's technical manual provides information concerning the collector bias to be applied for a

Digitized by Google



70.42

Figure 17-17.—Measuring collector leakage current, Ico, using transistor test set TS-1100/U.

particular transistor and the maximum permissible leakage current.

The test set is also equipped to indicate a short between any two of the elements of the transistor under test. With the transistor in the circuit, it will indicate a short if the circuitry between any two of the transistor elements has a resistance of 500 ohms or less. To determine whether the short is in the transistor itself, or in the associated circuit, it is necessary to remove the transistor from the circuit.

The test set has the following additional features: a switch marked PNP-NPN, which selects the proper bias polarity for the type of transistor under test; a temperature alarm indicator lamp which will light when the ambient temperature surrounding the equipment exceeds 50° C; and a switch marked TEST which checks the test set battery output.

Testing With Ohmmeter

While the TS-1100/U tester or its equivalent is required to test all parameters of the transistor, the ohmmeter function of either the VOM or VTVM can be used with fairly accurate results in determining whether a transistor is open or shorted. Before using an ohmmeter to test a transistor, check the current that the ohmmeter passes on all ranges as described previously. Do not use any range for testing which passes more than one ma.

The most common method of testing a transistor with an ohmmeter, is to take resistance readings across each junction (emitter-base and base-collector) in both directions. If the transistor is good, the readings in the forward direction will be somewhere around midscale on the meter, and the readings in the reverse direction will be near the infinity mark. Any reverse reading which is excessively lower than normally expected indicates a shorted transistor, or at least a very large leakage current. If both the forward and reverse readings are near infinity, the transistor is open.

Another quick transistor test with an ohmmeter is as follows:

- For PNP transistors—connect the negative lead of the ohmmeter to the collector of the transistor to be tested, and the positive lead to the emitter. Select a scale on the ohmmeter that gives approximately a midscale reading. Short the base to the emitter. An increase in the resistance reading on the meter indicates a good transistor. A decrease or no change in the reading indicates a faulty transistor. Both open and shorted transistors will indicate bad. A transistor with a lower than normal gain however, will indicate good, provided the gain is greater than one.
- For NPN transistors—use the same procedure as for PNP, except connect the positive lead of the ohmmeter to the collector and the negative lead to the emitter.

SERVICING PRECAUTIONS

Because of their reliability, transistors are usually soldered in the circuit. Removing and testing each transistor will not only unnecessarily subject the transistor to heating, but may also result in damage to some other component, particularly in the case of a printed circuit board. Transistors may be removed however, if the proper precautions are observed. Care must be taken to prevent damage to the transistor by the heat from the soldering iron. Also, the leads must be handled carefully as they are very brittle. Do not remove or replace a transistor while the battery or power source is connected.

Before removing a transistor for replacement, note the orientation of the collector, base, and emitter leads. Preshape and cut

Digitized by Google

the leads of the new transistor to the proper length, using sharp cutters to prevent undue stress on the leads entering the transistor. Pigtail leads should have a minimum clearance of one-sixteenth inch between bend and transitor body. Shape any bend required in a gradual curve. Sharp (90°) bends are not acceptable. With the transistor properly positioned, solder the leads to the connections using the proper solder, soldering iron, and a heat sink.

For stability of the electrical characteristics, the maintenance of the hermetic seal of the transistor must be emphasized. This seal in addition to maintaining the carefully controlled environment in which the transistor operates, also excludes moisture which causes instability.

Battery eliminators should not be used as the source of power for transistors or other semiconductor devices. Because of the low current drain of transistor circuits, the voltage regulation of battery eliminators is poor.

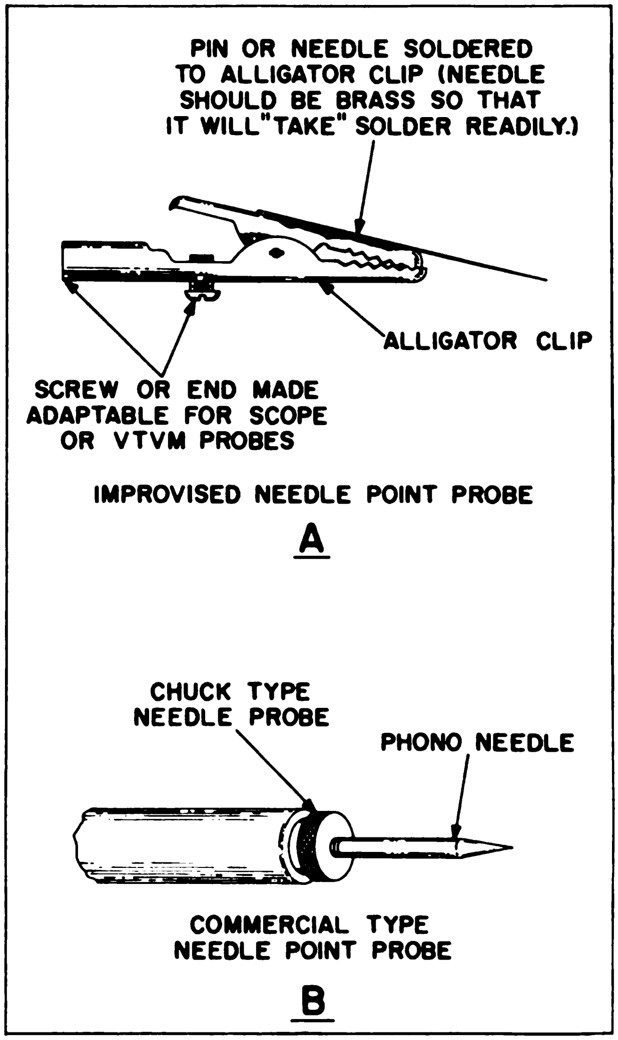
It should be remembered that temperature is the most important factor affecting transistor life, and that it is important to keep the ambient temperature as low as possible. It has been estimated that for every 10° C the junction temperature is lowered, the life of the transistor is doubled.

PRINTED CIRCUITS

Although the troubleshooting procedures for printed circuits are similar to those for conventional circuits, the repair of printed circuits requires considerably more skill and patience. The printed circuits are small and compact, and require special servicing techniques.

It is advisable to first check the defective printed circuit before beginning work on it to determine whether any prior servicing has been done. The defective part should be pinpointed by a study of the symptoms and by careful analysis of the circuit before attempting to trace trouble on a printed circuit board. Ascertain whether the conducting strips are coated with a protective lacquer, epoxy resin, or similar substance. If so, carefully scrape it away, or better still, use a needle or chuck type needle probe to penetrate the coating so that continuity checks can be made (fig. 17-18).

Breaks in the conducting strip (foil) can cause permanent or intermittent trouble. In many instances these breaks will be so small that they cannot be seen with the naked eye. These



70.109

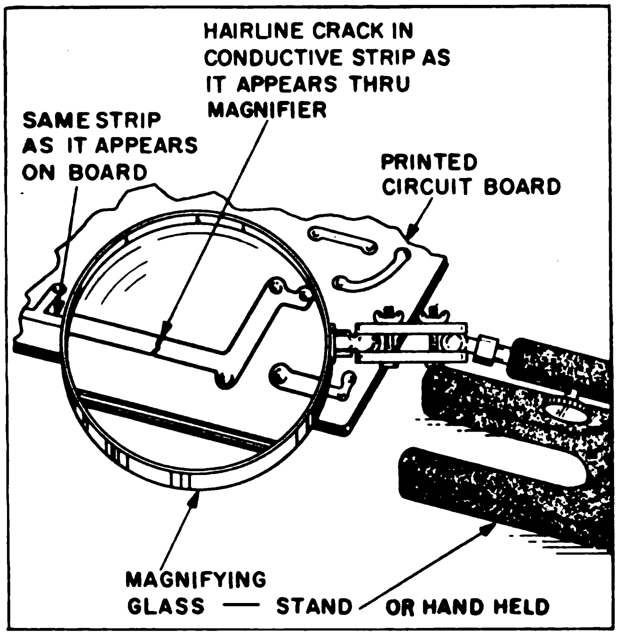
Figure 17-18.—Needle probes.

almost invisible cracks (breaks) can be located readily with the aid of a hand or stand-held magnifying glass (fig. 17-19).

The most common cause of an intermittent condition is poorly soldered connections. Other causes are broken boards, broken conducting strips, fused conducting strips, arc-over, and loose terminals.

To check out and locate trouble in the conducting strips of a printed circuit board, set up a multimeter (one which does not pass a current in excess of one ma) for making point-to-point resistance test using needle point probes (fig. 17-20). Insert one point into the conducting strip close to the end or terminal,

Digitized by Google



70.110
Figure 17-19.—Using a magnifying glass to locate a hairline crack.

and place the other probe on the terminal or opposite end of the conducting strip. The multimeter should indicate continuity. If the multimeter indicates an open circuit, drag the probe along the strip (or if the strip is coated, puncture the coating at intervals) until the multimeter indicates continuity. Mark this area and then use a magnifying glass to locate the fault as shown in figure 17-19.

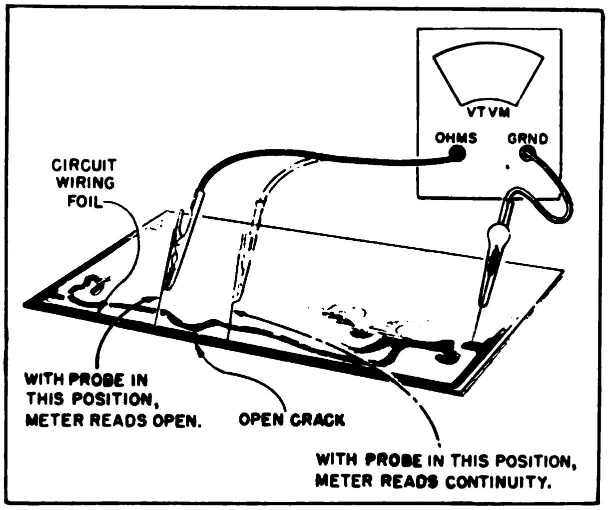
If the break in the conducting strip is small, lightly scrape away any coating covering the area of the strip to be repaired. Clean the area with a firm bristle brush and solvent, then repair the cracked or broken area of the strip by flowing solder over the break (fig. 17-21A). If there is any indication that the strip might peel, bridge the break with a small section of bare wire approximately two inches in length, as shown in figure 17-21B. Apply solder along the entire length of the wire to bond it solidly to the conducting strip. Exercise care in applying the solder to prevent it from flowing onto or near an adjacent strip. Keep the solder within the limits of the strip being repaired.

If a conducting strip is burned out or fused, cut and remove the damaged strip. Connect a length of insulated wire across the break or from solder point to solder point as shown in figure 17-21C.

It is best not to glue or bond a conducting strip that has been lifted or peeled from the board at a terminal or solder point. Instead clip off the raised section and replace it with insulated hookup wire from solder point to solder point. Always check printed circuit boards carefully after repairs for solder droppings that may cause shorts.

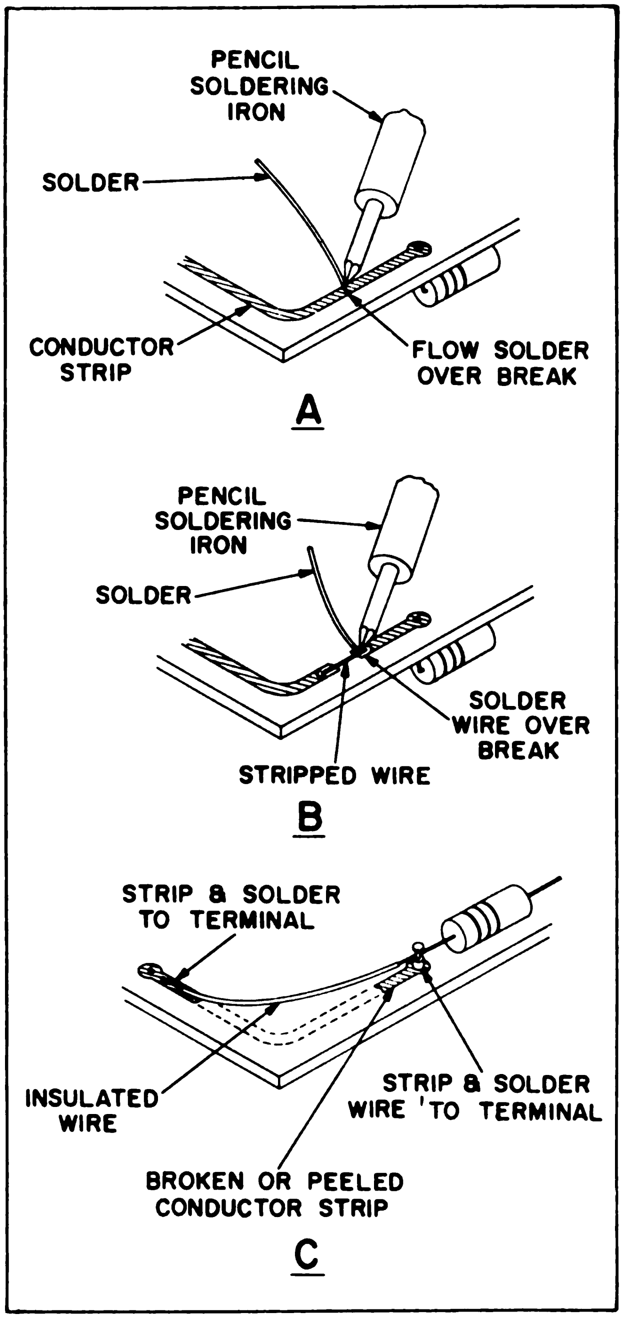
Frequently, a low-resistance leakage path will be created by moisture or dirt that has carbonized onto the phenolic board. This leakage can be detected by measuring the suspected circuit with a multimeter. To correct this condition, clean the carbonized area with solvent and a stiff brush. If this does not remove it, use a scraping tool (spade end of a solder-aid tool or its equivalent) to remove the carbon, or drill a hole through the leakage path to break the continuity of the leakage. When the drilling method is used, be careful not to drill into a part mounted on the opposite side.

Most printed circuit boards have areas of conduction known as grounding conductors at each edge of the board, or on the parts-mounted side of the board. These grounding conductors are conducting strips used for grounding parts and as a mounting contact for the chassis or common ground. Occasionally an intermittent condition will result if the



70.111
Figure 17-20.—Using a VTVM to locate a break in a conductive strip.

Digitized by Google



70.112

Figure 17-21.—Three methods of repairing broken conducting strips.

grounding screws or mounting screws become loose. If this occurs, tighten the screws, and then solder a good bond directly from the grounding strip to the chassis or equipment ground. If this is not practical, bond the screws (after tightening) with an epoxy resin or similar compound.

The most common cause of broken boards is droppage. Some boards are broken because of careless handling during servicing. Be extremely careful at all times while handling a board. Do not flex the board indiscriminately; be especially careful when removing the board or replacing parts; do not force anything associated with the board. It is advisable to use a chassis-holding jig or vise when servicing printed circuit boards.

When a printed circuit board is broken it is better to replace the entire board. If the board is not too complicated, or the damage not too extensive however, the board can probably be repaired in an emergency, as discussed later.

Special Techniques

It is always desirable to replace parts on a printed circuit board without applying heat directly to the conducting strip. This procedure prevents damage to the printed circuit conductors, feed-through devices, eyelets, and terminals, and saves time in repair. It also prevents damage to semiconductors and other heat sensitive parts that may be in close proximity to the part being replaced.

Replacing parts requires that each type of part mounting be considered individually for the best methods of removal. A part to be removed may be too close to a heat sensitive semiconductor or other part to allow the hot soldering iron to be applied. A quick test to determine the safe distance is to place your finger between the semiconductor (or heat sensitive part) and the part to be removed. Place the hot soldering iron in the position to be used. If the heat is too great for your finger, it is too hot for the semiconductor. If this is the case, place a shield (asbestos or similar substance) between the parts before applying the hot soldering iron, and place heat sink clamps on all leads from the heat sensitive part.

Solid-state parts and their associated circuity are extremely sensitive to thermal changes. Heat sinks and shunts must be applied with shields inserted to protect the associated parts any time repair or removal of a part requires the use of a hot soldering iron.

Removal of an axial lead part (a part mounted by leads that extend from each end, such as

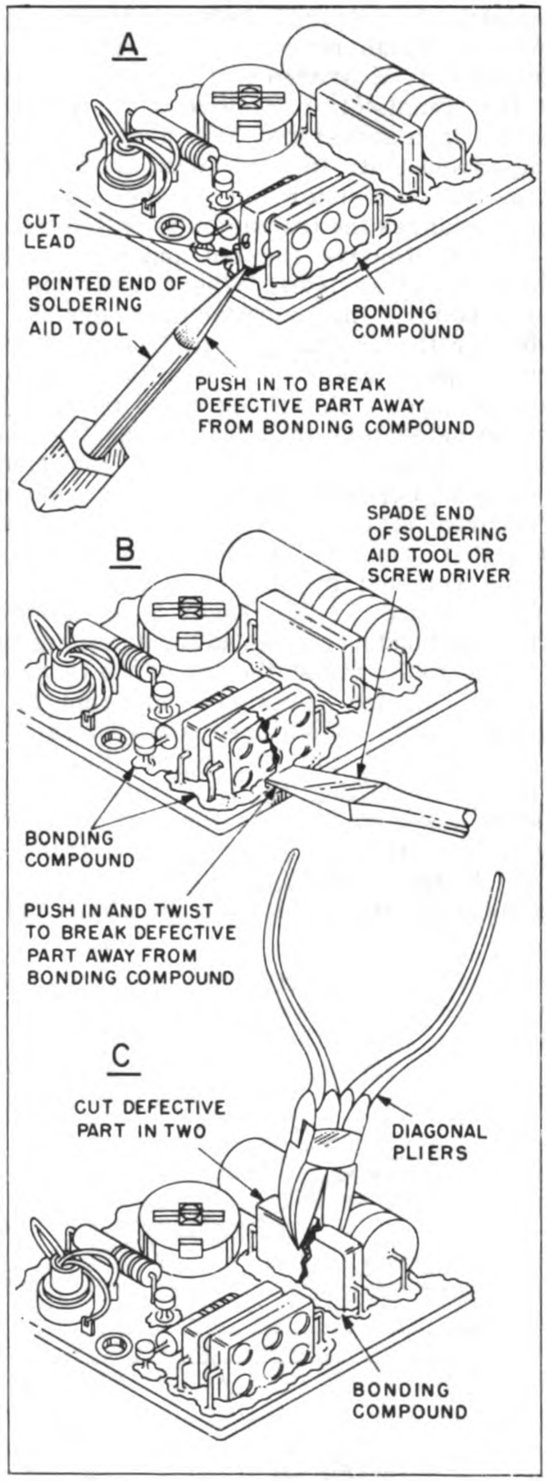
Digitized by Google

a common resistor or capacitor) that has been bonded to a printed circuit board can be accomplished by breaking the defective part or by applying heat to the bonding compound. The method to be used depends upon the part itself and its location. If the part cannot be removed by heat, cut or break the part away from the bonding compound. Figure 17-22 shows two methods of breaking the part away from the bonding compound where the part is too close to other parts to use cutting pliers. In some instances, the part to be replaced is so closely positioned between other parts that one lead must be cut close to the body of the defective part to permit application of the prying tool. When possible, cutting the defective part with end-cutting pliers or diagonals (as shown in part C fig. 17-22) is the preferred method to use.

Regardless of which tool is used (round pointed or spade type, parts A and B fig. 17-22), great care must be used in its application to prevent the printed circuit board or other parts from being damaged. Apply the point of the tool against the bonding compound between the part and the printed circuit board. Use the tool in such a way that it works away the bonding compound from the part to be broken away, until enough has been removed for the tool to exert pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board; this helps to prevent the tool from gouging or breaking the board. Never apply heavy pressure against a printed circuit board.

After the defective part has been removed from the bonding compound, remove the leads or tabs from their terminals on the printed circuit board. Clean the area thoroughly before installing the new part. Do not remove the compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as the new part; thus inserting the new part in this mold helps to secure it from vibration. After the repairs have been completed and the circuit tested, spray the newly soldered area with an insulating varnish or equivalent. Coat the new part or parts with a bonding compound.

To replace a defective transistor, first cut all its leads then remove it from the assembly. Transistors are mounted on printed circuit boards in many different ways; thus

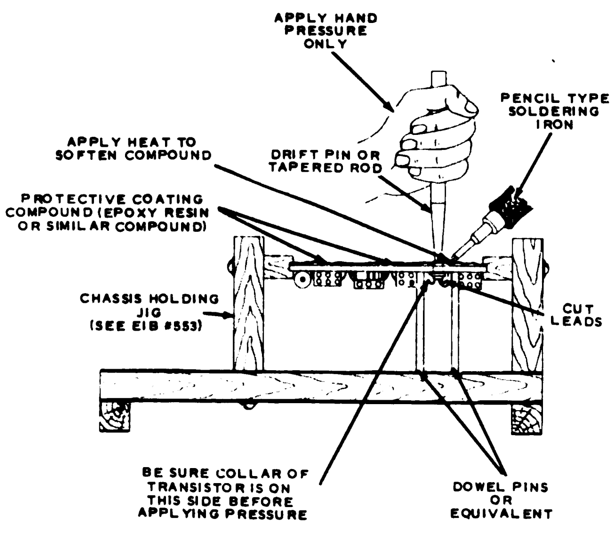


70.113
Figure 17-22.—Removing a defective part from bonding compound.

Digitized by Google

it is necessary to study how a particular transistor is secured before attempting to remove it. A transistor with clamp type mounting requires only a pointed tool between the clamp and the transistor to remove it. A transistor mounted in a socket may have a wire or spring clamp around it. Remove this clamp before pulling the transistor out of the socket. In some instances the transistor is bolted through the board. Remove the nut and washer, then remove the transistor. Where vibration is a prime factor, the manufacturer mounts the transistor through the circuit board and bonds it with epoxy resin or a similar compound. For this type, a flat-ended round rod type tool of a diameter less than that of the transistor case is required. Be sure that the printed circuit board on which the transistor is mounted is secured in a proper device, and in such a way that pressure exerted against the board will be relieved by a proper support on the other side (fig. 17-23). Apply a hot soldering iron to the bonding compound and simultaneously apply the tool against the top of the transistor exerting enough pressure to remove the transistor from the softened compound, and then on through and out the board (fig. 17-23).

Before installing the new transistor, care must be taken to prepare the part for installation. Test the transistor in a transistor tester before installing, as transistors can become defective in storage. Preshape and cut



70.114

Figure 17-23.—Removing a transistor that has been through-board mounted.

the new transistor leads to the shape and length required for easy replacement. Use sharp cutters and do not place undue stress on any lead entering the transistor. The leads are fragile and are susceptible to excessive bending or too sharp a bend as mentioned previously. A safety measure to ensure that the lead will not break off at the base, is to use two pairs of needle-nose pliers. With one pair grasp the lead close to the transistor base while shaping the rest of the lead with the other pair.

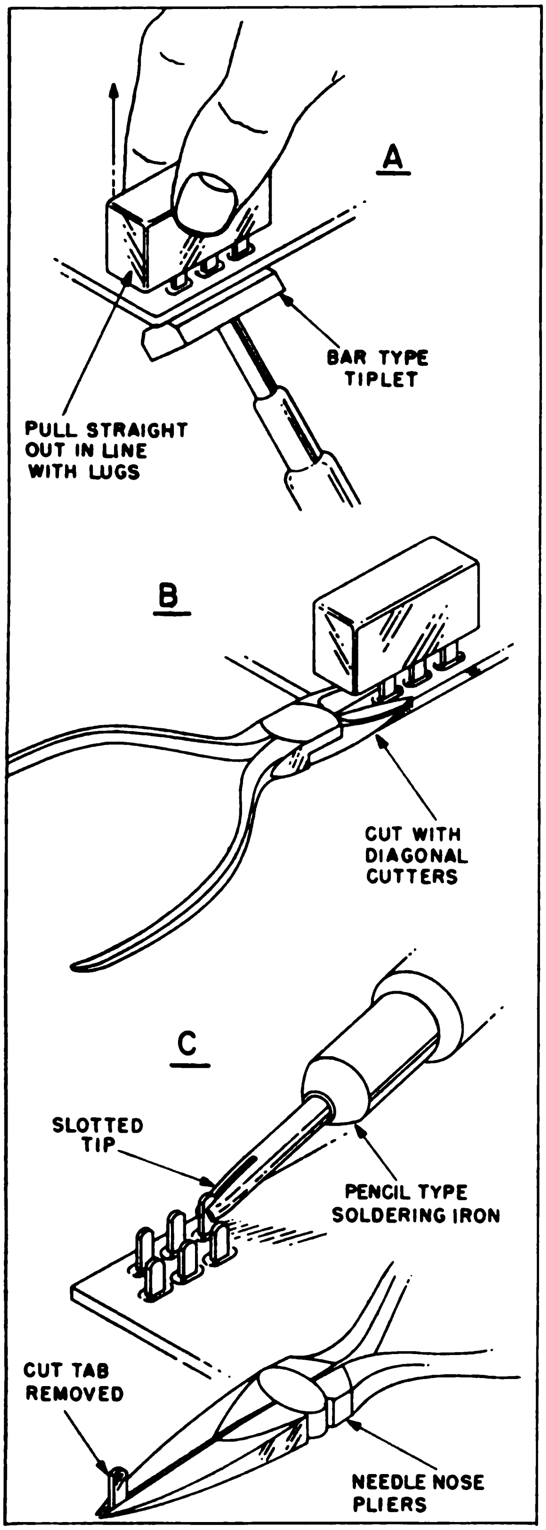
After the remaining pieces of the defective transistor terminal leads have been removed and the terminals on the board are cleaned, connect the new transistor to its proper terminals. Test the circuit to ensure that it is operative, then rebond the transistor. Do not use heat to rebond replaced transistors or other semiconductors.

To remove and replace a multilug part such as a transformer, choke, filter, or other similar potted, canned, or molded part, release the part from its mounting before disconnecting or cutting its conductors. Before applying pressure to remove such a part, inspect it carefully to be sure that the part is completely free of all its connections to the printed circuit board, and that all bent or twisted mounting lugs have been straightened; otherwise you may break the board by applying pressure to it. Do not wrench or twist a multilug part to free it, as this may cause the conducting strip to become unbonded from the board. Work this type of part in and out in line with its lugs, while applying a hot soldering iron using a bar type tiplet adapter or similar tool as shown in figure 17-24A.

When possible cut the conducting or mounting leads and lugs of the defective multilug part on the mounting side of the board (fig. 17-24B). Heat and straighten the clipped leads with a hot soldering iron and slotted soldering-aid tool (or slotted soldering iron tiplet or similar desoldering tool) applied to the circuit side of the board; pull the leads or tabs through with pliers as shown in figure 17-24C.

To replace the new multilug part, check to be sure that all of the lead holes or slots are free and clean, allowing easy insertion of the multilug part. Do not force the part; if it does not position easily, check and rework the terminals and holes or slots until it does seat freely, then proceed to solder.

Digitized by Google



70.115

Figure 17-24.—Removing a defective multi-lug part.

Be very careful when replacing defective parts that have leads terminating on standoffs, feed-through terminals, etc. In most cases, standoffs and feed-through terminals are very small and are mounted on a thin phenolic board; thus they are very susceptible to damage by heat and undue pressure.

Emergency Techniques

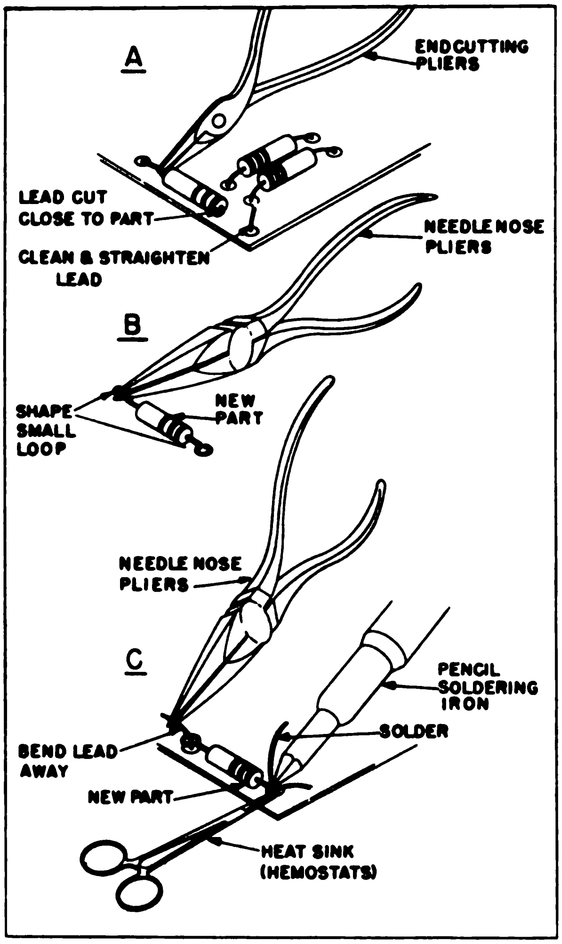
In many instances there is a need for a time-saving technique and procedure for emergency repair. It is desirable when making and emergency repair, to avoid unnecessary disassembly to expose the defective part when testing and/or repairing. In many instances this can be accomplished by removing only the cover from the unit to be repaired.

To remove and replace an axial lead part, cut the leads as close as possible to the body of the part, then connect the leads of the replacement part to the leads remaining on the board. The cutting is accomplished with a pair of end-cutting pliers (fig. 17-25A). Clean and straighten the leads remaining on the board. Fashion small loops in the leads of the replacement part (fig. 17-25B), making the loop size and lead length such that the loops slip easily over the leads projecting from the board. Secure these connections by bending the old leads away from the part. Place a heat sink clamp on the lead from the board, between the board and the connection to be soldered, then solder the connection (fig. 17-25C). The heat sink prevents the leads connected to the board from becoming unsoldered and causing a short or open circuit. Check to ensure that the old leads are still properly connected to the conducting strip.

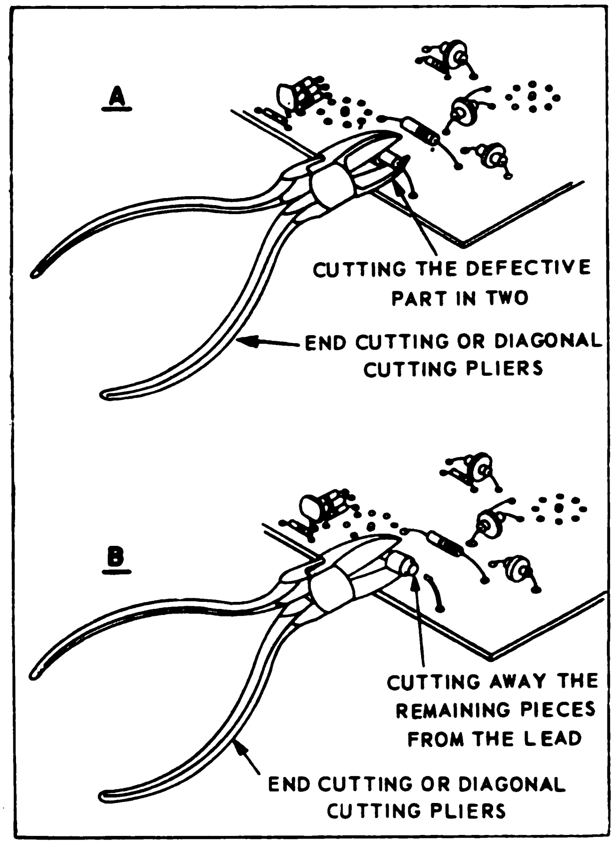
If cutting the leads of a defective axial lead part would result in leads that are too short for the replacement part to be connected properly, cut the defective part in half with a pair of diagonal or end-cutting pliers (fig. 17-26A). Then carefully cut away the pieces of the part from each lead (fig. 17-26B). This will yield leads of sufficient length to permit the replacement part to be fitted and soldered.

Care must be taken when replacing a defective part that terminates on miniaturized standoffs and feed-through terminals as stated previously. For emergency or temporary repair purposes, the following techniques may be used. Cut the lead close to the defective

Digitized by Google



70.116
Figure 17-25.—Replacing a defective part by cutting its leads.



70.117
Figure 17-26.—Cutting the defective part for maximum lead length.

part as shown in figure 17-27A. Use a heat-sink clamp or pliers next to the terminal, then solder a spliced lead from the terminal to the new part (fig. 17-27B).

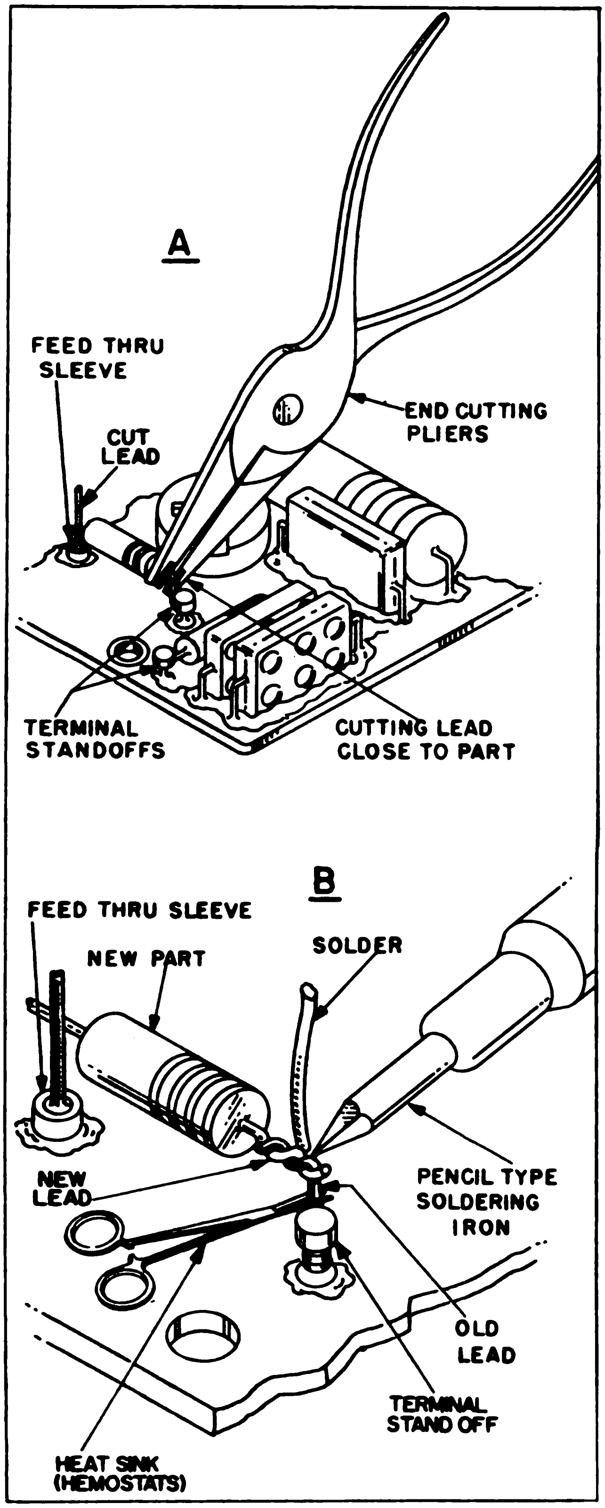
A helpful heat control technique is to place a small piece of beeswax on the terminal behind the heat sink. When the beeswax melts, the temperature limit has been reached, and the soldering iron must be removed immediately. Allow the area to cool before attempting to complete the soldering of the connection. Apply a new piece of beeswax to the terminal, repeating this procedure until the connection is satisfactorily soldered.

A broken printed circuit board may have to be repaired in an emergency, where no replacement is available. If the board is not completely broken but is only cracked, drill a hole at the end of each crack (fig. 17-28A), to prevent further lengthening of the crack. Then repair the crack by placing a conductive material across the defective area.

If a small portion or corner of the board is broken off, it may be rebonded with a non-conductive cement or its equivalent. If cementing is not practical, or does not hold satisfactorily, the pieces can be fastened together with wire staples cut from solid conducting wire of the diameter and length required, depending upon the width of the conducting strip to be repaired.

To insert the staples, drill holes about 1/4 inch in from each side of the break (fig. 17-28B&C). The holes should be just large enough to accommodate the wire used for stapling. Drill the holes through the conducting strips so that the staples will provide a good electrical contact across the break. This method will permit the use of enough staples to hold the

Digitized by Google



70.118
Figure 17-27.—Removing a defective part from a miniature standoff terminal.

pieces together without danger of shorts between conductors. If the break is sufficiently large, position additional staples at all points possible to give the board more support.

Where the methods described above do not provide structural strength or sufficient rigidity, splints or a double may be used. Strips of thin card material are glued across the crack with a nonconductive adhesive. Where needed, additional strength may be obtained by gluing a plate of the card material to the splints with the nonconductive adhesive.

Rebond any loose conducting strips with a nonconductive bonding cement, then apply nonconductive cement to both sides of the break, and join the sections together. Insert half of the measured and precut wire staples from bottom to top, bending the ends flush against the board (fig. 17-28D). Solder these staples to the conducting strip (fig. 17-28E).

After the repairs are completed, clean both sides of the repaired area with a stiff brush and solvent. Allow the board to dry thoroughly, then coat the repaired area with an epoxy resin or similar compound. This coating protects and strengthens the repaired area.

MAINTENANCE AND MATERIAL MANAGEMENT SYSTEM

A Standard Navy Maintenance and Material Management System (3M System) is being installed throughout the operating forces of the Navy. The objectives of the 3M system are:

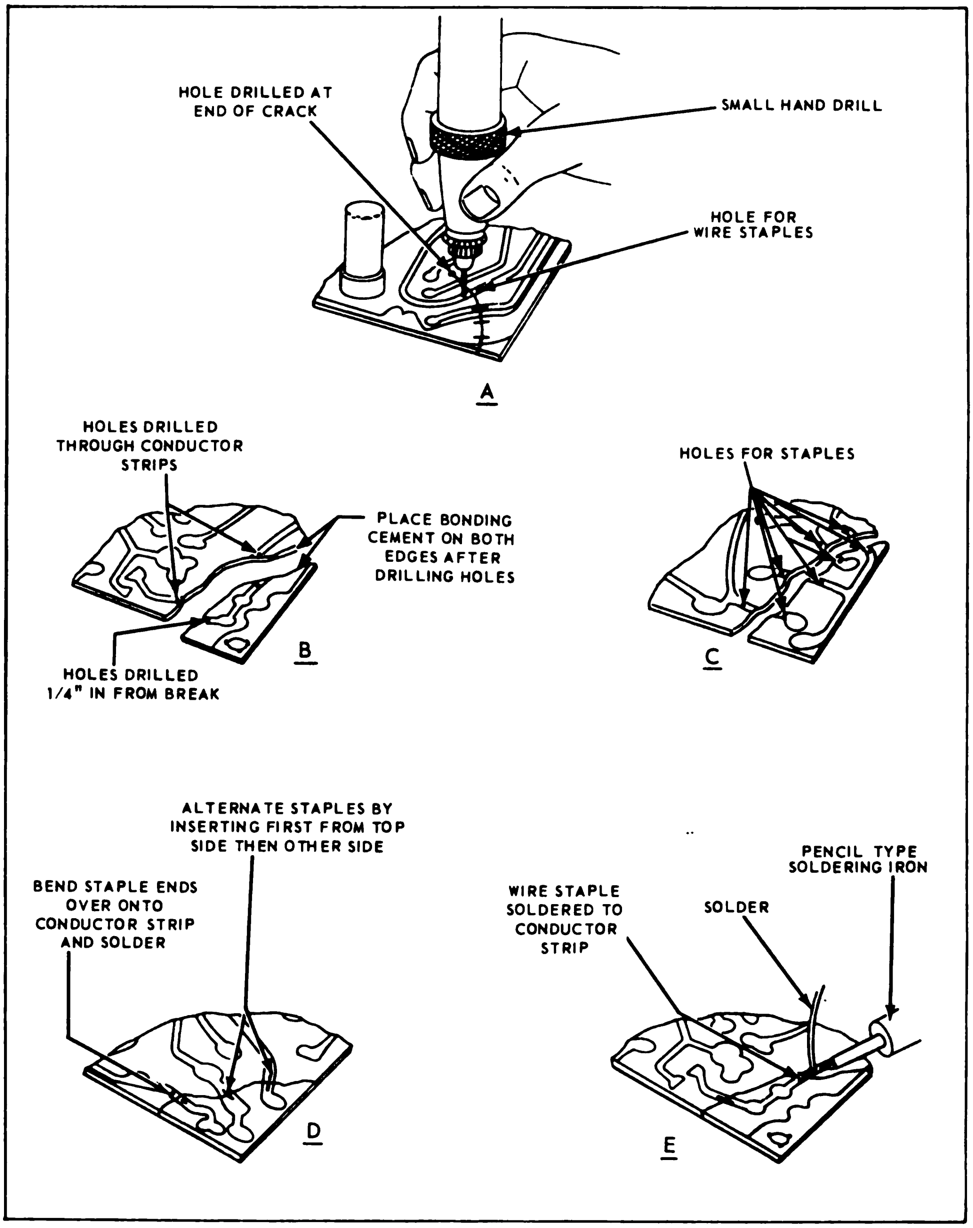
1. The use of a Planned Maintenance System (PMS), to attain and maintain maximum operational efficiency of all fleet equipment at all times; reduce down-time of equipments to the minimum, consistent with good maintenance practices; and reduce the cost of maintenance in money and man-hours.

2. The use of a Maintenance Data Collection System (MDCS), to provide the means for collecting data, such as expenditure of man-hours, parts, and materials; types of equipment failures; delays incurred, and reason for delays; equipment down-time; and the rates which performed the maintenance action.

PLANNED MAINTENANCE SYSTEM

The Planned Maintenance System (PMS) defines and schedules the preventive maintenance requirements for all shipboard

Digitized by Google



70.119

Figure 17-28.—Repairing a broken printed circuit board.

equipments down to the methods and tools to be used and the time and rates required for accomplishment.

Forms and documents used in carrying out the PMS are planned maintenance system manuals, cycle schedules, quarterly schedules, weekly schedules, maintenance requirement cards, and PMS feedback reports.

Planned Maintenance System Manual

A PMS manual is made up for each ship listing all maintenance groups in a department. The manual is used by the department head or planning officer and maintenance group supervisors to plan and schedule the maintenance for each group.

Digitized by Google

The manual contains a brief description of each maintenance requirement, the rate(s) that should perform the requirement, the average time required, and the frequency with which each requirement must be carried out. The frequency code is as follows: D—Daily, W—Weekly M—Monthly, Q—Quarterly, S—Semiannually, A—Annually, C—Overhaul Cycle (scheduled once between overhauls in quarter desired by ship) and R—Situation Requirement (every 1000 hrs., specific current or voltage, etc.)

The time listed to perform the requirement is the average time required to perform the maintenance only, and does not include time required to collect or put away tools, material, or test equipment.

A group maintenance book containing copies of applicable maintenance index pages (MIP) from the department PMS manual is kept in the applicable working space. Figure 17-29 shows a sample MIP from the engineering department PMS manual. A copy of this page and all other pages listing IC equipments are kept in the IC group maintenance book.

Cycle Schedule

The cycle schedule (fig. 17-30), is a visual display which lists the components for each maintenance group, and schedules their annual, semiannual, and overhaul cycle maintenance requirements into "quarters after overhaul." The schedule also lists the quarterly and monthly requirements that must be scheduled every quarter. A situation requirement (R), may also be listed. Daily and Weekly requirements are scheduled on the Weekly schedule, and do not appear on the cycle or quarterly schedule.

The cycle schedule is used by the department head in preparing the quarterly schedule.

Quarterly Schedule

The quarterly schedule (fig. 17-31) is a visual display of the ship's employment schedule and provides space, by weeks, for the assignment of specific maintenance requirements, as determined from the cycle schedule. Blank spaces are available to insert the name of the maintenance group involved, the current year, quarter after overhaul, months concerned, and ship's employment schedule. Thirteen, columns, one for each week in the quarter is available to schedule maintenance on a weekly basis throughout the three month period. The "at sea" time is marked by drawing a red line through the tick marks denoting days of the week.

Maintenance requirements from the appropriate "Quarter After Overhaul" from the cycle schedule is transcribed to the "Current Quarterly Schedule" into the week which it is felt that work can be accomplished. A "Subsequent Quarterly Schedule" for the following three months is maintained for continuity. At the end of the quarter all work not accomplished is scheduled on the Subsequent Quarterly Schedule which then becomes the Current Quarterly Schedule, and a new "blank" Subsequent Quarterly Schedule is started.

The quarterly schedule is most important in the PMS program. It is usually completed by the department head in conjunction with his division officers and maintenance group supervisors. This schedule, when updated weekly, provides a ready reference for the current status of preventive maintenance.

Weekly Schedule

The weekly schedule (fig. 17-32) is a visual display assigning specific personnel to perform required maintenance on specific components and is posted in each maintenance group's working area.

The group area name, week concerned, components listed, specific personnel responsible for maintaining, and PMS manual equipment page number, are entered in the proper spaces. The maintenance group supervisor enters the daily and weekly maintenance from the "working" maintenance requirement cards.

The current quarterly schedule is used in entering the requirements due for the appropriate week. The man assigned or the maintenance group supervisor, marks the maintenance requirement with an X after the maintenance has been completed. The group supervisor reschedules uncompleted work, when possible, during the same week.

At the end of the week the group supervisor brings the current quarterly schedule up to date by crossing (X) out all the maintenance (Q, M, etc.), completed on the weekly schedule. Quarterly scheduled maintenance not completed is circled on the quarterly schedule and rescheduled on the current quarterly schedule or subsequent quarterly schedule. Any weekly maintenance circled on the weekly schedule is rescheduled on the following weekly schedule.

Maintenance Requirement Card

The maintenance requirement card (MRC) shown in figure 17-33, contains the same

Digitized by Google

System, Subsystem, or Component	Reference Publications and/or Maintenance Significant Number
Alarm and Warning Systems	NAVSHIPS 365-2051

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd	Man Hours	Related Maintenance
CB	ZZ2HAG5	63	1104	W	Hi Temperature Alarm 1. Perform silent alarm test on each circuit. 2. Perform silent trouble test on each circuit.	W-1	ICFN	0.1 unit	None
CB	ZZ2HSW1	53	1107	A	Hi Temperature Alarm Switchboard 1. Inspect and clean the magazine sprinkler and Hi-temperature alarm switchboard. 2. Inspect for loose connections and mechanical soundness. 3. Inspect and clean contact makers.	A-1	IC3	1.0 unit	W-1

Bureau Page Control No. IC-4 / 3

Maintenance Index Page
OpNav Form 4700-3

98.171

Figure 17-29.—Sample MIP from engineering department PMS manual.

Digitized by Google

information concerning the maintenance requirement as listed on the MIP. The card also defines the job in a step-by-step procedure, and lists tools, parts, and materials required to perform the job. Applicable safety precautions are also listed.

A master set of MRCs for all department maintenance groups is kept in the engineering office files. A working set of MRCs is kept in each maintenance group area to be used while performing the work.

The man assigned work selects the appropriate card or cards from the set and carries out the required maintenance. After completing the work, he returns the card(s) to the proper place and makes a report or log entry as required. For example, Baker IC3 is scheduled to perform maintenance requirement, A1, on the Hi Temperature Alarm Switchboard on Monday 8 Nov, 1965 (fig. 17-32). To perform this requirement, he selects the appropriate MRC (fig. 17-33 from the set of working cards and obtains the tools and equipment listed on the card before starting the job. After completing the job he crosses out the A1 on the weekly schedule (fig. 17-32), and reports his action to the maintenance group supervisor who crosses out the appropriate A1 on the quarterly schedule (fig. 17-31).

PMS Feedback Report

The feedback report (fig. 17-34) is designed to provide the ship with an easy method of recommending changes to maintenance requirement

	TYPE DDG CLASS 10	SCHEDULE AS INDICATED QUARTER AFTER OVERHAUL				
EQUIP PAGE	MAINTENANCE GROUP (IC) ELECTRICAL COMPONENT	1 5 9	2 6 10	3 7 11	4 8 12	EACH QUARTER
IC1	IC SWITCHBOARD	A1				
IC2	GYROCOMPASS		S1		S1	M1, 2 Q1, 2, 3
IC3	MOTION PICTURE PROJECTOR	A1	S1	C1(7)	S1	M1
IC4	HI TEMPERATURE ALARM SWITCHBOARD		A1			
IC5	UNDERWATER LOG	S1		S1		
6						
34						
35						
36						
37						

CYCLE SCHEDULE OPNAV FORM 4700-4 (4-64) 0107-766-4000 C-40996

98.172

Figure 17-30.—Cycle schedule.

Digitized by Google

MAINTENANCE GROUP ELECTRICAL (IC) | YEAR 1965 | QUARTER AFTER OVERHAUL 2

MONTH OCTOBER | MONTH NOVEMBER | MONTH DECEMBER

EMPLOYMENT SCHEDULE

4		18	25	1	8							
1.	A 1											
2.	M1,2		Q 1		M1,2		Q 2	Q 3	M1,2			
3.			A 1				M1					
4.					~~A1~~							
5.	S1		M1,2		M1,2				M1,2			
6.												
36.												
37.												

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

98.173

Figure 17-31.—Quarterly schedule.

WEEKLY SCHEDULE

GROUP ELECTRICAL (IC) WORK SCHEDULE FOR WEEK OF NOV. 7-13

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT SUN	OUTSTANDING REPAIRS AND PM CHECKS DUE BY NEXT 4 WEEKS
I.C. SWITCHBOARD	SMITH	IC1		W 1					
GYROCOMPASS	JONES	IC2	M1, D1	M2, D1	D 1	D 1	D1, W1	D1	Q 2, 3
PROJECTOR	FOX	IC3	D 1	D 1	D 1	D 1	D 1	D 1	M 1
HI TEMP ALARM SWBD	BAKER	IC4	~~A1~~						
UNDERWATER LOG	COX	IC5		M 1		M 2			

98.175

Figure 17-32.—Weekly schedule.

cards, ordering MRC's which have been lost or mutilated, and notifying the material bureaus of any discrepancies in coverage. The report form (fig. 17-34) is made up in five sheets. The original (white) and a copy (yellow) are sent to the addressee. The three other copies sent are, one copy (pink) to the type commander, one copy (blue) to the ship, and one copy (green) to the originator.

MAINTENANCE CONTROL BOARD

The maintenance control board (fig. 17-35), is usually posted outside the engineering office and consists of a visual display of the cycle schedule, a current quarterly schedule, and a subsequent quarterly schedule (left to right). The current quarterly schedule is kept up to date at the end of each week by the weekly schedule.

Digitized by Google

(A)

SYSTEM	COMPONENT	M.R. NUMBER	
Communications and Control	Hi-Temperature Alarm Switchboard	IC-4 A-1	
SUB-SYSTEM	**RELATED M.R.**	**RATES**	**M/H**
Interior Communication System and Equipment	W-1	IC3	1.0 unit

M.R. DESCRIPTION
1. Inspect and clean the magazine sprinkler and hi-temperature alarm switchboard.
2. Inspect for loose connections and mechanical soundness.
3. Inspect and clean contact makers.

TOTAL M/H: 1.0 unit
ELAPSED TIME 1.0 unit

SAFETY PRECAUTIONS
1. De-energize circuit at the I.C. Switchboard and tag, "Out Of Service".

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT
1. Vacuum Cleaner and attachments
2. Screwdrivers, 4", 8"
3. Rags, clean, dry
4. Voltage tester
5. Air drying varnish and brush
6. Crocus cloth

PROCEDURE
1. Obtain permission from Engineering Officer to secure the alarm relay panels for inspection and cleaning. Notify Officer of the Deck.
   a. Secure power at I.C. switchboard and tag, "Out of Service".
   b. Open hinged doors and test to insure voltage is secured.
   c. Using a vacuum cleaner, vacuum rectifiers, switches, terminal boards, and other internal parts, to remove dirt and dust.
   d. Wipe rectifiers, switches, terminal boards, and parts with clean rags.
   e. Wipe cables and lead wires with clean dry rags. Inspect for frayed insulation. Touch up with air drying varnish.
2. a. Inspect all electrical and mechanical connections. Tighten all fastenings.
   b. Inspect to see that mechanical moving parts are free to function.
   c. Visually inspect rectifier, porcelain faces and resistor supports for cracks or burned spots. (cont.)

LOCATION

Page 1 of 2 | CB | ZZ2H | SW1 | 53 | 1107 | A

(B)

Procedure (cont.)

Renew as necessary.
3. a. Magazine sprinkling contact makers:
   (1) Remove cover from each contact maker.
   (2) Inspect contacts for corrosion.
   (3) Clean with crocus cloth.
   (4) Inspect for and tighten all loose connections.
   (5) Replace cover.
   b. Energize circuits and remove tags.
   c. Notify Engineering Officer and Officer of the Deck that alarm panels are back in service.

Page 2 of 2 | CB | ZZ2H | SW1 | 53 | 1107 | A

98.176

Figure 17-33.—Maintenance requirement card; (A) Front; (B) Back.

Digitized by Google

INSTRUCTIONS

FROM: Indicate Ship Hull Number when Applicable And Originating Activity If Other Than Ship

SERIAL # No. In Sequence

DATE Date written

VIA

SUBJECT: PLANNED MAINTENANCE SYSTEM FEEDBACK REPORT

SYSTEM Same As On MRC	COMPONENT Same As On MRC
SUB-SYSTEM Same As On MRC	M.R. NUMBER Same As On MRC BU. CONTROL NO. Vertical No. on R.H. Side of MRC

DISCREPANCY:

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

1. Handwritten copies acceptable. Use Ballpoint pen.
2. Check appropriate box.
3. Use this space for all comments. State what is wrong and recommended correction. Give reason for recommended change (Unless comment is obvious).
4. For missing MRC, MIP & when Bu Control Number is not available identify equipment by noun name and APL/CID or AN Number.
5. For equipment change report, identify equipment removed and that installed by noun name EIC and APL/CID or AN Number.
6. "Tech Publications" Block includes all BUWEPS and BUSHIPS publications. Identify Publication Number, Volume, Revision, Date, Change Number, Page, Paragraph and/or Figure. When referring to PMS/SMS Equipment Volumes 2 or 4, the "M.R. Number" and "BU. Control No." Blocks should also be completed.
7. Distribution: As shown on bottom of each page.
   Installation Team: Forward reports within 10 days of installation.
   Ship: Forward reports within 90 days after installation and as required thereafter, via appropriate TYCOM.
8. Request additional forms from supply.

C.O. or designated Rep.

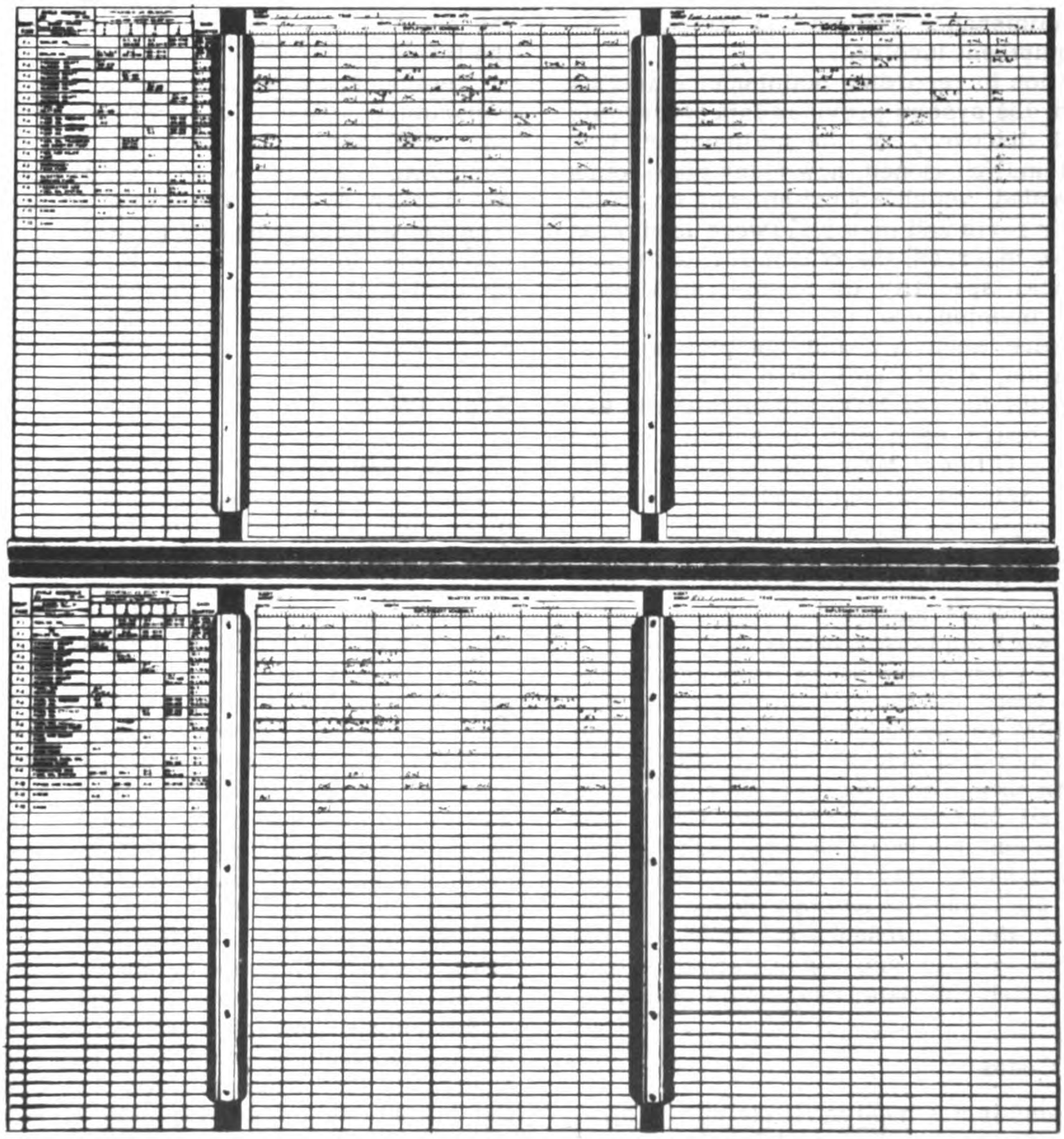
SIGNATURE

(BACK OF GREEN PAGE)

40.101

Figure 17-34.—PMS feedback report.

Digitized by Google



40.101

Figure 17-35.—Maintenance control board.

Any maintenance scheduled and not held in the current quarter is rescheduled on the subsequent quarterly schedule. At the end of each quarter, the current quarterly, schedule is removed and retained as a preventive maintenance record. The subsequent quarterly schedule is completely filled out and moved to the left to become the current quarterly schedule and a blank subsequent quarterly schedule posted.

The control board is used by the department head, maintenance CPO and group supervisors as a long range schedule, to plan and schedule maintenance.

MAINTENANCE DATA COLLECTION SYSTEM

The maintenance data collection system (MDCS), is the feedback part of the 3-M system

Digitized by Google

and works in conjunction with the PMS. MDCS is designed to provide a means of recording maintenance actions in substantial detail so that a variety of information may be retrieved concerning maintenance actions and the performance of equipment involved.

In addition to recording maintenance actions performed, the system provides data concerning the initial discovery of the malfunction, how equipment malfunctioned, how many man-hours were expended, which equipment was involved, what repair parts and materials were used, what delays were incurred, the reason for delay, and the technical specialty or rating which performed the maintenance.

To ensure accuracy and completeness of documentation, a data collection center, office or focal point for the MDC organization is established aboard each ship or activity by the Commanding Officer. Maintenance control numbers are assigned all documents by the data collection center.

Each group supervisor is responsible for ensuring that maintenance data forms are complete and accurate and that a document is submitted for each applicable action.

The data processing center transpose the information from the maintenance forms to a standard IBM keypunch card, using codes found in Chapter 8 of 3-M manual (OpNav) 43P2). The data center then forwards its punched cards to a designated Maintenance Support Office for reading into computerized storage. In the future, pre-punched cards may be issued to ships or activities for monthly and quarterly maintenance. When the maintenance is performed, the pre-punched card(s) are submitted to a data center to punch the date, man-hours and other variables.

Document Codes

Two manuals are used in filling out the MDC system documents, or forms. The 3-M manual (OpNav) 43P2) is used mainly for codes to fill out tender and shipyard Work Supplement Cards, and Document Keypunch IBM Cards.

The appropriate (Engineering) Equipment Identification Code Manual (EIC) (fig. 17-36), provides the method for encoding ship equipment. These codes are used to fill out the basic forms and parts of the additional MDC collateral forms. This coding system is desirable because a system, assembly, or even a component part may be positively identified by a seven-digit letter/number sequence, thus avoiding ambiguous or vague description or noun names. Section I of this manual (fig. 17-36) is a brief description to complete the basic forms. Section II through IX is standard in all department manuals and list the various code descriptions needed to fill out the forms.

Section X is the EIC needed for a specific department, (Operations, Engineering, Weapons, Hull and Miscellaneous), equipment description. Each major system is logically coded and broken down to the lowest level needed to manage the equipment effectively. The EIC is extremely important since it is the only data element that identifies the equipment, component, or part upon which the maintenance is performed.

Basic Forms

The basic forms used to record maintenance actions aboard ship are discussed briefly. A more detailed description in filling out these forms is presented in the 3-M manual (OpNav 43P2), and enlisted training courses, Military Requirements for P. O. 3 & 2. (NavPers 10056-B), and IC 1 & C, NavPers 10557-B.

SHIPBOARD MAINTENANCE ACTION.—The shipboard maintenance action, OpNav form 4700-2B (fig. 17-37), is a single sheet document used to record the completion of planned maintenance actions, corrective maintenance actions, and authorized alterations that have been performed by shipboard personnel. All planned maintenance actions except daily and weekly preventive maintenance are recorded.

Two key entries on the form (fig. 17-37A) are, block number 3, maintenance control number, which is assigned by the ship and block number 5, equipment identification code, which is a number taken from section X of the Engineering Equipment Identification Code manual to identify the lowest designated assembly on which maintenance is performed. These two block numbers are used on all forms relating to a specific job or same maintenance event.

The reverse side of the 4700-2B form (fig. 17-37-B) is completed by maintenance personnel to report only material obtained from outside normal supply channels, such as from pre-expended material bins, salvage, or cannibalization.

Examples of pre-expended parts reported are resistors, capacitors, electron tubes, carbon brushes, and switches. No price is entered for pre-expended bin material since costs were

Digitized by Google

ENGINEERING
DEPARTMENT

MAINTENANCE DATA COLLECTION SYSTEM

EQUIPMENT
IDENTIFICATION
CODE
MANUAL

CODE MANUAL
TABLE OF CONTENTS

40.103

Figure 17-36.—EIC manual, front cover page and table of contents.

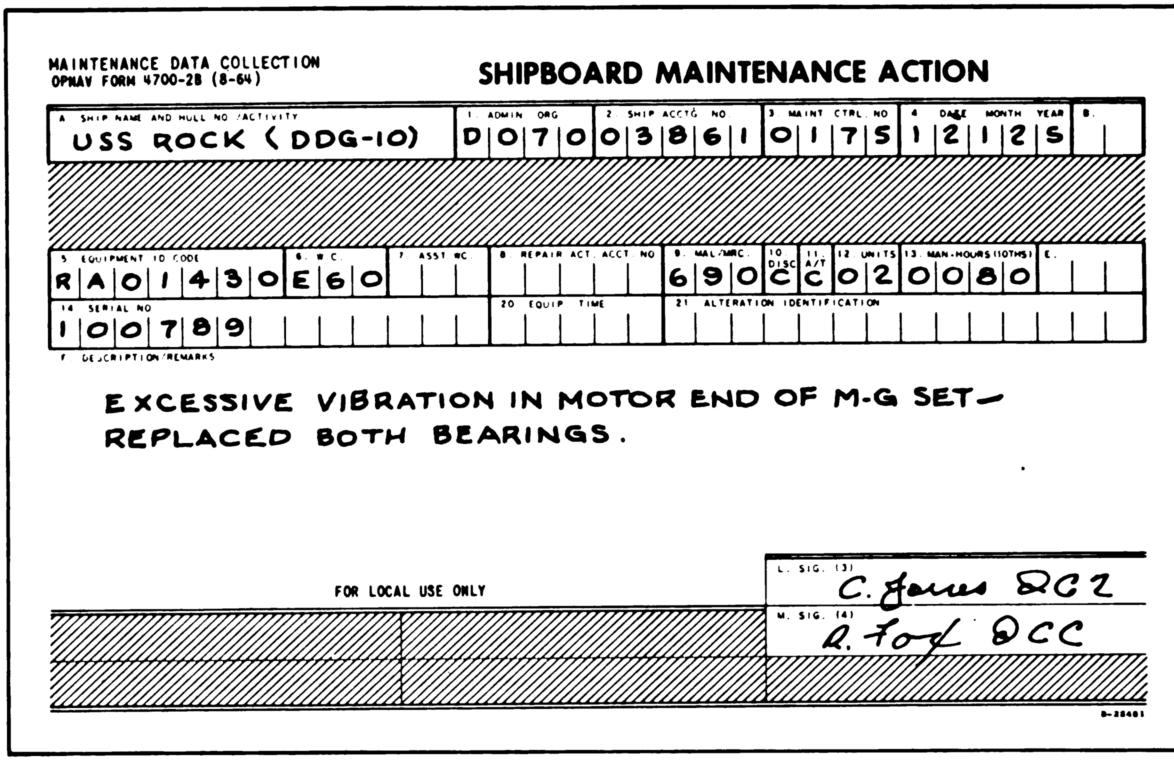
reported when the material was issued from supply. Parts from pre-expended bins not reported are screws, nuts, cotter pins and solder. Other items classified as pre-expended are consumable material such as wire, plexiglass, and sheet material used for manufacture work.

Items which were cannibalized or from salvage and are identified by a part number or a federal stock number, are reported on the 4700-2B form with cost price. Items not identified by FSN or part number are not reported.

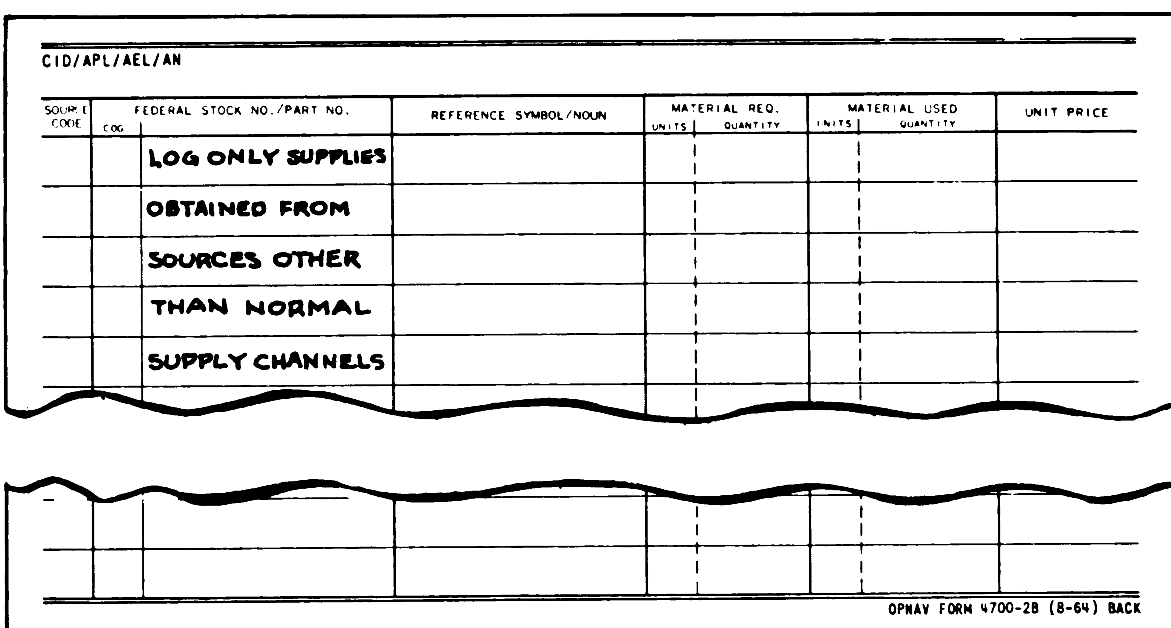
If in doubt as to the status of maintenance material used, report it on the 4700-2B form. Material obtained through normal supply channels is reported on either NavSandA form 1250 or DD form 1348. These forms are discussed in Military Requirements for P. O. 3 & 2, NavPers 10056-B, and IC 1 & C, NavPers 10557-B.

DEFERRED ACTION.—The deferred action form (OpNav 4700-2D, (fig. 17-38), is a two-sheet document used to record corrective maintenance actions that are deferred due to ship's operations, lack of repair parts, or need for

Digitized by Google



A



B

17.81B

Figure 17-37.—Shipboard maintenance action, OpNav form 4700-2B; (A) Front; (B) Back.

Digitized by Google

MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION — 1

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE	B.
USS ROCK (DDG-10)	D0170	03861	01176	12125	

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. W.C.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MANHOURS	E.
RC01430	E60			080	C	J	01	0005	

14. SERIAL NO.	20. EQUIP/TIME	21. ALTERATION IDENTIFICATION
428339		

F. DESCRIPTION/REMARKS

SYNCHRO OVERLOAD TRANSFORMER ON IC SWITCHBOARD BURNED OUT. NO SPARE ON BOARD.

L. SIG. (3) C. Jones – IC1

M. SIG. (4) R. Fox – ICC

FOR LOCAL USE ONLY

MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION — 2

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE	B.
USS ROCK (DDG-10)	D0170	03861	01176	14125	

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. W.C.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MANHOURS	E.
RC01430	E60			080	C	C	01	0010	

14. SERIAL NO.	20. EQUIP/TIME	21. ALTERATION IDENTIFICATION
428339		

F. DESCRIPTION/REMARKS

SYNCHRO OVERLOAD TRANSFORMER ON IC SWITCHBOARD BURNED OUT–NO SPARE. RECEIVED SPARE FROM USS TIDEWATER.

L. SIG. (3) C. Jones – IC1

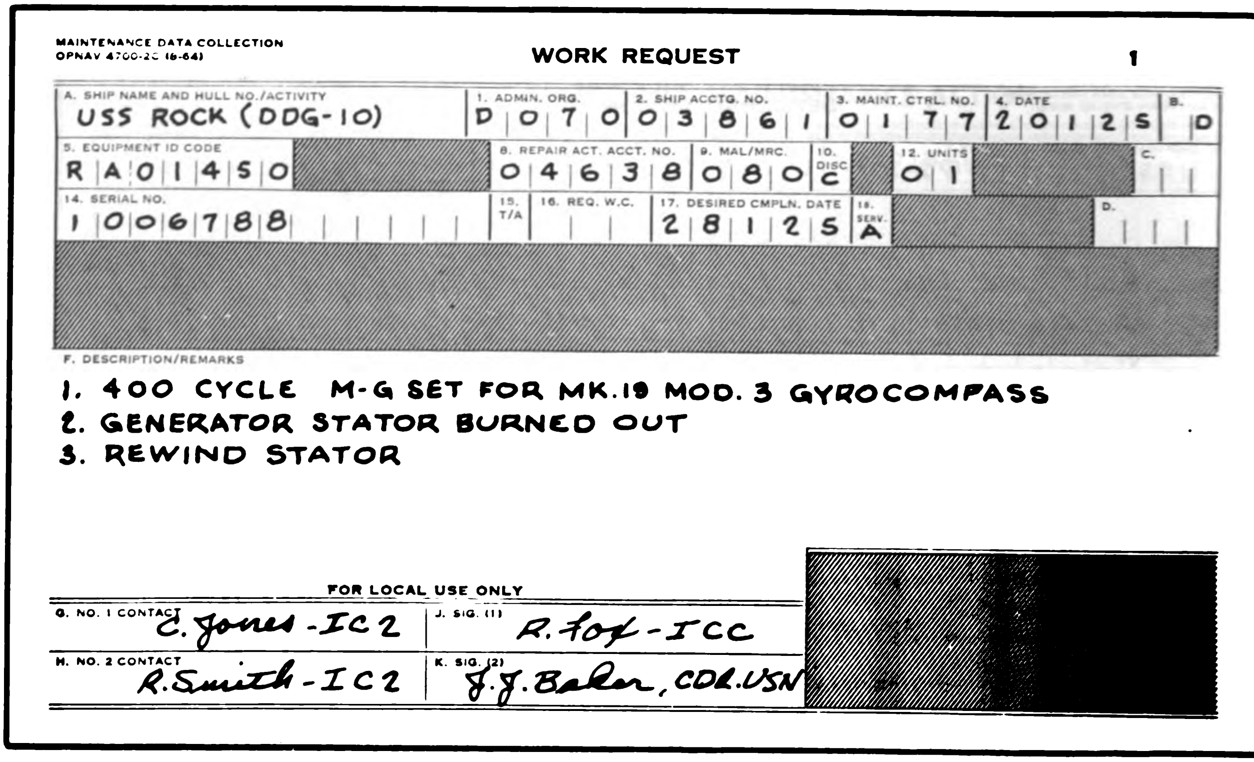
M. SIG. (4) R. Fox – ICC

FOR LOCAL USE ONLY

17.81D

Figure 17-38.—Deferred action, OpNav form 4700-2D.

Digitized by Google



MAINTENANCE DATA COLLECTION
OPNAV 4700-2C (6-64)

WORK REQUEST 1

A. SHIP NAME AND HULL NO./ACTIVITY: USS ROCK (DDG-10)
1. ADMIN. ORG.: D 0 7 0
2. SHIP ACCTG. NO.: 0 3 8 6 1
3. MAINT. CTRL. NO.: 0 1 7 7
4. DATE: 2 0 1 2 5
B.: D
5. EQUIPMENT ID CODE: R A 0 1 4 5 0
8. REPAIR ACT. ACCT. NO.: 0 4 6 3 8
9. MAL/MRC.: 0 8 0
10. DISC: C
12. UNITS: 0 1
C.
14. SERIAL NO.: 1 0 0 6 7 8 8
15. T/A
16. REQ. W.C.
17. DESIRED CMPLN. DATE: 2 8 1 2 5
18. SERV.: A
D.

F. DESCRIPTION/REMARKS
1. 400 CYCLE M-G SET FOR MK.19 MOD. 3 GYROCOMPASS
2. GENERATOR STATOR BURNED OUT
3. REWIND STATOR

FOR LOCAL USE ONLY
G. NO. 1 CONTACT: C. Jones - IC2
J. SIG. (1): R. Fox - ICC
H. NO. 2 CONTACT: R. Smith - IC2
K. SIG. (2): J. J. Baker, CDR. USN

17.81C

Figure 17-39.—Work request, OpNav form 4700-2C, sheet 1.

outside assistance. The first sheet is used to record the reason for deferral, and the second sheet is used to report the completion of the deferred action. The reverse side of the form is filled in for parts used from outside normal supply, the same as the 4700-2B form.

When a corrective maintenance action is deferred because of ship's operations or lack of repair parts, a 4700-2D form is prepared and Copy 1 submitted with the proper date in block 4, the proper action taken (A/T) code in block 11, and the man-hours expended, if any, in block 13. When the maintenance is completed, Copy 2 is submitted, with the date in block 4, block 11 filled in with the proper code and man-hours expended to complete the work entered in block 13.

Corrective maintenance action requiring outside assistance requires a completed 4700-2D form. Copy 1 requires the proper block 11 code, and the man-hours in block 13 required to investigate and remove the equipment to a ship. Copy 2 requires the proper code in block 11, and the man-hours in block 13 required to reinstall the equipment when returned to the ship. A work request OpNav form 4700-2C (discussed below), using the same maintenance control number in block 3 is submitted through proper channels.

WORK REQUEST.—Work request form OpNav 4700-2C (fig. 17-39), is a four sheet document used to record the need and request for outside repair or "manufacture" assistance (other than shipyards), and for all scheduled availabilities. It is used for workload planning by repair activities (tenders, repair ships). Part II (not shown) is a continuation of the basic form, section F, which provides additional space for written description, diagrams, and sketches.

Sheet 1 of the form(s) (fig. 17-39), is completed and retained by the shipboard personnel, sheets 2, 3, and 4 are carbon copies of Sheet 1 with additional blocks to be filled in by the tender or repair activity performing the work.

Block 3 will have the same maintenance control number, and block 5 the same equipment code if associated with another 4700-2 form.

Digitized by Google

APPENDIX 1

TRAINING FILM LIST

Training films that are directly related to the information presented in this training course are listed below. Under each chapter number and title the training films are identified by Navy number and title. Other training films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

Chapter 1

ADVANCEMENT

MN-6798D Your Job in The Navy—Part 4. (31 min.—Color—Sound—Unclassified—1950.)

Chapter 3

POWER DISTRIBUTION SYSTEMS

SN-3485A Electric Power Afloat—Ship's Service System (Electric Plants.) (16 min.—B&W—Sound—124 frames—Unclassified—1945.)

SN-3485C Electric Power Afloat—Starting and Applying Load. (12 min.—98 frames—B&W—Sound—Unclassified—1945.)

SN-3485D Electric Power Afloat Paralleling and Securing. (10 min.—88 frames—B&W—Sound—Unclassified—1945.)

Chapter 5

TEST EQUIPMENT

MA-7812A Circuit Testing with Meters and Multimeters—Theory. (35 min.—Sound—1951.)

MA-7812B Circuit Testing with Meters and Multimeters—Practical Applications. (33 min.—Sound—1951.)

MN-8687B Reading Multimeter Scales. (6 min—Sound—1956.)

MN-2104B The Cathode Ray Oscilloscope. (23 min—Sound—1944.)

MN-2104A The Cathode Ray Tube—How It Works. (15 min.—Sound—1943.)

Digitized by Google

Chapter 12

GYROCOMPASSES, PART I

MN-1792C The Gyrocompass—The Gyroscope and Gravitation. (12 min.—B&W—Sound—Unclassified—1944.)

MN-1792D The Gyrocompass—The Gyro Becomes a Compass. (15 min.—B&W—Sound—Unclassified—1944.)

MN-1792E The Gyrocompass—The Compass System. (16 min.—B&W—Sound—Unclassified—1944.)

MN-7465A Gyrocompasses Mk 19 Mod 3 and Mk 23—Earth Rates. (17 min.—B&W—Sound—Unclassified—1954.)

MN-7465B Gyrocompasses Mk 19 Mod 3 and Mk 23—The Gyro as a Compass. (15 min.—B&W—Sound—Unclassified—1954.)

Chapter 13

GYROCOMPASSES, PART II

MN-7465C Gyrocompasses Mk 19 Mod 3 and Mk 23—General Description. (25 min.—B&W—Sound—Unclassified—1954.)

MN-7465D Gyrocompasses Mk 19 Mod 3 and Mk 23—Compass Control Mk 23. (15 min.—B&W—Sound—Unclassified—1954.)

MN-7465E Gyrocompasses Mk 19 Mod 3 and Mk 23—Errors and Corrections Mk 23. (18 min.—B&W—Sound—Unclassified—1954.)

MN-7465F Gyrocompasses Mk 19 Mod 3 and Mk 23—Followup System Mk 23. (13 min.—B&W—Sound—Unclassified—1954.)

Chapter 16

SHIP'S METERING AND INDICATING SYSTEMS

MN-9775A Ship's Wind Indicating Equipment—Installation. (10 min.—B&W—Unclassified—1964.)

MN-9775B Ship's Wind Indicating Equipment—Maintenance. (11 min.—B&W—Unclassified—1964.)

Chapter 17

MAINTENANCE

MN-10041 Electronic Assembly Repair Techniques. (28 min.—Color—1965.)

MC-9655B The Printed Circuit Story. (28 min.—Color—1962.)

MN-10043A The Planned Maintenance System. (20 min.—B&W—1965.)

Digitized by Google

INDEX

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

YE 10319

Digitized by Google

Digitized by Google