CONFIDENTIAL

FEBRUARY 1948

BUSHIPS Electron

NavShips 900,100

FEBRUARY 1948 • VOLUME 3 • NUMBER 7

FRONT COVER—The instrument pictured on the front cover is an item of RADIAC equipment used for detecting the presence and computing the strength of nuclear radiations. RADIAC means Radio Activity Detection, Identification And Computation.

BUSHIPS Electron

A MONTHLY MAGAZINE FOR ELECTRONICS TECHNICIANS

DISTRIBUTION: BuShips Electron is sent to all activities concerned with the installation, operation, maintenance, and supply of electronic equipment. The quantity provided any activity is intended to permit convenient distribution—it is not intended to supply each reader with a personal copy. To this end, it is urged that new issues be passed along quickly. They may then be filed in a convenient location where interested personnel can read them more carefully. If the quantity supplied is not correct (either too few or too many) please advise us promptly.

CONTRIBUTIONS: Contributions to this magazine are always welcome. All material should be addressed to

The Editor, BuShips ELECTRON
Bureau of Ships (Code 993-b)
Navy Department
Washington 25, D. C.

and forwarded via the commanding officer. Whenever possible articles should be accompanied by appropriate sketches, diagrams, or photographs (preferably negatives).

BUREAU OF SHIPS — NAVY DEPARTMENT

MEASURING ANTENNA PATTERNS WITH SHIP MODELS . . . . . .

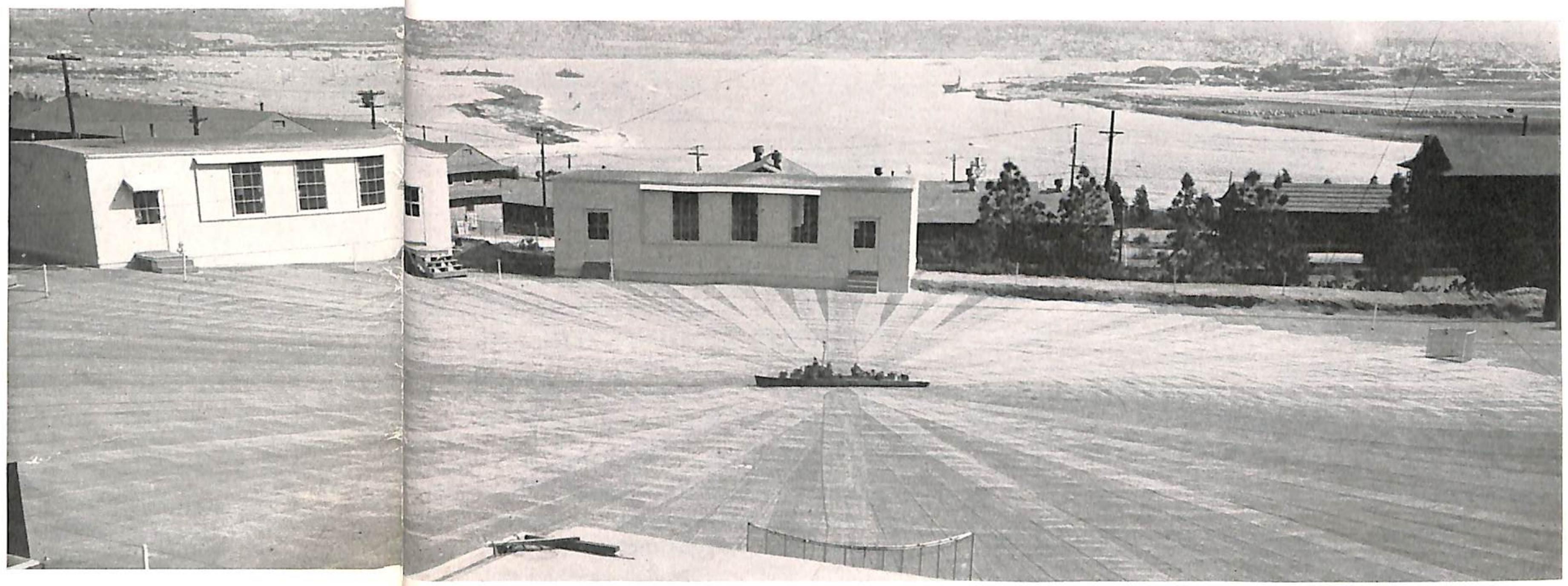


Figure 1—*General view of a portion of the model range facilities, showing ship model and measuring-apparatus antenna. In the background beyond the Laboratory buildings lies San Diego harbor, suggestive of the practical application of the model range.*

INTRODUCTION

■ It was related in the December, 1947, issue of the Electron, in "Early Antenna Program at NEL," the first of a series of four articles on antennas, how the number of antennas increased greatly on vessels of all classes during the recent holocaust. From superstructure and mast sprang up a veritable jungle of "dishes," "bedsprings," "wires," "whips," "turnstiles," and other type antennas for radio, radar, i-f-f, and other forms of electronic equipments. This situation, the article pointed out, adversely influenced radio transmission and reception because of the resulting poor antenna directivity, and hampered fleet operations.

It was further related that the Bureau of Ships had instituted a program of research and development to clear up the difficulties. Emphasis was laid in this program on the new doctrine of "antenna systems engineering." Now the goal became the best performance of the entire system of antennas, and each antenna was to be evaluated in terms of its contribution to the overall efficiency; every individual antenna must be completely and satisfactorily usable at all times, although some sacrifice in the individual efficiency of some antennas might have to be accepted in order to achieve this end. Now, too, it became imperative to judge the performance of an antenna—no matter how carefully-designed it might be in the laboratory—only when it is actually mounted in place on shipboard.

The new requirements immediately complicated the problem of antenna design—never easy at best. First, it became necessary to take data in greater detail, for radical changes in the radiation pattern of an antenna often occur with relatively small changes in frequency when it is mounted in place on a vessel in company with other antennas, unlike the behavior of that antenna in "free-space." Second—consider this—a change in the construction or electrical characteristics of any one antenna requires retesting of the performance of each of the other antennas mounted on the vessel, and an evaluation again of the overall functioning of the system. Thus, the amount of data to be taken assumed astronomical proportions; yet, taken it had to be.

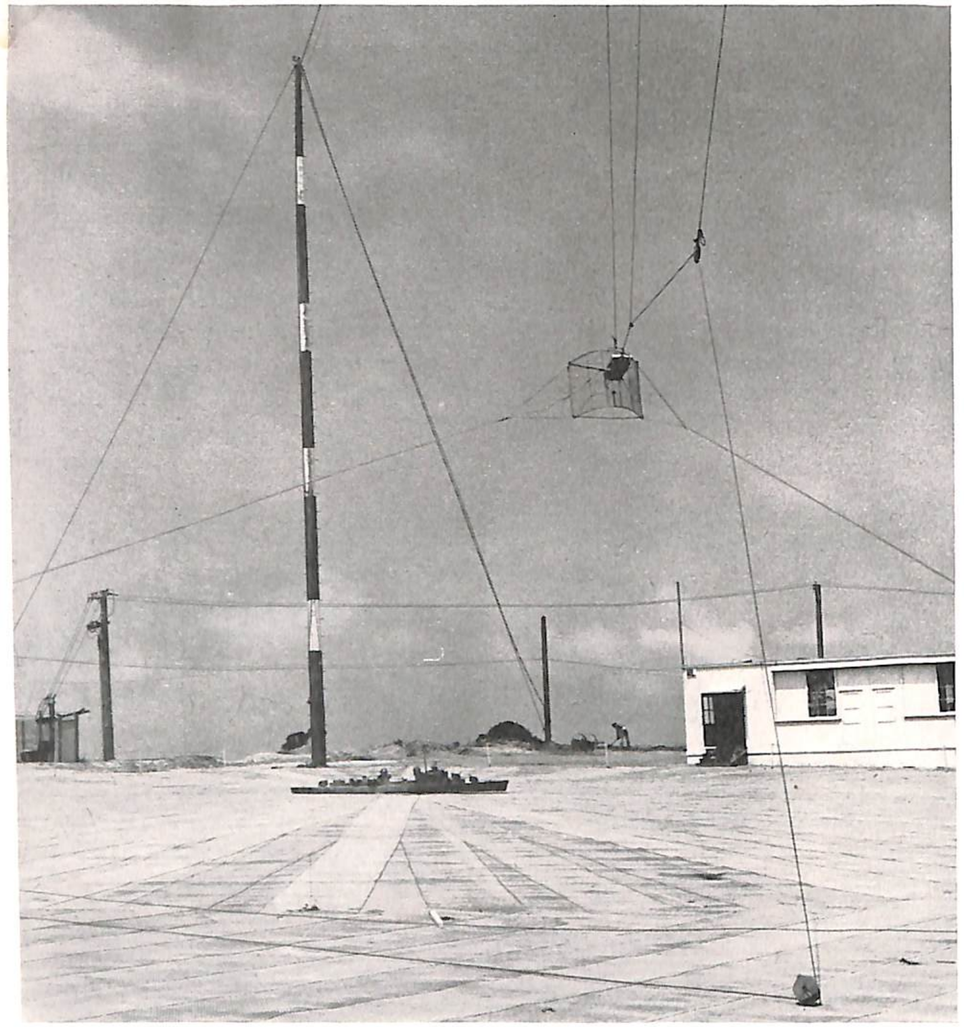


Figure 2—*Model range for the m-f and h-f ship communication band 2 to 27 Mc. The antenna of the measuring apparatus can be seen suspended by cables for patterns in a vertical plane.*

THE MODEL TECHNIQUE

From the second article in the series, "Measurement of Antenna Characteristics," Electron, January, 1948, an idea may be gained of the effort that must be put forth in taking readings of antenna performance on actual ships. Because of those difficulties it was proposed to obtain antenna directivity data *in miniature* in some form in the laboratory and extrapolate the results to full-scale ships. Final choice of antenna design would depend on actual shipboard measurement, of course.

In the laboratory, it would seem logical to believe, techniques could be devised to record the data in a fraction of the time and with a fraction of the effort required for full-scale operations. The final tests on actual craft would be kept at a minimum, and the program could move along at a much faster pace.

Measurement in miniature is based on well-established theoretical principles of similitude. If the dimensions of the vessel and the antenna, the resistivity (electrical resistance per unit volume), and the wavelength are all scaled down from full size to miniature in the same ratio, then the antenna directivity characteristics will remain the same. This, of course, calls for small ship models and facsimile model antennas, carefully constructed to adequately reproduce in miniature the pertinent electrical and mechanical features of the equipment and vessel under investigation; it also calls for an artificial ocean consisting of some sort of electrically-conducting plane with sufficient resistance uniformly distributed to produce the correct value of resistivity; the third requirement is easily met by using laboratory transmitters operating at the appropriate higher frequencies.

The potential practical value of the model was realized early in the antenna systems engineering program, with the consequence that the Bureau of Ships on 1 August, 1944, assigned to the U. S. Navy Electronics Laboratory at San Diego the task of investigating the model technique and of developing it into a practical tool for application to the Bureau's program of antenna improvement.

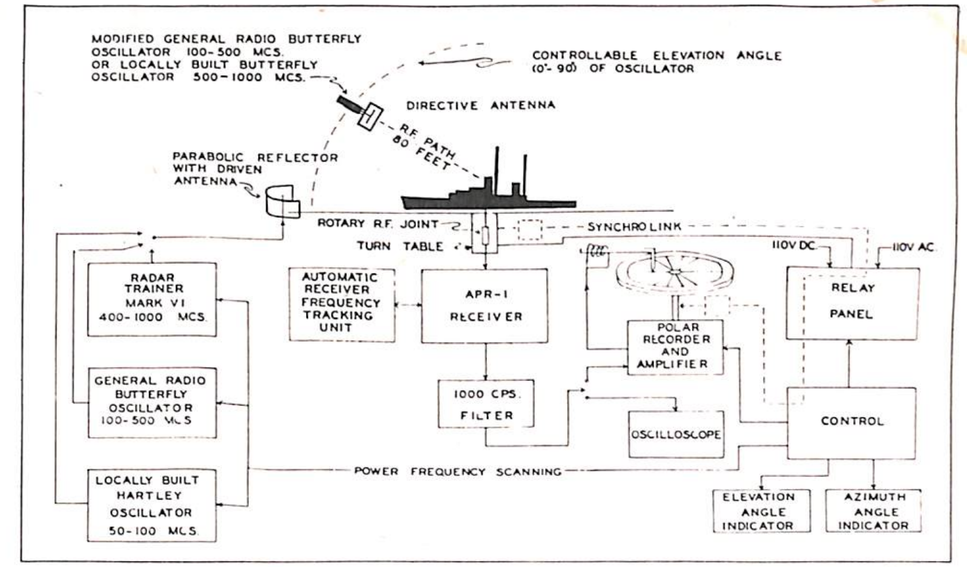


Figure 3—*Diagram of the m-f and h-f range.*

The ensuing work has included, 1—Construction and procurement of model ranges and the associated models and equipment; 2—Validation tests with actual vessels, and continued development of techniques and equipment so as to resolve discrepancies between data obtained on the model range and on shipboard, hence increasing the reliability of the technique; 3—Auxiliary studies to improve the knowledge of fundamental antenna behavior; 4—Practical application of the model ranges to the re-design of the antenna systems of many vessels of the fleet, and to new designs.

The first ranges constructed were for the purpose of work on m-f and h-f antennas. Later, a separate range was established to include v-h-f and u-h-f antenna performance as well.

Because the improvement in the technique as applied to the various frequency ranges has been continued and steady, and in many cases concurrent, no attempt will be made to present the following more detailed account in strict chronological sequence.

M-F AND H-F COMMUNICATION ANTENNAS (2-27 MC)

First priority was accorded the 2 to 27 Mc ship communication range, and a temporary model range was built at Point Loma. It consisted of a circular area of asphalt about 200 feet in diameter covered by a layer of ordinary 2-inch galvanized poultry netting to simulate the ocean. At the center of the range was located a small turntable, upon which the ship model was placed, and capable of being rotated through an angle of 360°. A transmitter was placed at the edge of the range, and fed radio energy to the facsimile antenna mounted on the model and connected to a receiver. An alternative scheme is, of course, to set the receiver at the edge of the "ocean" and connect the model antenna to a transmitter. Whichever method may be chosen, the results are the same. The testing procedure is to rotate the vessel continuously throughout 360° and record data in some form, later to be plotted in polar co-ordinates. Transmitters have outputs of a fraction of a watt, and operate at from 100 to 1000 Mc.

The first model constructed came from the shops of the David Taylor Model Basin, a 1/24-scale replica of a destroyer of the *Fletcher* class, and was modeled from wood and sprayed with metallic paint to supply it with the requisite conductivity.

Once the first model range was constructed and some idea of the practical problems of technique had been obtained, a second model range was set up for permanent use. This range was similar to the first, but, on the basis of preliminary reflectivity and conductivity tests, was covered with 1/2-inch instead of 2-inch netting. The netting was laid out in long strips projecting out radially from the center of the range, because there had been indications from experience with the first model range that strips of netting acted like waveguides, distorting the radio waves and antenna patterns unless they were laid out radially. The platform at the center elevated the vessel about one inch above the ground plane. The periphery was cut in an irregular manner to prevent the formation of standing waves.

The patterns were first obtained by plotting from data recorded on tape on an Esterline-Angus recorder. Because this procedure required that the curves be plotted by hand, an attempt was made to develop an oscillographic recording system: twelve receivers were spaced equally around the edge of the earlier, circular range and were connected to an oscilloscope; the ship model with its antenna transmitting was then rotated around and back through an angle of 30°, thus causing the antenna pattern to be portrayed directly on the screen. The equipment kept falling out of adjustment, but was ultimately developed to function properly. This device is used for rapid preliminary determination of the antenna patterns to mark out the regions where rapid anomalous pattern changes take place.

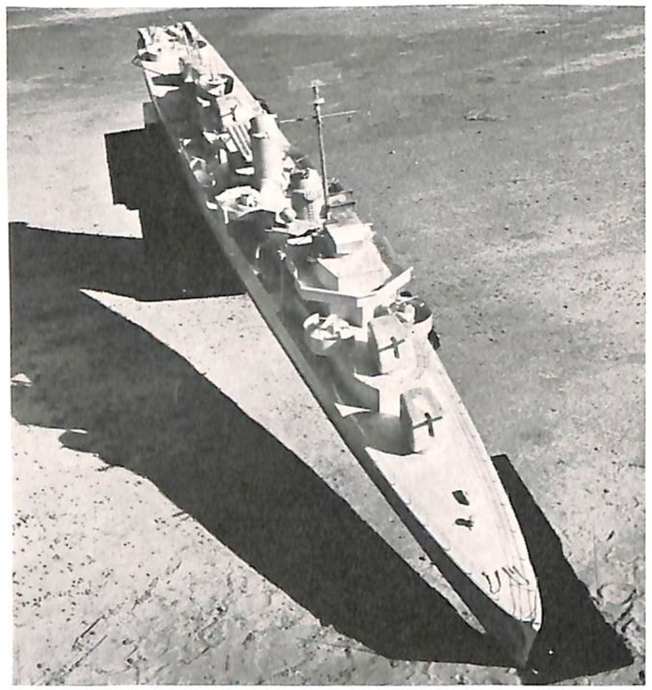


Figure 4—*Model of the* Fletcher *class destroyer prepared by the David Taylor Model Basin.*

For use in obtaining the actual measurements, however, this scheme has been supplanted by another which has proven highly successful—so much so that it is now employed on all the model ranges. As before, the model is rotated, a receiver is set up at the edge of the range, and the data is recorded on a polargraph plotting-machine developed and built in the Laboratory shops. This device utilizes pneumatic pressure to drive the recording arm with its pen. As the ship model rotates on the turntable, the polar graph paper on the machine is simultaneously rotated by synchros in exact correspondence with the rotation of the model.

In many cases it has been found that changes in antenna patterns with changing frequency take place with great rapidity in some frequency ranges, whereas in other, much broader, ranges there is almost no noticeable variation. With the purpose in mind of avoiding the wasteful duplication in data occurring when such ranges as the latter are explored, the model range engineering staff at N. E. L. developed an automatic frequency-scanning system for preliminary visual exploration of the frequency range of the antenna. The model is rotated around as usual at about ten r.p.m., but a special transmitter is employed that is slowly changed in frequency at a rate of about 0.2 to 0.5 Mc per rotation, being automatically tracked in frequency by a self-tuning receiver designed for the purpose. The receiver output is viewed on an oscilloscope. With this system it is possible to de-

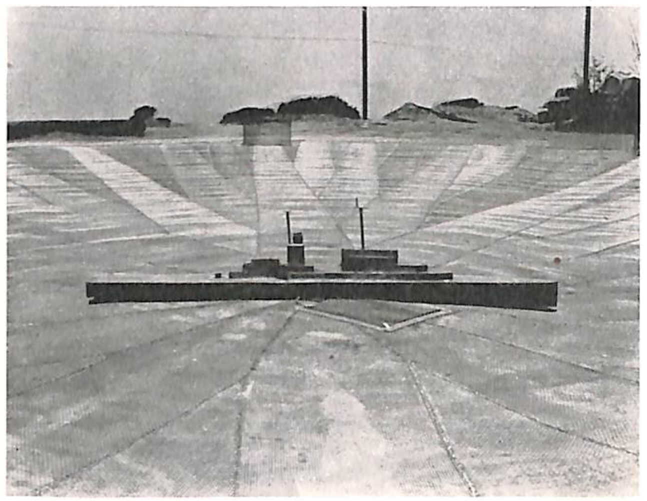


Figure 5—*Simplified model of a light cruiser.*

lineate at just which frequency points the rapid antenna pattern changes occur, and to restrict the more careful accumulation of data using the automatic plotter to these points; thus the burden of pattern-recording is greatly reduced.

The permanent model range has been modified so that patterns in the vertical plane (which is to say, patterns in directions above the horizon) may be obtained as well. Four 95-ft wooden poles have been erected from which is suspended by a system of cables a transmitter and antenna unit containing a butterfly-type unmodulated r-f oscillator. The antenna of this unit has directional properties to reduce reflection from objects outside the model range. The cable system is so designed that the transmitter may be positioned at any angle to the ship model and ground plane up to 90°. This arrangement will star in the investigation of ship-to-plane communications.

For the validation tests, a destroyer of the *Fletcher* class, the U. S. S. *Wiley* (DD597) was temporarily assigned to the Laboratory. Careful measurements were made of the physical dimensions and electrical characteristics of the masts, antennas, superstructures, stays, leads, and other parts of the *Wiley*, so that the David Taylor Model Basin model could be corrected wherever discrepancies occurred. The destroyer then put to sea and antenna patterns were taken of the vessel's TBL transmitter antenna, using frequencies ranging from 6.54 to 16.9 Mc. Directivity patterns were then recorded of the $\frac{1}{24}$-scale facsimile antenna at frequencies 24 times as great, and the results were compared. Some dis-

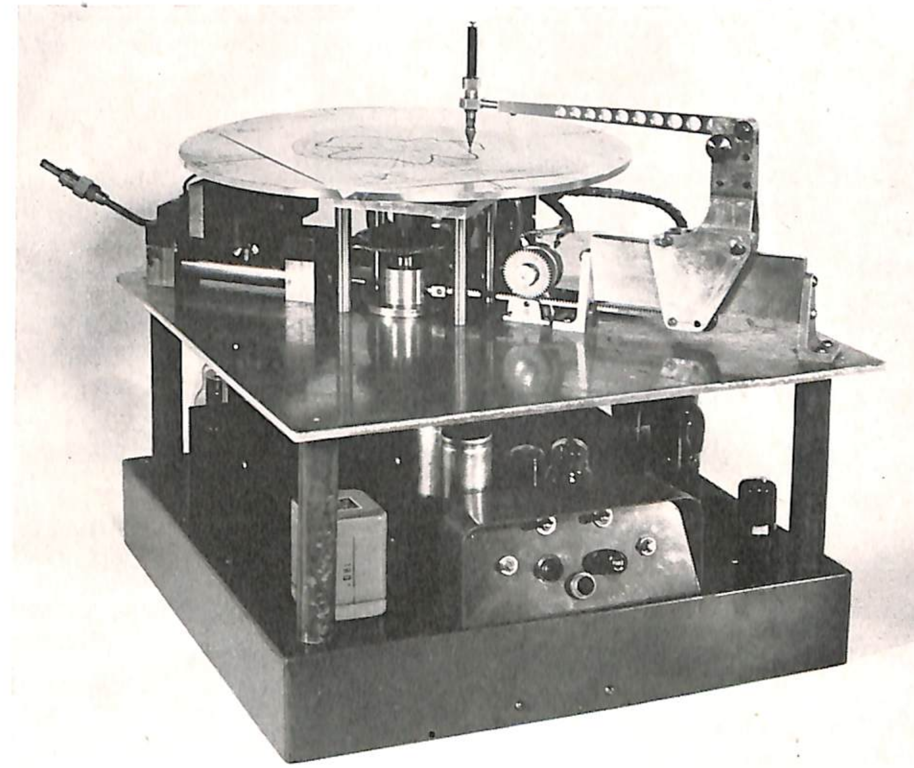


Figure 6—*Automatic polar-graph plotting-machine.*

crepancies were found, but as the model technique has been improved, the discrepancies have become fewer in number and in seriousness, as shown by further tests. At present a 180-ft escort carrier (rescue), Laboratory Ship EPCE (R) 857, has been assigned to N. E. L. for electronics research, and will be available for more detailed and thorough validation tests. The model range itself is known to give accurate measurements; carrying out the modeling in miniature of the electrical features of a full-sized vessel is what remains to be studied. It might be pointed out that the validation tests in no way reflected any doubts about the validity of the principle of similitude involved, but only about the actual practical utilization of that principle as carried out in a particular range with models constructed in accordance with a particular modeling procedure.

In addition to the original destroyer model, the following models of sheet copper and brass have been constructed at the Laboratory and utilized in investigations: 1—Simplified $\frac{1}{48}$-scale model of a light cruiser (CL98), so constructed that masts, funnels, etc., could be removed and rearranged as desired; 2—Simplified $\frac{1}{48}$-scale model of an escort carrier (CVE105); 3—Detailed $\frac{1}{48}$-scale model of the central portion of the hull and superstructure of a heavy cruiser (CA73); 4—Detailed $\frac{1}{24}$-scale model of another destroyer (DD692).

V-H-F AND U-H-F COMMUNICATION ANTENNAS (100-400 MC)

Once the m-f and h-f investigations were well under way, the program was extended to embrace the u-h-f and v-h-f ranges of frequency. This extension added new problems, as will be seen. Those structures which lie within a few wavelengths from the antenna have the greatest influence on the formulation of the final pattern of the radio waves propagated across the surface of the ocean. At v.h.f. and u.h.f., this means that those structures immediately adjacent to the antenna have to be reproduced with much more precision than is necessary at m.f. and h.f. The only practical way to do this is to build large models which have been reduced less in size

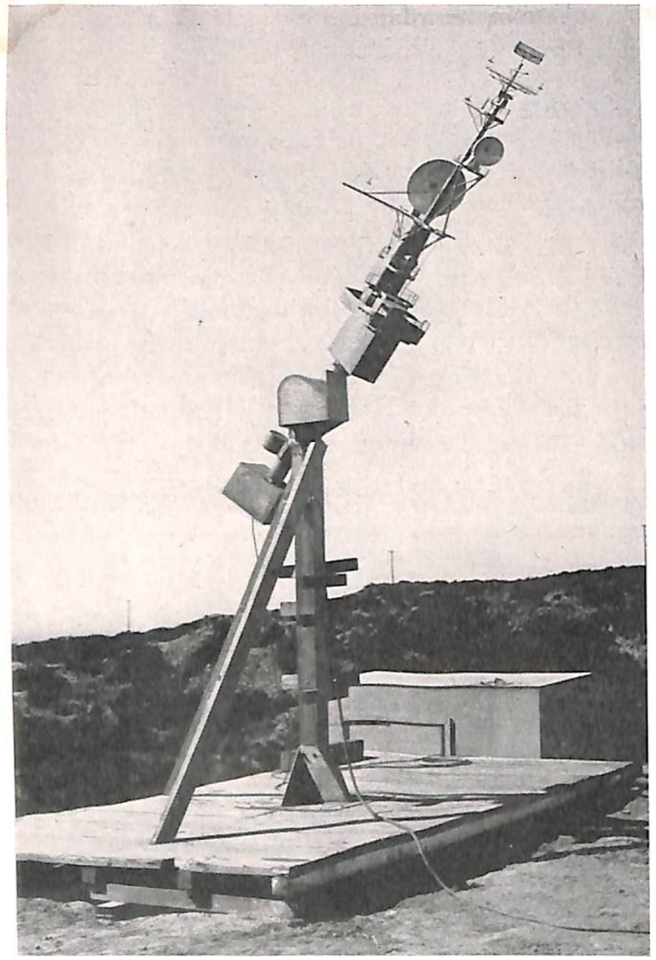


FIGURE 7—*Model range for the v-h-f and u-h-f ship communication band, 100-400 Mc. The model may be rotated and tilted as desired. A counterweight is visible, which balances the weight of the model.*

from full-scale ships. Frequency limitations of available oscillators and receivers also indicate the necessity for large models. The model range with a simulated-ocean ground plane then becomes excessively large, and the construction of suitable models becomes a bothersome task. Therefore, it was decided to duplicate only vessel structures within a radius of about ten wavelengths of the antenna, and to obtain the pattern, including such lobes as would result from reflection from the surface of the ocean, by calculation after the patterns had been recorded.

The model range for the v-h-f and u-h-f bands consists of an upright post upon which the model may be elevated with provision for rotating the model throughout 360°, and for tilting it through a total angle of 210° in the vertical plane. The oscillators in the test apparatus are operated at frequencies of from 1200 to 4800 Mc, and a scale of twelve to one is employed in the modeling. Other frequencies and scaling factors may be used, as determined by the requirements of the particular problem, of course. The automatic plotter draws out the polar graphs as on the m-f and h-f ranges.

The first model constructed for v-h-f and u-h-f tests was a model of the island structure of an escort carrier. Patterns were obtained for the TDZ/RDZ antenna.

SPECIAL STUDIES AND OTHER INVESTIGATIONS

A number of special studies have been undertaken in connection with the model technique itself.

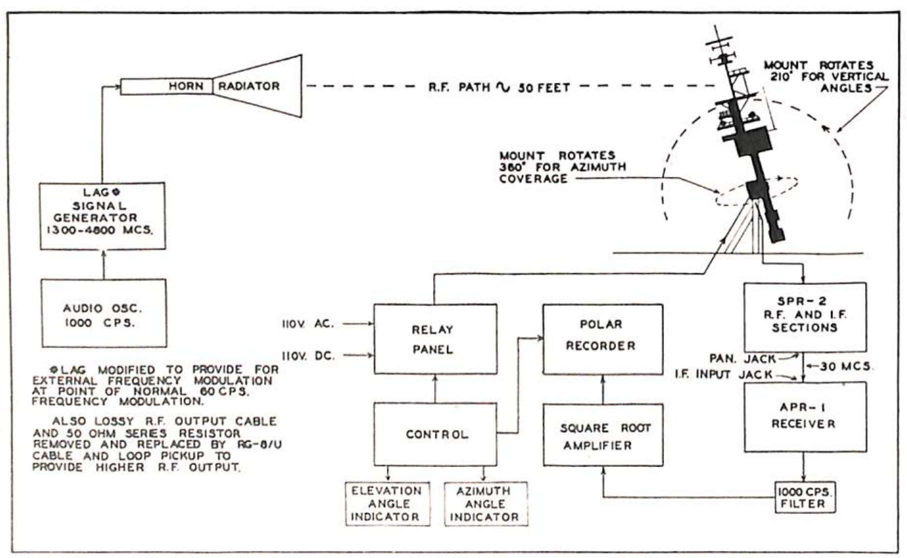


FIGURE 8—*Diagram of the v-h-f and u-h-f model range.*

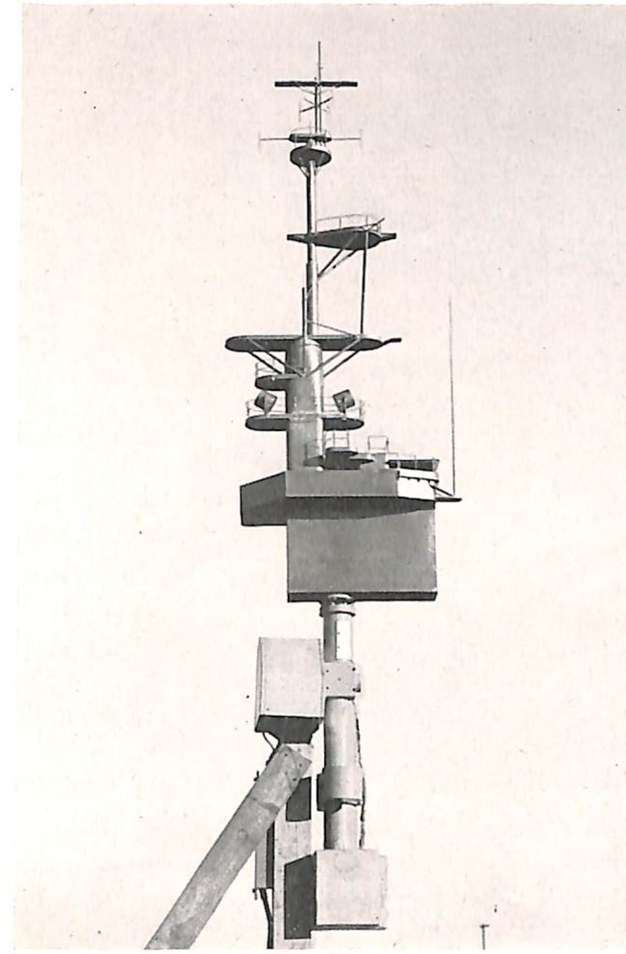


FIGURE 9—*Close-up view of a model on the range shown in figure 8.*

An example is the investigation of whether the model on the m-f and h-f ranges must be in actual physical contact with the ground plane for satisfactory electrical contact and satisfactory patterns, or whether mere capacitative coupling by elevating the model an inch above the ground plane is sufficient. For this investigation, a separate model range has been constructed with a mercury pool at the center to maintain continuous electrical contact as the model is rotated.

An auxiliary test range has also been set up to permit reflectivity and conductivity tests to be carried out on various materials which may be used to simulate expanses of ocean.

An important series of fundamental tests is under way to determine how effective are various simple geometrical structures (cubes, spheres, etc.) in introducing distortion in antenna patterns. This will help future designs.

The frequency ranges in which tests can be carried out have been extended down to the v-l-f and up to the s-h-f (microwave) bands by the construction of two additional model ranges and associated test equipment. On the former, by way of presenting an idea of the work that is being done, it may be said that tests are being made of an extremely large v-l-f installation for the Pacific Northwest.

RESULTS ACHIEVED—PRESENT STATUS—FUTURE OUTLOOK

The model range developed useful information almost from the start, such as:

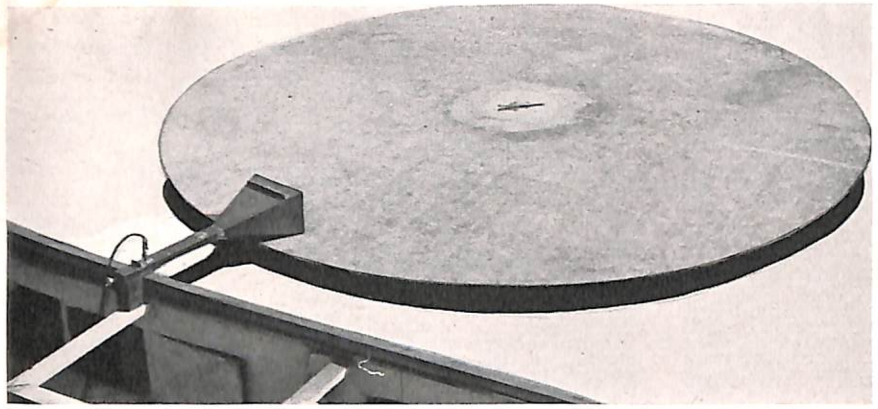
1—A better design of the antenna system for the *Fletcher* class of destroyers with much better relative forward coverage in the ranges of from four to ten, and from fourteen to seventeen megacycles than had been obtained with any previous arrangement of antennas.

2—Data on radio and radar antennas from the former German cruiser *Prinz Eugen*.

3—Studies of the horizontal and vertical directional characteristics of an experimental rhombic antenna.

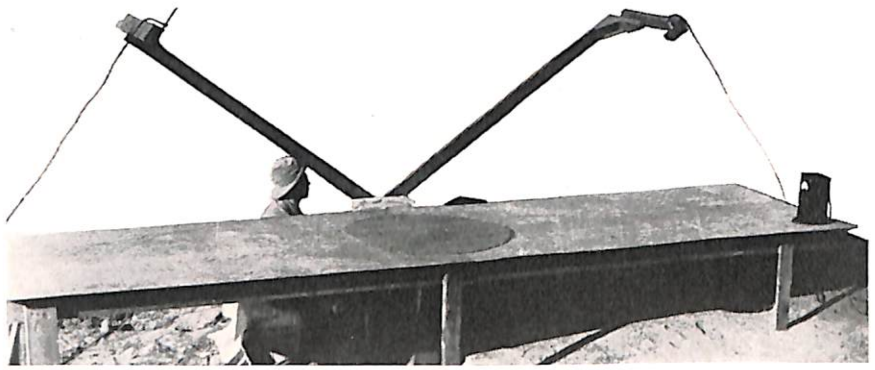
The model ranges are now regularly employed in practical use in conjunction with the overall Bureau of Ships program. The progress attained in the last three and one-half years in the development of such an involved scientific project has been highly gratifying. Although, from the academic standpoint of the field of measurements, the ideal of exact point-to-point correspondence between model and full-scale antenna performance has not yet been attained, chiefly because of the difficulty of properly modeling details electrically, it should be emphasized that this has not been an impediment in the way of a really valuable, practical utilization of the model technique on a large scale of operation. The reliability of the data taken on the model range is already sufficiently good that discrepancies can be spotted and resolved without too much difficulty. Indeed, almost all antenna research projects, at some stage in their history, now involve the use of the model range facilities. By the use of the ranges, the aims of reducing the tiresome burden of recording measurements and the time required to take the data have been achieved to a remarkable extent.

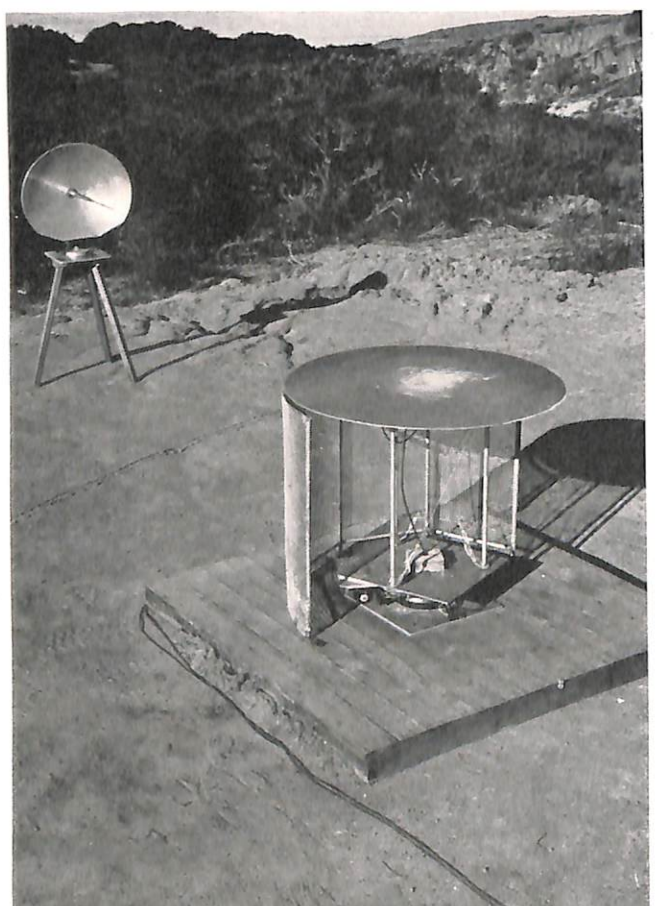
Further work on the development of the model ranges will, it appears, consist in obtaining better knowledge of the modeling procedure in reproducing the details of a full-scale ship on the scale model. Due to the pressure on fleet vessels and personnel, no full-scale vessel has been available to



(a)

(b)





(c)

FIGURE 10—*Typical auxiliary studies: a—Model range with mercury pool to study model-to-netting contact effects; b—Test bench for ground-plane reflectivity and conductivity measurements; c—Fundamental antenna studies (here for effect of parasitic antenna elements).*

the Laboratory for the relatively-prolonged period of time necessary for this knowledge to be obtained with the requisite thoroughness. With the assignment of the EPCE (R) 857 as Laboratory Ship to N. E. L., such a craft has become available. Investigations now under way to determine which details of a vessel's structure are important in the formulation of an antenna pattern, and which ones may be neglected, will be much easier.

In conclusion, it should be pointed out that model range technology can never take the place of measurements on actual full-sized vessels, nor is it intended to do so. The criterion for the evaluation of any antenna design is its performance on shipboard. However, the practical, valuable information which flows from the model range has already, even at an incomplete stage of development, firmly established the position of the model range technique as an indispensable adjunct to other phases of antenna research and design, and a tool of great value.

—L. M. F.

Electronics Division Publications

■ Numerous requests from various naval activities asking for certain of the Electronics Division publications have shown that all naval activities are not cognizant of the subject matter, purpose and distribution of these publications. The Communication Equipment Maintenance Bulletin, Sonar Bulletin, Radar Maintenance Bulletin, Radio Installation Bulletin, BuShips ELECTRON, and Electronic Equipment Type Allowance Book have each been requested at one time or another by an activity not entitled to and not having any practical use for the publication.

In order that all electronics installation, maintenance and repair personnel may obtain a better knowledge of these publications, a description of each of them follows. The description of each covers its material content, distribution, physical construction, and other features.

SONAR BULLETIN

The Sonar Bulletin, NavShips 900,025A, is a loose-leaf publication grouping together in one volume all the existing non-obsolete maintenance information for all types of sonar equipments, sonar components, sonar attachments, sonar training equipments, bathythermographs, fathometers and harbor detection equipments. In addition, it carries a list of all existing field changes for these equipments, complete instructions for accomplishing all field changes that do not require kits, and a chapter on sonar publications and corrections. The present bulletin is in its sixth edition and contains about 400 pages divided into 28 chapters.

Information in the Sonar Bulletin is kept up-to-date by loose-leaf supplements of about 50 pages each, issued quarterly. These pages either replace or follow existing pages in the bulletin, and each article on each page is dated to show the time at which it was written.

The Sonar Bulletin is distributed to all sonar schools, ships with sonar equipment (other than fathometer) on board, sonar repair ships, sonar installation or repair activities, sonar equipment manufacturers, and any other activities with clearly-defined uses for the bulletin.

A vessel which has only fathometer equipment on board is not entitled to the Sonar Bulletin. Information on fathometer equipment is published in BuShips ELECTRON and in letters direct to the vessels involved.

SHIPBOARD RADAR MAINTENANCE BULLETIN

This bulletin, NavShips 900,096, is a confidential, loose-leaf publication in two editions, containing pertinent information necessary for the efficient maintenance of shipboard equipment. It is divided into ten sections: General, Radar Fire Control, Search Large, Search Small, Submarine Equipment, IFF, Beacons, Repeaters, Test Equipment and Miscellaneous. The General section is reserved for information which is of special interest but which does not apply to any one specific equipment. The other sections are divided into specific equipment types, listed alphabetically or numerically, and containing four parts each, General, Maintenance and Service, Field Changes, and Trouble-Shooting Notes.

As in the case of the other maintenance bulletins, this publication is kept up-to-date by loose-leaf supplements issued quarterly. The pages of these supplements are inserted in the basic book in the manner outlined on the back of the supplements title page. The result is a permanent file of useful radar maintenance information.

The two editions of the R. M. B. are the "C" edition and the "S" edition. The "C" edition, intended for major ships and activities, is a complete copy containing all ten sections. The "S" edition contains only those sections which apply to equipments on the allowance of smaller ships. The quarterly supplements pages which do not apply to those activities possessing the "S" edition contain the note, "C edition only." These pages should be removed from the supplement and destroyed by holders of the "S" edition.

The R. M. B. is distributed to all radar schools, ships on the radar allowance list, radar repair activities, radar equipment manufacturers, and other miscellaneous activities having a clearly-defined need for the information.

COMMUNICATION EQUIPMENT MAINTENANCE BULLETIN

The C. E. M. B., NavShips 900,020A, is a loose-leaf publication containing information on the maintenance and repair of all electronic ship-to-ship and ship-to-shore communications equipment used by the navy. Supplements are issued every three months to keep the bulletin up-to-date, as in the case of the two bulletins mentioned above.

This publication is written as the result of close cooperation between manufacturers, the Bureau of Ships, and the fleet. Most of the material is originated by the engineering staff of the Bureau, which investigates difficulties reported by the fleet and makes recommendations which appear as field changes, alterations, and authorized procedures. Also included are handy maintenance tricks which have been evolved by technicians in the field, endorsed by the Bureau, and passed on for the benefit of all maintenance personnel.

The C. E. M. B. is divided into thirteen sections: General, Antennas and Transmission Lines, Interference, Direction Finding Equipment, Calibrating Equipment, Combination Transmitting and Receiving Equipment, Measuring Equipment, Receiving Equipment, Transmitting Equipment, Aircraft Navigation Equipment, "AN" and Army Equipment, Miscellaneous Equipments and Components, and Navy Type Numbered Components.

Distribution is to all ships except landing craft, all Type and Force Commanders, and all advance bases and major shore activities.

RADIO INSTALLATION BULLETIN

The Radio Installation Bulletin, NavShips 900,022, is published bi-weekly for naval electronics installation and maintenance activities such as naval shipyards, bases, tenders and repair ships. It contains advance information on field changes, installation techniques, beneficial suggestions adopted by various yards and bases, and, in general, is devoted to information which is of primary benefit to the shore bases and tenders to which it is distributed.

This publication is not furnished to forces afloat (except tenders) or operational or training commands. All material contained in it which is of interest to activities not receiving it is also published in other mediums such as BuShips ELECTRON, C. E. M. B., R. M. B., and Sonar Bulletin. Full coverage of all pertinent material is thus assured.

The R. I. B. is a loose-leaf publication but does not include a basic book. The loose pages received bi-weekly may be filed in notebook or folder by consecutive issue numbers. The publication is printed by a photographic method, the quickest and cheapest way to get this advance information printed for distribution to cognizant activities.

ELECTRONIC EQUIPMENT TYPE ALLOWANCE BOOK

Otherwise known as the T. A. B., the Electronic Equipment Type Allowance Book, NavShips 900,115 is a loose-leaf book kept up-to-date by the periodic issue of revisions, additions, or corrections. It contains the official Bureau of Ships allowance of electronic equipment for all types and classes of naval vessels. The allowances listed are based on the military requirements prescribed by the Chief of Naval Operations to be met by the electronic installations in ships.

Distribution of the complete T. A. B. is limited to certain major commands, and to planning, installation and supply activities directly concerned with the installation and supply of electronic equipment. Individual ships are not supplied with the complete book, but receive only those pages from the book which apply to the individual ship type. Such pages are intended to be inserted in the ship's on-board copy of the Machinery Allowance, as they constitute the ship's allowance of Group S67 material.

ELECTRON MAGAZINE

The magazine, BuShips ELECTRON gets the widest distribution of any of these publications. All ships with electronics maintenance personnel, all shore activities engaged in electronics work, all radio stations, bases, air stations, GCA units, shipyards, electronics schools, naval reserve training centers, and in general all activities connected in the least manner with installation, maintenance or operation of navy electronic equipment, or in the training of naval personnel for such duty, receive copies.

The purpose of the magazine is to keep electronics personnel, whether enlisted, officer, or civilian, up-to-date in the navy's broad field of electronics and to help them gain an over-all understanding of the subject. Frequently an individual, with an individual job to do, loses sight of the work that others are doing and the equipments that others are working on. In keeping all personnel informed of the many types of equipment, and of the problems and answers to problems of others, it is believed that they are enabled to do their own work a little more efficiently. If an individual makes a concerted effort to understand the principles of a new equipment as outlined in the ELECTRON he is bound to pick up a bit of information here and there which definitely adds to his electronics education. The next time he runs into the same situation in a new problem he is better enabled to reason through his difficulty.

In addition to the above, information on field changes is promulgated; available instruction books are listed; Bureau policies concerning certain equipments are outlined; interesting developments are published for their news interest.

It is the policy of the magazine never to publish any information of technical nature which has not been endorsed by the cognizant section in the Electronics Division. Readers are thus assured that if an article suggests a certain procedure, such procedure is not in violation of regulations or policies.

FINAL INSTRUCTION BOOKS

Almost all electronic equipment currently in use by the navy was designed prior to VJ day, so that in most cases sufficient time has elapsed for final instruction books to have been prepared and distributed. ComServPac, however, reports that a recent check of the books on hand in ships and stations in the Pacific revealed that many preliminary books are still being used.

In order to keep the naval service informed of the distribution of new final instruction books, the Bureau of Ships from time to time has published lists of these final books as they have been received, but these lists may not all have reached every interested activity. Accordingly, on Page 18 of the December 1947 ELECTRON, a list was published of all instruction books, final or otherwise, issued since 1 October 1945. A supplementary list appeared on page 13 of the January issue. Additions to these lists will be printed in future issues of ELECTRON. All ships and stations should check their files of instruction books against this list and order copies of those final books not already on hand for all electronic equipments under their control.

In the case of equipments installed before 1 October 1945, where no final book appears on the ELECTRON list, activities should request final books for these equipments, but should clearly indicate on the request "Final book only; do not substitute preliminary book." This should be done to prevent exhausting the stock of preliminary books in those cases where the final books are still not available. All requests should be addressed to the nearest District Publication and Printing Office, which will supply the books it has on hand, and forward the request for the balance.

All ships and stations should also check their Communication Equipment Maintenance Bulletins, their Radar Maintenance Bulletins, and their Sonar Bulletins to see that the bulletins contain the latest supplements and are up-to-date. Any desired changes in the distribution lists for these bulletins should be sent to the Chief of the Bureau of Ships, Code 993b, Washington 25, D. C.

RE-FORMING ELECTROLYTIC CAPACITORS

Electrolytic capacitors depend for proper operation on a chemical bond which deteriorates or ages over a period of time when the capacitors are not in use. If an electrolytic capacitor in which this bond has deteriorated is installed in an equipment, the over-aged capacitor can cause excessive damage to expensive power-supply equipment in a short interval of time.

The original preparation of this bond by the manufacturer is called *forming*. Accordingly, the repair process by which old capacitors may be rejuvenated to re-make this chemical bond is called *re-forming*. The process involves the use of a gradually-increasing d-c voltage of proper polarity and under controlled conditions.

Electrolytic capacitors that have been stored away as spares for a period of some time should be re-formed before being put into service. This can be done using any re-forming unit of simple design, such as the Navy Type -60007 Capacity and Resistance Bridge. The instruction book for this bridge, NavShips 900,628, contains instructions for re-forming electrolytic capacitors. Such instructions are contained in the paragraph under the heading, "Measuring Capacity (Electrolytic Condensers)," paragraph 304 (c), page 13.

After a capacitor has been re-formed, it should be given all tests described in the instruction book, and rejected if found defective.

ELECTRONIC EQUIPMENT RECORDS

A forthcoming revision of Chapter 6 of the Bureau of Ships Manual will require a change in the keeping of shipboard electronic history records. New forms recently adopted by the Bureau for recording failures and other highly pertinent data on electronic equipment are now available for this purpose.

These new forms, mentioned in paragraph 47-1119 of the Navy Department Bulletin for November, 1947, are known as the Electronic Equipment History Card (NavShips 536), Record of Field Changes (NavShips 537), and Tube Performance Record (NavShips 538). When appropriate data has been correctly recorded on them, these cards will serve important purposes in the maintenance, supply and design of electronic equipment.

The Bureau of Ships Manual will give only general instructions on the keeping of these records. For that reason the following discussion is published to provide a more detailed analysis of the use of the cards, and information to the electronics maintenance personnel who, being responsible for the equipment, will be the first to benefit from their proper use.

ELECTRONIC EQUIPMENT HISTORY CARD

The Electronic Equipment History Card is used to record all the information concerning failures and any other pertinent information on units of electronic equipment. One of these cards should be made out for each unit of electronic equipment. Electronic Equipment History Cards for a particular unit shall be transferred with the unit when the unit is removed from the ship.

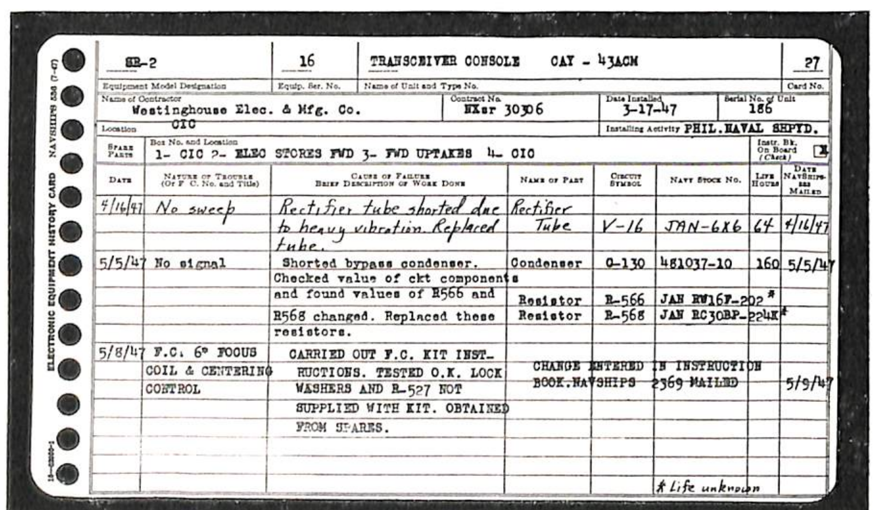
The heading is so designed that all the information necessary for completing the upper part of NavShips (NBS)-383 (Electronic Equipment Failure Report) is readily available when properly filled in.

The headings of the cards should be typed. The body of the card may be typed, or written in ink or indelible pencil. Ordinary pencil results in smeared records and shall not be used.

The history card is shown in figure 1. The following instructions should be closely observed in filling out the form.

Equipment Model Designation. The equipment model in full, including all letters and numbers, should be included. For example *AN/ARC-1* should not be entered as *AN/ARC* or *ARC-1; TDY-1a* should not be entered as *TDY.*

Equipment Serial Number. This number is taken from the equipment name plate, not the unit name plate. This applies to both models and type numbers. Where it has been definitely determined that an item does not bear a serial number, an asterisk (*) shall be placed in this space. If an overall equipment serial number covering all units is not available, the serial number of the major unit shall be listed for the entire equipment.



ELECTRONIC EQUIPMENT HISTORY CARD — NAVSHIPS 536 (7-47)

Equipment Model Designation: SR-2 | Equip. Ser. No.: 16 | Name of Unit and Type No.: TRANSCEIVER CONSOLE CAY - 43ACM | Card No.: 27

Name of Contractor: Westinghouse Elec. & Mfg. Co. | Contract No.: NXsr 30306 | Date Installed: 3-17-47 | Serial No. of Unit: 186

Location: CIC | Installing Activity: PHIL.NAVAL SHPYD.

Spare Parts — Box No. and Location: 1- CIC 2- ELEC STORES FWD 3- FWD UPTAKES 4- CIC | Instr. Bk. On Board (Check): X

Date	Nature of Trouble (Or F. C. No. and Title)	Cause of Failure, Brief Description of Work Done	Name of Part	Circuit Symbol	Navy Stock No.	Life Hours	Date NavShips-383 Mailed
4/16/47	No sweep	Rectifier tube shorted due to heavy vibration. Replaced tube.	Rectifier Tube	V-16	JAN-6X6	64	4/16/47
5/5/47	No signal	Shorted bypass condenser.	Condenser	C-130	481037-10	160	5/5/47
		Checked value of ckt components and found values of R566 and	Resistor	R-566	JAN RW16F-202 *		
		R568 changed. Replaced these resistors.	Resistor	R-568	JAN RC30BP-224K *		
5/8/47	F.C. 6* FOCUS COIL & CENTERING CONTROL	CARRIED OUT F.C. KIT INSTRUCTIONS. TESTED O.K. LOCK WASHERS AND R-527 NOT SUPPLIED WITH KIT. OBTAINED FROM SPARES.	CHANGE ENTERED IN INSTRUCTION BOOK. NAVSHIPS 2369 MAILED				5/9/47

* Life unknown

FIGURE 1—*The Electronic Equipment History Card.*

Name of Unit and Type Number. This information should be taken directly from the name plate of the unit.

Card Number. The number in this space will be number "1" on all cards in the original set-up. The cards will be numbered consecutively for all additional cards under each unit.

Name of Contractor. The name of the contractor in full as given on the equipment name plate or instruction book.

Contract Number. The contract number with all letters and numbers as given on the equipment name plate.

Date Installed. The date the unit was installed. Where installation required several days, the date of completion of installation.

Serial Number of Unit. The serial number of the unit taken from the unit name plate. This should not be confused with the Equipment Serial Number.

Location. The location of the unit aboard ship. If the unit is portable, enter the space where it is normally stowed.

Installing Activity. The name of the activity which actually performed the installation.

Box Number and Location. Enter the box numbers and locations of all boxes containing spare parts for that particular unit.

Instruction Book on Board. This box should be checked when the final instruction book is received. It should not be checked if only the preliminary book is received. Notice of the availability of final instruction books will be found in the appropriate maintenance bulletins.

Date. The date of a failure, field change, or other work involving repair or maintenance should be entered in this column.

Nature of trouble. In this column external evidence of the trouble should be entered. Describe in detail how the equipment acted which was symptomatic of trouble. Also, wheneve· a field change is made which affects a unit, the field change number and title should be entered in this column. This entry is in addition to the entry on the Record of Field Changes, NavShips 537.

Cause of Failure. This column is most important. Describe how the trouble was traced and what corrective measures were taken. Give detailed information. Note peculiarities and weaknesses of the unit. The better the information in this column, the more will be its value to the ship, the manufacturer, and the Bureau. *Everything that is put in this column—and reported on NavShips (NBS) 383—will some day be reflected in better and more reliable equipment.* Some activities may (optionally) wish to record in this column such information as the name and rate of the person actually doing or supervising the work, the man-hours spent, the signature of the Division Officer, or other similar data.

Name of Part. The names of the parts involved in the failure should be listed.

Circuit Symbol. The symbol designations of the parts which failed, as listed in the instruction book.

Navy Stock Number. The Navy Stock number of the part, including all prefix and suffix letters exactly as given in the instruction book.

Life Hours. Estimate the life of the part in hours as closely as possible. Use these machinery history cards, readings of tube hour meters, or any other available data, to obtain this figure.

Date NavShips 383 Mailed. Record the date the NavShips (NBS)-383 Failure Report Card was mailed to the Bureau. This column may also be used to record the date the Field Change Record Card (NavShips 2369) was mailed to the Bureau after a field change has been completed.

RECORD OF FIELD CHANGES

Field Change Records are of paramount importance. There is no record more essential than that which describes the changes made to the equipment. Without these modifications, an equipment may be old-fashioned, dangerously out-of-date, and suffering from a host of serious difficulties. Without the records, no one can be sure that the changes were made.

This information is an absolute necessity for routine maintenance, for trouble shooting, and for ordering spare parts which belong to the improved apparatus.

A report card (NavShips 2369) is packed with each field change kit. This card is to be filled out and mailed as soon as the change is made.

All the field changes affecting a given type of equipment are listed in the C. E. M. B., R. M. B., or the Sonar Bulletin. Space is provided in the field change form to describe them with a number corresponding to the number of the field change.

Figure 2 shows the Record of Field Changes Card. The blank spaces for *Equipment Model Designation, Serial Number, Date Installed,* and *Card Number* should be typed in, or written using ink or indelible pencil. Ordinary pencil shall not be used.

The official name and navy type number (or other official identification) of each unit affected by a field change should be shown parenthetically after the title of that change. See figure 2.

Columns headed *Number, Title of Field Change,* and *Authority for Change* should be completed in numerical order for all changes which affect this type of equipment.

If the change has not actually been made, the columns headed *Change Made By* and *Date of Change* should be left blank. When the change is made, the name of the person making the change, and the date on which the change was made should be recorded. If the change concerns the type of equipment but not this particular model or serial number, the words "not applicable" should be entered in these two columns.

NAVSHIPS 537 (7-47) — RECORD OF FIELD CHANGES

Equipment Model Designation: QGB	Serial Number: 120	Date Installed: 1 February 1945		Card No. 1
NO.	**TITLE OF FIELD CHANGE**	**AUTHORITY FOR CHANGE**	**CHANGE MADE BY**	**DATE OF CHANGE**
~~1~~	~~Removal of Flyback Control (Indicating Unit CRV-55135)~~	~~Sonar Bulletin Art 26.41~~	~~J. Brown ETM~~	~~4/1/47~~
~~2~~	~~Changes to MTB Switch (Indicating Unit CRV-55133)~~	~~RIB #125~~	~~S. Jones CETM~~	~~2/21/47~~
3	Shield for BDI Scope (Bearing Deviation Indicator CRV-55132)	RIB #125	S. Jones CETM	3/10/46
4	NRL #56 Solution for Projector. (Projector CRV-78211)	NOT APPLICABLE		
5	REPLACEMENT OF FIBRE GEAR ON SWEEP MODULATOR MOTOR. (DRIVER CRV-52329)	NOT APPLICABLE		
6	Addition of Reset for Master Interlock Shorting Switch (Rectifier Power Unit CRV-20254)	RIB #141		

FIGURE 2—*Record of Field Changes.*

When a unit of a major equipment is surveyed or exchanged, it is necessary to correct the field change records to show what equipment actually remains on board. Therefore, the following actions should be taken:

1—A line should be drawn through all field changes that apply only to the unit being surveyed or exchanged. The field change numbers so cancelled should be entered on a supplementary "Record of Field Change" card. See figure 3, Field Changes 1 and 2.

Equipment Model Designation: QGB	Serial Number: 120	Date Installed: 1 February 1945	Supplementary	Card No. 1A
NO.	**TITLE OF FIELD CHANGE**	**AUTHORITY FOR CHANGE**	**CHANGE MADE BY**	**DATE OF CHANGE**
1	Removal of Flyback Control (Indicating Unit CRV-55135)	Sonar Bulletin Art 26.41		
2	Changes to MTB Switch (Indicating Unit CRV-55135)	RIB #125	F. LAPP ETM/1c (Already made when new unit rec'd)	1/5/45
99	Improve performance of Driver and Indicating Unit (Indicating Unit CRV-55135 only)	Sonar Bulletin		
84	Change Wiring Between Indicator and Driver (Indicating Unit CRV-55135 only)	Sonar Bulletin	S. Jones CETM	4/4/46

FIGURE 3—*Record of Field Changes showing supplementary entries.*

NAVSHIPS 538 (7-47) — TUBE PERFORMANCE RECORD

Tube Type: JAN 993999	Serial No.: 12345	Manufacturer: Tube Mfg. Co.				Contract No.: N7sr 99999	Acceptance Date: 2/16/47	Guar. Hours:	Card No. 1
Date	**Equipment Installed In**	**Equip. Serial No.**	**Ckt. Symbol**	**Meter Reading In**	**Meter Reading Out**	**Total Hours**	**Condition, Cause of Failure, Remarks, Etc.**		**Entry By**
3/4/47	TZZ	909	V 101	2794			Initial test O.K. in equipment		
5/5/47	TZZ	909	V101		2895	105	Removed in order to rotate tube stock.		
6/19/47	TZY	84	V 104	987			Replaced in TZY power amplifier stage when tube in TZY failed.		
8/1/47	TZY	84	V 103		1087	100	Tube emission too low to be used in power amplifier stage. Put it in IPA stage. Works ok there.		
9/5/48	TZY	84	V 103		2087	1000	Filament opened. Navships 383 sent to Bureau.		

Use first line for initial test on receipt

FIGURE 4—*Tube Performance Record.*

2—Where field changes apply only partially to the unit being surveyed or exchanged, the field change number and title should be entered on the supplementary card with a parenthetical note that it applied only to the particular unit. See Figure 3, Field Changes 99 and 84.

3—Replacement units received with Electronic Equipment History Cards shall have field change information posted from those cards to the supplementary Record of Field Changes mentioned above. See columns 4 and 5 of Field Change 2 in figure 3. Where no history is available, the unit should be carefully examined and those field changes which have been performed should be noted on the supplementary card.

For reporting field changes in which no kit is supplied or in which no modification card is available, follow this easy and convenient procedure: Fill out the top half of a NavShips (NBS)-383 (Failure Report-Electronic Equipment) card and under "Remarks" note: "Navy Field Change Number _____ made."

If properly filled out, the card should contain the following information:

Equipment model and serial number.

Unit name and serial number.

Navy Field Change Number.

Date Field Change made.

Name and rank, rating, or title of person making the change.

When the card is filled out, enclose it in its self-addressed envelope, seal and mail. If no self-addressed envelope is available, mail the card to the Bureau of Ships, Code 980, Navy Department, Washington 25, D. C.

TUBE PERFORMANCE RECORD

This form, figure 4, is for use with Service Life Guaranteed Tubes, and where tube performance is recorded. The column headings are self-explanatory.

All personnel are enjoined to keep all of these records to the very best of their abilities. Only when properly kept will the records prove their worth, but when kept up-to-date in accordance with instructions they will provide a valuable reference and an aid in maintenance and repair, and at the same time serve to improve the quality and dependability of future electronic equipment.

WARNING PLATES FOR SMALL CRAFT

Decalcomania water transfer plates have been prepared reading "WARNING. DO NOT ENERGIZE ELECTRONIC EQUIPMENT UNTIL VENTILATION BLOWERS HEVE BEEN OPERATING A MINIMUM OF FIVE MINUTES TO EXPEL EXPLOSIVE VAPORS." These warning plates are for use aboard small craft using hi-test fuel for propulsion. A substantial quantity of them is under procurement and will be distributed to the various Electronics Supply Offices. Interested activities should request a sufficient quantity of these decals from the nearest ESO, and transfer them to all electronic starter panels, remote starting units and other power switching devices aboard vessels requiring them.

SHOCKMOUNTS ON CHANNEL SELECTOR UNIT

The Bureau recently received information which may be the key to the cause of failure of some of the Type -23497 Selector Control units: namely, failure of the rectifier and resistors in the selsyn bridge circuit which are mounted on the stepper switch. It was reported that when the housing of the Type -23445 Channel Selector Unit is rotated 270 degrees, so that the terminal tube is on the left side, one of the terminals on the back of the selsyn indicator actually grounds against the boss of the rear terminal tube entrance. This causes a considerable current overload to be applied to the rectifier and resistors mentioned above.

To remedy this very undesirable condition, the Bureau recommends the removal of the shockmounts by means of which the selsyn indicator is mounted. Remouting of the indicator with #6-32 oval-head machine screws is acceptable. Shock tests conducted by Naval Research Laboratory have shown that the shockmounts are unnecessary.

As stated above, this difficulty only occurs when the housing is rotated 270 degrees, with the terminal tube protruding from the left side. Therefore, when the selector unit is installed so that this does not occur, removal of the shockmounts is unnecessary.

MORFLEX COUPLING FAILURES

An increasing number of requests for morflex couplings, item 729 of the model SV radar equipment, are being received by the Electronic Supply Office. This item is supplied through procurement, which means that it is not carried in stock and must be purchased as needed at an exorbitant price. It is suggested, therefore, that an effort be made to repair mechanical damage, either locally or at a shipyard.

When repair is impossible, the part may be requisitioned from Naval Supply Depot, Bayonne, or Ships Supply Branch, Naval Supply Center, Oakland. The requisition should give the E.S.O. stock number, N16-C-36608-2.

Letters describing the nature and causes of breakdowns of this part, whether mechanical or electrical, are solicited by the Electronic Supply Office. Correspondence should be addressed,

Electronic Supply Office
Bldg. 2B, Code 6-2B
Great Lakes, Illinois.

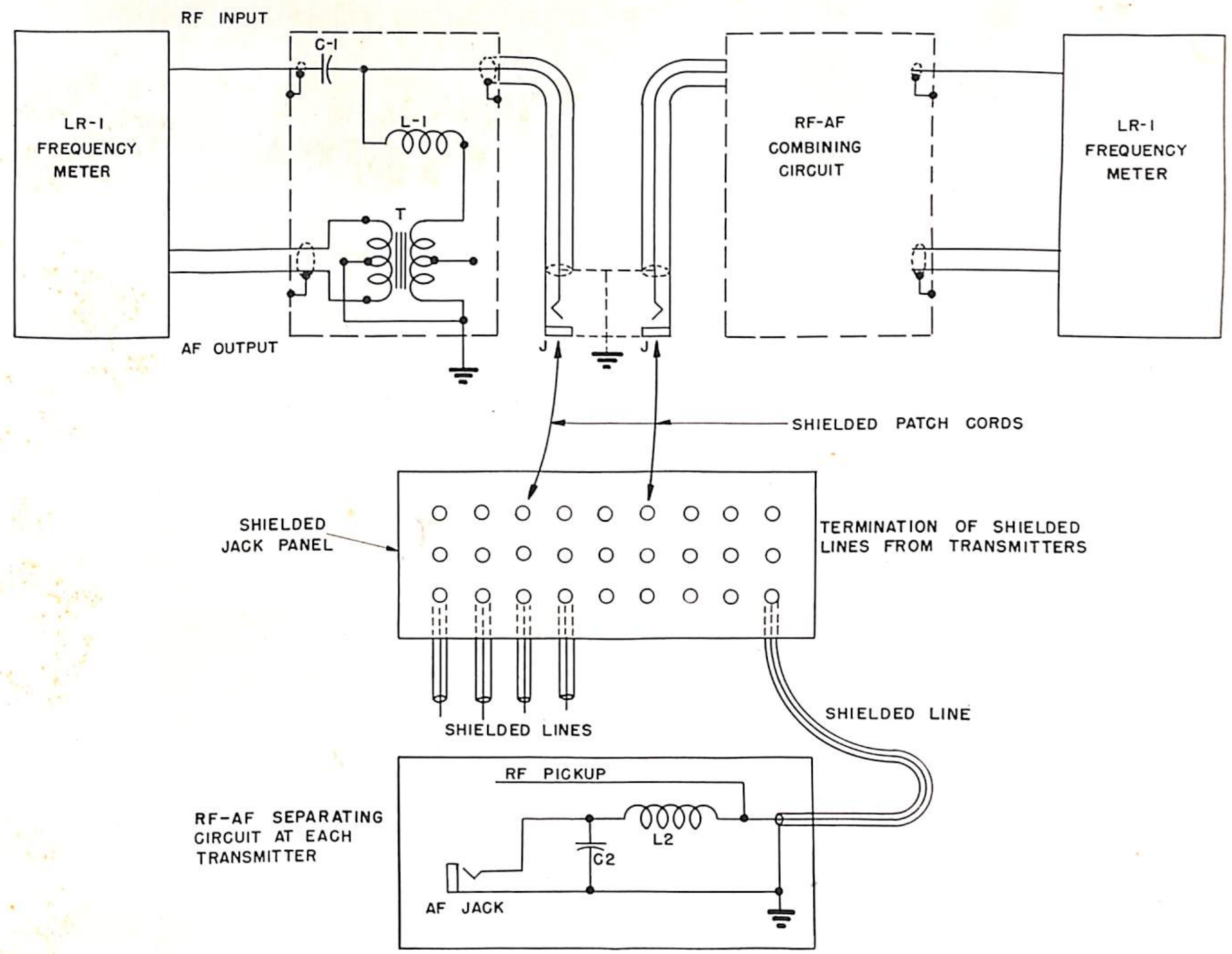
FREQUENCY METER PATCHING AT ANNAPOLIS

■ The burden of radio communication traffic is quite heavy at the Naval Radio Station, Annapolis, Maryland. About forty transmitters are available, of which perhaps twenty may be operating at one time. Moreover, the operating frequency of each transmitter is changed from time to time in accordance with message requirements. Since at the Annapolis station the transmitter frequencies are adjusted to the required narrow tolerances each time by the use of a General Radio Model LR-1 Heterodyne Frequency Meter, the meter is in constant use. There is a tendency for a bottleneck to develop at this operation, for, although two meters are available, only one can be used at a given time with the conventional parallel circuit arrangement.

Realizing the necessity for making more "measuring time" available, the electronics maintenance personnel at Annapolis have developed a circuit and switching arrangement which makes both meters available for measurement at the same time. The new arrangement is simpler and much more convenient, and halves the number of leads required, as well as reduces r-f cross-pickup when simultaneous measurements are in progress.

In the usual arrangement with the LR-1 meter, an r-f sampling line feeds energy to the meter from the transmitter whose frequency is to be measured. A standard signal, generated in the meter, mixes with the unknown signal and the resultant audio signal is carried to all transmitters over paralleled lines. The disadvantages of this system lie in the fact that two separate lines are needed to each transmitter, and only one transmitter may be adjusted to frequency at a time. The audio lines being in parallel, all frequency meter heterodyne signals may be heard at all transmitters simultaneously.

The arrangement developed at Annapolis, shown in figure 1, consists first of a circuit at the LR-1 terminals, which mixes the r-f signal from the transmitter with the audio signal from the meter. By the use of this mixing circuit, only one coaxial cable, carrying both r.f. and a.f., is needed to connect the transmitter with the frequency meter. At the transmitter, a corresponding circuit separates the r.f. from the a.f. The combining and separating circuits are simple and easily-constructed, consisting of 0.001 μf and 50 $\mu\mu$f capacitors, 2.5 mh chokes, and small transformers. The space taken up by them is very little; they may be mounted in two



PARTS:
C 1 - 50 mmf MICA CAPACITOR
C 2 - .001 mf MICA CAPACITOR
L1, L2, - 2.5 mh RF CHOKE
J - SHIELDED JACK
T - 500/500 OHM, CENTER-TAPPED TRANSFORMER (KENYON T-26 OR SIMILAR)

FIGURE 1

small boxes which may be made a permanent part of each cable.

The transformer is employed to convert the balanced a-f line arrangement at the meter audio output terminals to the unbalanced line layout of the connecting coaxial cable, which permits one side to be grounded for shielding purposes. C1 is small and offers a high reactance to the audio signals in the secondary of the transformer. L1 is inserted to pass the audio frequencies from the transformer to the line, but at the same time to offer a high reactance to the r.f. and keep it from being shunted by the transformer. At the transmitter end of the line, the low-pass characteristics of the filter consisting of L2 and C2 prevent r-f currents from flowing through or being shunted by the headphones. Audio signals are present on the r-f pick-up line, but since this line is essentially a probe inserted but not connected to any components in the transmitter oscillator assembly, this fact offers no disadvantage. All connections are made employing navy shielded jacks, shielded wire, and shielded patchcords.

Any number of transmitters may be connected with any number of meters, and interchanges made at will, by means of the shielded jack panel shown in figure 1. This adds much to the convenience of the layout.

The improved arrangement has been in continuous use at Annapolis since 1944, and has proved highly satisfactory. By permitting two meters to be employed simultaneously, it has doubled the number of frequency measurements which can be made. The layout may be applied to any installation employing heterodyne frequency meters.

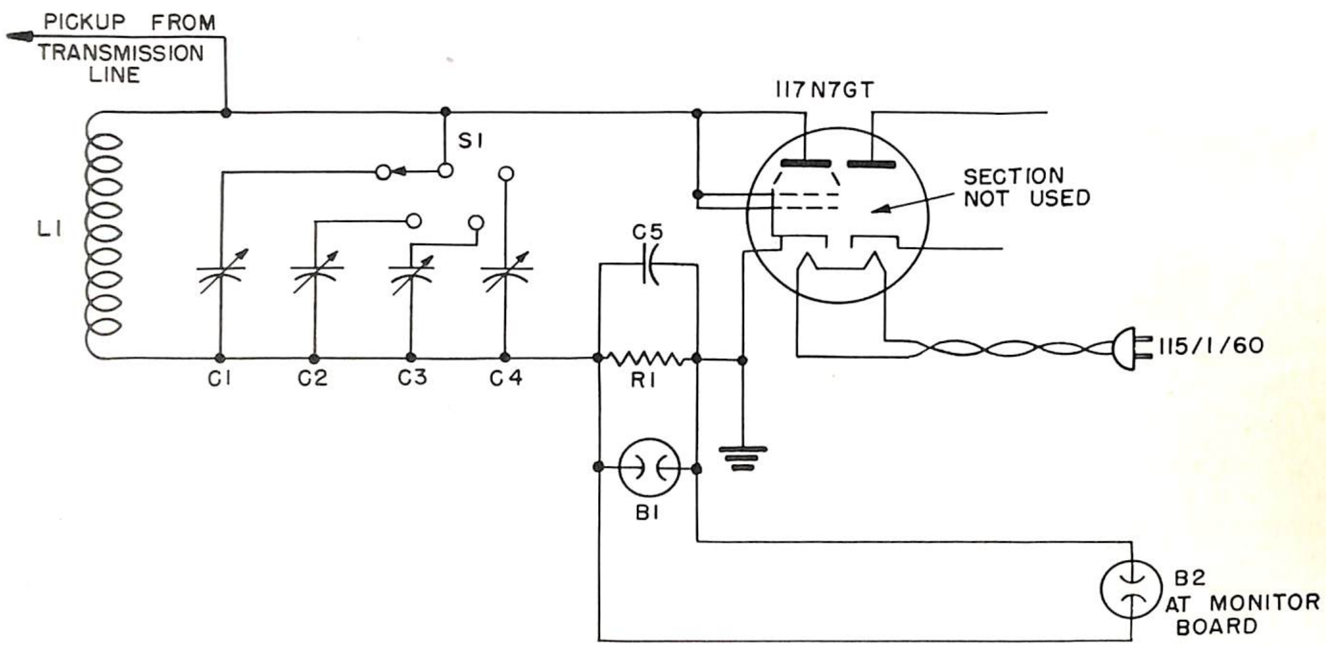
Transmitter Monitor

■ A simple monitoring device has been designed by John Tocarsic, CETM, and adopted by the Naval Radio Station at Annapolis. Designed for continuous use with the Model TEF single side band transmitter, it shows continuously whether the transmitter is on or off the air. Without its use, the operator at the transmitter must depend on notification of loss of output by the operator at the receiving station.

The monitor consists essentially of a tuned circuit loosely coupled to the antenna transmission line, a diode-connected detector, two neon lamps and associated components and wiring. With r-f signals of sufficient amplitude in the tuned circuit, the lamps will glow.

Figure 1 shows the monitor as designed for use with the Model TEF transmitter. The 4-position switch selects the preset trimmer capacitor resonant with L1 to the carrier frequency being used. The rectified output currents through B1 and B2 are sufficient to light the lamps unless the TEF power output is below normal.

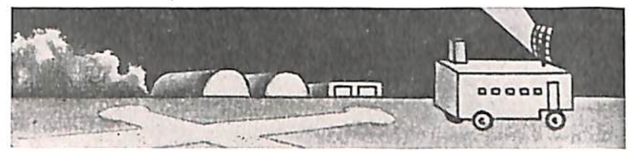
Although this monitor was designed for use with the Model TEF equipment, its use is readily adapted to any radio transmitter. The trimmer capacitors must, of course, be resonant at the transmitter frequencies being used, and the degree of r-f coupling to the monitor, depending on the individual installation and the power output of the transmitter, must be determined by experiment.



L1 . . . . *3½ turns No. 20 enameled wire.*
S1 . . . . *4-position frequency selector switch.*
C1, C2, C3, C4 . . . *0.00014 μf trimmer capacitors.*
C5 . . . . *0.001 μf paper, 600 volts.*
R1 . . . . *1 Meg, 1-watt carbon.*
B1, B2 . . . . . . *115-volt neon lamps.*

FIGURE 1—*Monitor used with Model TEF transmitter at Annapolis.*

Type of Approach	Last Month	To Date
Practice Landings	5,904	77,280
Landing Under Instrument Conditions	254	4,018



ELECTRONIC EQUIPMENT TYPE ALLOWANCE BOOK REVISIONS

Due to the incidental delays and the relatively higher costs encountered when "letterpress" printing methods are employed, it has been decided that future revisions of the Electronic Equipment Type Allowance Book (NavShips 900,115) will be printed by "photo-offset" methods. In order to further simplify processing and distribution problems, each revision, starting with Revision No. 7 will be confined to a single ship type. This will result in a considerable increase in the number of effective revisions, but will assure a more prompt and timely distribution. The proof of this is that Revision No. 7, the first revision printed by photo-offset methods, was actually distributed before Revision No. 6, the last one printed by letterpress methods.

All correspondence concerning the T.A.B. should be addressed to the Chief of the Bureau of Ships, Code 981, Washington 25, D. C. Use of this address will expedite the handling of the correspondence, and save time and effort in the Bureau of Ships.

PAINTING RADAR ANTENNA HOODS

Painting of radar antenna hoods still seems to be the subject of much controversy among navy maintenance activities. A review of Bureau directives should clarify the subject, but as an added measure the following helpful information is submitted.

The antenna hoods for the SF, SU, SO and SL series radars are made of fiberglass and require no paint for preservation. If it is desired to paint these hoods to match the ship's color, however, any nonmetallic paint may be used providing that no more than two thin layers are applied to the surface.

A non-metallic paint is one that has no metallic flakes suspended in the body. Navy haze grey paint (Spec. 52-P-45) falls in this category and is approved for painting navy radar antenna hoods. Metallic paints such as aluminum, gold, and others contain flakes of metal which attenuate electromagnetic energy. These paints should never be used where that is a consideration.

Although the kind of paint used is of primary consideration, the procedure for preparing the surface and applying the paint is also quite important. The first step in the procedure is an inspection of the hood. If more than one coat of paint has been previously applied, the surface should be cleaned either by sandblast or by use of liquid paint remover. Paint is then applied with a spray gun, never with a brush. Just enough paint to color the surface is sprayed on. When the surface has dried, the words *DO NOT PAINT* should be stencilled on two opposite sides, about four inches above the bottom edge of the hood.

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

1 gallon outside white (Navy Spec. 52-P-28), 1¾ pounds yellow ochre in oil (Fed. Spec. No. TT-P-381), 2½ ounces vermillion red in oil (Fed. Spec. No. TT-P-381).

A shop man says that 25% of ship radio trouble can be traced to painted antenna insulators.

PERFORMANCE OF UHF EQUIPMENT

The Commander of a Destroyer Division reported in a recent letter to the Bureau of Ships that the Model TDZ/RDZ u-h-f communications equipment was found to function very satisfactorily when properly tuned. Reception was loud and clear under all conditions, and was much superior to reception with the TBS equipment.

The greatest difficulty experienced with the TDZ/RDZ equipment, the letter reported, could be attributed to the manner in which the equipment was operated. Some tendency was found on the part of personnel to continually tune and retune the equipment if immediate communication was not established. This hampered message transmission until proper tuning was achieved. However, on one occasion during a period of seven days the personnel of one of the destroyers did not touch either the transmitter or the receiver after it had once been set up. At no time during this period did communication difficulties occur with this particular equipment. This experience indicates that the TDZ/RDZ is stable, and will operate quite some time if left alone except for the usual routine tests, which, of course, should always be made.

• • •

Seven out of fourteen radio transmitter failures of one model of equipment were due to failure to replace blower motor brushes. Although motor-generator sets usually are cared for properly, many technicians overlook the brushes in the little, hidden blower motors, which get no attention at all until they fail.

• • •

CRYSTALS FOR U-H-F EMERGENCY FREQUENCY

Crystals for the new u-h-f universal emergency frequency, 243 Mc, are now available for use with the models TDZ and RDZ equipments. This brings the number of crystals comprising a complete set for those equipments to one hundred and one.

Two of the new crystals are allowed for each ship having TDZ and RDZ equipments, regardless of the number of equipments installed. No crystals are being supplied at this time for models MAR and RDR equipments.

All ships having models TDZ and RDZ equipments installed should apply to the nearest Electronics Officer to obtain their allowance of the new crystals.

LOCATION OF REMOTE CONTROL-INDICATOR UNITS

Models TDZ/RDZ or MAR/RDR u-h-f equipments are now being installed in nearly all classes of vessels prior to the shifting of ship-to-ship and other communication channels from the very-high frequencies to the ultra-high frequencies. Installation plans issued by the Bureau of various classes of ships have directed installation of remote channel-selection facilities in the pilot house, chart house, combat information center, and other spaces.

A study of remote channel-selection requirements has recently been completed, however, and it is now possible to state the location and type of control facilities best suited for remote spaces. In order to preserve strict intra-ship frequency-control doctrine, it is considered advisable to limit the number of remote channel selectors to the barest minimum that will provide the necessary operational flexibility.

The maximum numbers and the only authorized locations of remote u-h-f channel-selection devices (Type -23496 Remote Control-Indicator Units or Type -23445 Remote Channel-Selector Units) which will be specified in future electronic equipment type allowances for all ships are given below. One unit includes remote channel-selection of one TDZ and two RDZ's or one MAR and one RDR.

Location	*Number*
Radio Central	1
C. I. C.	2
Auxiliary C. I. C.	1
CO Tactical Radio Center	1
Flag Radio Center	1

When Type -23496 Remote Control-Indicator Units are installed in spaces other than those listed, the channel-selection circuits and cables should be omitted. Type -23500 Radiophone Units, however, will be specified rather than type -23496 units in those spaces where channel-selection remote facilities are not desired. The Bureau of Ships plans to incorporate this change in all present and future installations of models TDZ/RDZ and MAR/RDR equipments. Future revisions of the Electronic Equipment Type Allowance Book will reflect this policy.

OPERATING MERCURY-VAPOR RECTIFIERS

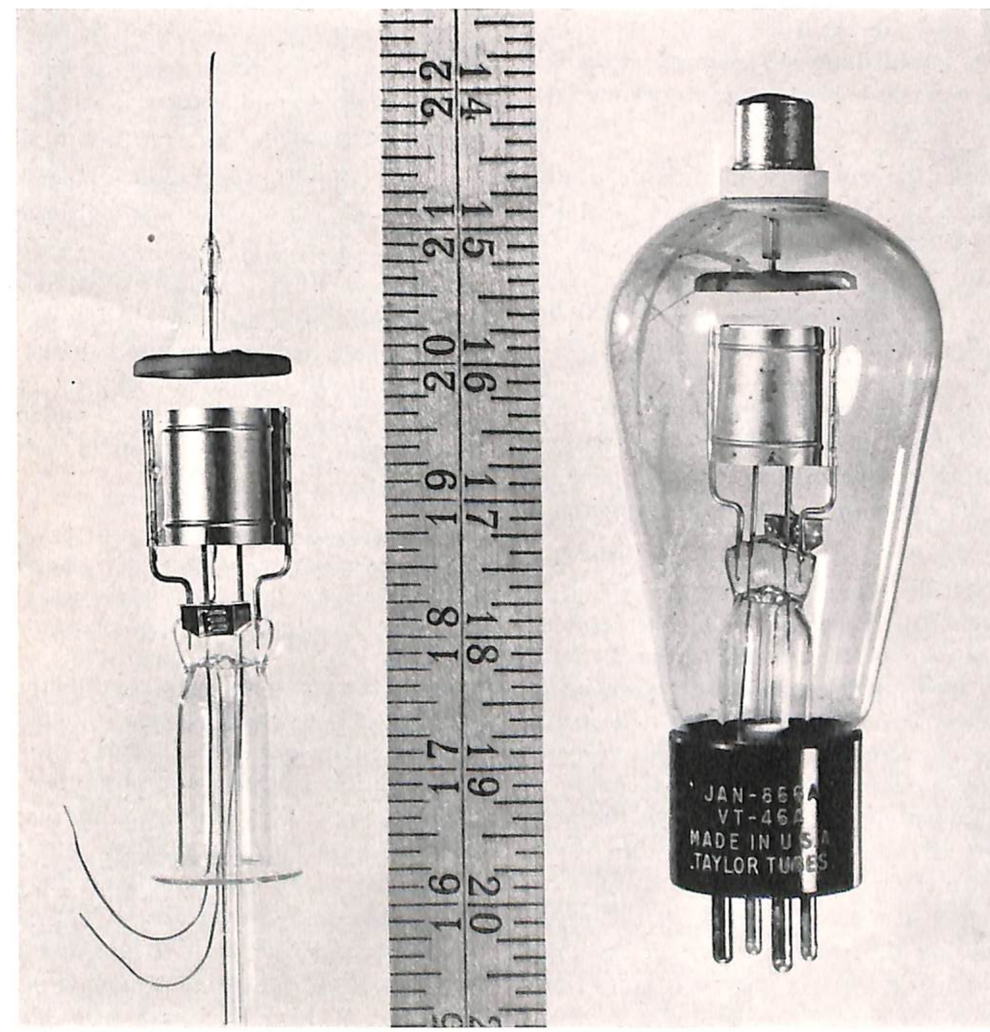
■ When mercury-vapor rectifier tubes such as the 816, 866A, 872A, 8008, and others are operated at conservative ratings and in conjunction with properly-designed smoothing filters, tube life is materially lengthened. There are other specifications, perhaps not so well known as the above, which also have an important bearing on how long a rectifier tube of this type will last. Although these specifications cannot always be met by maintenance personnel, especially in equipment which is not designed to meet them, they are listed below for their interest value, to be complied with whenever practicable.

1—When a mercury-vapor rectifier is being placed in service for the first time, tiny globules of metallic mercury will be found deposited on all elements within the bulb. These deposits must be removed before plate voltage is applied. To remove them, heat the filament with the rated filament current but with the plate voltage disconnected. This may be done by removing the plate cap in some cases; in others it may be necessary to remove a fuse in the high-voltage transformer primary. In some equipments, of course, a time delay is provided which automatically lights filaments a prescribed length of time before plate voltage is applied. This latter safety factor, if provided, must always be kept in perfect operating condition.

2—Before placing a rectifier tube in service, always wipe the bulb clean to avoid external leakage of current and the resultant heating effects.

3—Where forced ventilation is provided, insure that the blower is operating at rated speed and that no obstructions stand in the way of a full intake of air by the blower. Where a blower is provided, failure of the blower in all probability will result in a failure of the components cooled by it.

4—Whenever possible, maintain filament voltage within the specified limits to provide the proper amount of barium at the surface of the cathode.



A typical mercury-vapor rectifier.

Current and Resistance

BASIC PHYSICS PART 8

■ In the previous chapter it was learned: 1—that electrostatics is the study of electrical energy at rest or, in the language of physics, of potential electrical energy; 2—that a stationary or static charge possesses potential energy by virtue of the electric field of force which it sets up; and 3—that a static charge may accomplish work only by forcing another charge to move. At this stage of instruction, keep in mind the fact that electrostatics is important only in establishing the nature of electric energy, of the electric charge, and of the electric field.

Electrodynamics, on the other hand, is the study of charges in motion. A charge in motion possesses kinetic energy. When work is done on a charge by moving it against an electric force, kinetic energy is converted to potential energy. This should be evident from the fact that as a charge is moved against a field, it gains potential. A generator is said to generate a difference of potential across its terminals by moving elementary electric charges from one terminal to the other. Basically, a generator is a device for doing work upon elementary electric charges.

Potential electric energy (represented by a difference of potential) is converted to kinetic electric energy when an electric field is permitted to move a charge from a higher to a lower potential level. When electric energy is in kinetic form, it may readily be converted to other forms. For example, applying a difference of potential across a motor establishes an electric field through the motor. Elementary charges moved through the motor by this field have their kinetic energy converted to mechanical energy—the force exerted by the moving charges causing the rotor member of the motor to rotate. Kinetic electric energy is converted to potential chemical energy in charging a battery. It is converted to light energy in an incandescent lamp; to sound energy in a loudspeaker; to heat energy in an electric heater. Electrodynamics is a subject of much greater significance than electrostatics, and the study of it centers around the action of moving charges.

Electrodynamics may be divided into two parts: 1—the generation, and 2—the utilization of electrical energy. The number of methods by which various forms of energy may be converted to electrical energy are rather limited, but methods of utilizing or converting electrical energy to other forms are extremely varied. This is why utilization has greater significance than generation, although it should be evident that the latter must always precede the former.

In dealing with kinetic electric energy, the most important factor is the *time-rate of flow* of a moving electric charge. *A flow of moving charges constitutes an electric current* and is measured in terms of the time-rate of flow. It cannot be too strongly emphasized that current is a measurement of the quantity flowing in a unit of time, and not simply a measure of the quantity or volume of the charge. There is as much difference between coulombs and coulombs per second as there is between gallons and gallons per second.

Types of Electric Current. Since there are two kinds of charges, positive and negative, and a moving charge constitutes a current, there should be at least two kinds of current. Actually there are three possible types of current, the second of which will be explained last because it is the most important and leads into what follows. There are, 1—moving positive charges, 2—moving negative charges, and 3—a combination of moving positive and negative charges.

A current composed only of moving positive charges is very rare. An alpha particle (He++) emitted from a radioactive substance, for example, constitutes a moving positive charge.

A current composed of a combination of moving positive and negative charges is typical of electric conduction in gases and liquids. In any gas, thermal agitation will always create a few positive and negative ions. If a difference of potential is applied across a gas, the positive ions are attracted toward the negative terminal and the negative ions toward the positive terminal. The resulting current is composed of positive ions moving in one direction and of negative ions moving in the opposite direction. A long free path between atoms in a gas may permit high acceleration of the ions. An ion moving at high velocity may strike a neutral atom with sufficient force to liberate an electron, thereby creating an additional positive ion. If the liberated electron is captured by a neutral atom, an additional negative ion is created. This process is called ionization, and may build up in a gas until a high percentage of the normally neutral gas molecules are converted to ions. Currents in gases are often called ionization currents. Gaseous conduction will be treated in detail in the study of electronic vacuum tubes.

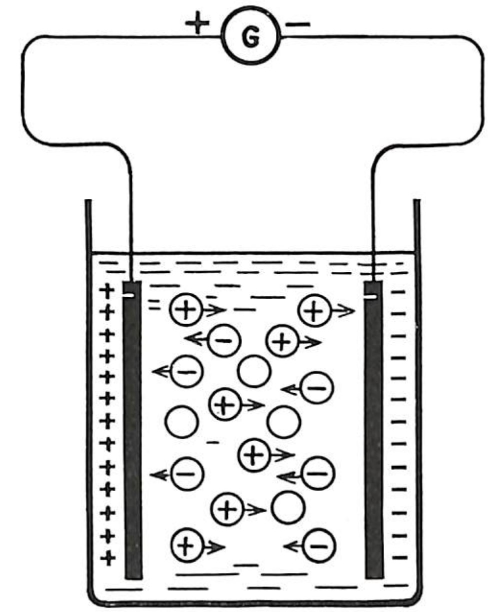


FIGURE 1—*Current composed of positive and negative ions.*

Many liquids, as the result of a chemical reaction, contain an appreciable number of positive and negative ions. For example, pure water contains very few ions and hence is an excellent nonconductor; but add a few grains of salt or a few drops of acid and the resulting chemical reaction creates large numbers of ions. If a difference of potential is applied across such a solution, a current composed of positive ions moving in one direction and negative ions moving in the opposite direction will be established. However, the movement of ions in a liquid is so restricted that production of additional ions by collision, such as occurs in gases, does not take place. When liquids are intentionally used as conductors, they are usually called electrolytes and the currents through them, electrolytic currents. In the study of batteries and dry-cells in a later assignment, a thorough discussion of electrolytic currents will be undertaken.

The type of current constituted by a movement of negative charges alone is of paramount interest in the study of practical electricity. Such a current typifies electrical movement of charges through solids and vacuo. It is called a *conduction* current.

An earlier chapter briefly explained that in any solid there are always some electrons more or less free of nuclear attraction, and hence capable of moving in any direction under the influence of an applied electric force. In a solid, the movement of atoms is so highly restricted that a normal electric force is incapable of moving positive ions; hence, the occurrence of currents in solids must always mean a movement of electrons. Throughout this and subsequent chapters it will be understood, unless otherwise stated, that the word "current" refers to a movement of electrons.

Concepts of Free Electrons. A mobile or free electron may be defined as one that moves readily when subjected to an external electric force. There are several explanations for the existence of mobile or free electrons in a substance. A few of these will be discussed briefly.

In the atomic structure, the diameter of the L-shell is about four times greater than that of the K-shell. The M-shell has a diameter approximately 9 times that of the K-shell. The force of nuclear attraction varies inversely as the square of the distance from the nucleus. In lithium, for example, the single electron in the L-shell is subject to a force of nuclear attraction only about one-sixteenth that exerted in the K-shell. It is conceivable that an electric force of reasonable magnitude may be capable of overcoming nuclear attraction and removing an outer planetary electron. It is, however, extremely difficult to remove more than one electron from any atom, for the instant one electron is removed, the nuclear attraction for the remaining electrons becomes so great that a very strong force is necessary to remove a second electron. Machines have been designed to strip planetary electrons from atoms, but such devices do so only by developing potentials of the order of millions of volts.

A second explanation for the existence of mobile electrons is based upon the crystalline arrangement of atoms in many solids. It is believed that, within an orderly arrangement of atoms, some electrons may be moving in delicately balanced orbits determined by the combined forces exerted by several nuclei. It is known that two or more atoms may share planetary electrons. It is conceivable that such shared electrons might be moved by an external electric force without much difficulty.

Thermal agitation also produces mobile electrons. Many non-conducting substances become conductors when their temperature is increased. Glass is a good insulator at normal temperatures, yet is a fairly good conductor in the molten state. This indicates that thermal agitation of molecules and atoms may liberate outer planetary electrons by molecular and atomic collision. Since thermal agitation increases as the temperature is increased, it would be expected that the number of free electrons increases with the rise in temperature. This is true only under certain conditions. In a non-conductor, the number of mobile electrons per unit volume is very small. As the temperature of a non-conductor increases, thermal collision liberates more electrons, and conduction increases. However, in substances in which the number of free electrons at normal temperatures approaches one per atom, an increase in temperature will not create an appreciable increase in the number of mobile electrons because removing more than one electron from an atom is extremely difficult. In conductors it will be found that increased temperature does not produce sufficient additional mobile electrons to offset the increased difficulty of electron movement through the highly agitated molecules.

Another factor tending to result in mobile electrons is based upon the complex nature of electron orbits. In elements of medium and high atomic number, the total number of protons and electrons in a normal atom is quite large. The reaction between the positive and negative fields of the particles produces some electron orbits having a high degree of eccentricity. By referring to Part 6, figure 7, in the December issue of ELECTRON it will be seen that the copper atom has one electron orbit which carries the electron to a comparatively great distance from the nucleus. The electron in this orbit is easily removed from the atom by an external force. Indeed, there is only one element that is better than copper as a conductor of electricity: silver. From an economic viewpoint, however, copper is the best conductor, and enormous quantities of this element are used in the manufacture of electric conductors and equipment.

Conductors and Non-Conductors. Regardless of the actual mechanism by which free electrons are operated in a substance, it may be said that all substances will conduct electricity to some degree. The difference between conductors and non-conductors is a relative one. A conductor has a relatively large number of mobile electrons per unit volume; a non-conductor, a relatively small number. The only perfect non-conductor is space devoid of all matter. Since the best man-made vacuum still contains millions of atoms per cubic centimeter of space, the perfect non-conductor does not exist. Similar reasoning indicates a perfect conductor cannot exist. A perfect conductor would be one in which an electric current would generate no heat.

In the maintenance of electrical equipment, retention of the conducting and non-conducting properties of materials is a major problem. Smoke deposits, dust, moisture, and chemcial reactions may destroy or seriously affect the insulating properties of a non-conductor. Similarly, poor contact, moisture, chemical reaction, etc., may decrease the conducting properties of a conductor.

Mechanism of Electron Movement in Conductors. By virtue of the exceedingly small volume of space occupied by an electron and the fact that an atom is mostly empty space, it might seem that free electrons move through conductors as smoothly as water flowing through a pipe. This is definitely not the case. Although an atom is mostly empty space, that space is occupied by comparatively strong electric fields. The electron, itself a minute negative particle of electricity, is thus acted upon by the forces of the atomic electric fields so that its motion is impeded. On this basis an electron cannot readily pass directly through an atom.

Another important fact is that while an electron may be liberated from an atom, it remains free for a very small instant only before falling into an outer orbit of an adjacent atom. Free electrons are nothing more than electrons in transit from one atom to another. In a neutral substance free electrons are jumping in all directions so the average motion in any one direction is zero. However, at some particular instant, it may be possible for more electrons to be jumping in one direction than in another, hence a minute current might flow for an instant in a small portion of the substance. Such currents are called *thermal-* or *noise-currents* and are similar to the eddies, whirlpools and back currents to be encountered in any flowing stream. It will be found that thermal currents place a limit upon electronic amplification because of the noise or electrical disturbance they create.

When a difference of potential is applied across a substance, the free electrons are all constrained to move in the same direction. A free electron moves only a minute distance before it is captured by an atom only to be instantly replaced by another electron liberated at a nearby point. The electric current may produce effects equivalent to those of a smooth stream of electrons, but the electron flow is actually a "hop, skip, and jump" affair made up of the erratic movements of innumerable electrons. In any conductor the average velocity of forward motion of free electrons is extremely small, at best only a small fraction of a centimeter per second. The speed of electricity is not the speed of the electron flow, however, but rather is the velocity at which an electric force is transmitted through a conductor. In figure 2 a number of billiard balls are lined up so adjacent balls are just touching one another. If ball A is given an impulse in the direction of F, ball B seems to move the instant the force is applied to A. Furthermore, the force is transmitted almost in full magnitude through the intervening balls without causing them to move more than a minute distance. In any circuit of reasonable length, an electric force may be assumed to be transmitted around the circuit instantaneously. Later, in the study of certain types of electronic circuits, it will be found that the transmission of the force is delayed, such delay being an important item in determining the action of certain circuits. In the early study of electrical principles, however, it may be assumed that an electric force is transmitted through a closed circuit at infinite velocity—at the instant the force is applied at point A it appears at some remote point B.

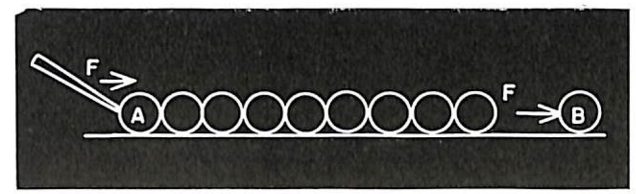


FIGURE 2.

Units of Electric Current. Current is a measure of the quantity of charge that is passing through a point in a given time. Hence a unit of current represents a unit quantity of charge passing through a point in a unit of time. When one statcoulomb of electric charge moves through a point in each second of time the current through that point is one statampere. The M. K. S. unit is the ampere, equivalent to a rate of flow of one coulomb per second. It has been explained that one coulomb is equivalent to an excess or deficiency of 10^{19} electrons. If 10^{19} electrons move through a point in one second one ampere flows through the point. However, if one electron moves through a point in $\frac{1}{10^{19}}$ second the current is also one ampere because, in both cases, the *RATE* of flow is 10^{19} electrons per second. In other words, a given current may be produced by either a large number of electrons moving slowly or by a smaller number moving more rapidly.

Mathematically:

$$\text{Current} = \frac{\text{Quantity of charge moved through point}}{\text{Time required to move through point}}$$

$$I = \frac{Q}{t},$$

where I is the current in amperes and Q, the charge in coulombs moved through a given point in t seconds. If ten coulombs move through a point in 2 seconds, the average current is 10/2 or 5 amperes.

A meter which measures the average rate of flow of charge is called an *ammeter* if it is calibrated in amperes, a *milliammeter* if it is calibrated in thousandths of an ampere, and a *microammeter* if it is calibrated in millionths of an ampere.

$$1 \text{ a} = 1000 \text{ ma} = 1{,}000{,}000 \mu\text{a}$$

The Greek letter μ, pronounced "Mu," is the standard symbol for the prefix "micro."

Direction of Current. In Faraday's time little was known about the nature of an electric current. It was assumed that electricity was a mysterious fluid capable of flowing through some substances and incapable of flowing through others. Since a liquid tends to flow from a higher to a lower level, it was only natural to make the assumption that the mysterious electrical liquid must flow from *positive to negative*. Several important electrical laws are based upon this assumption; in fact, the idea has become so firmly entrenched that today the positive-to-negative direction is known as the *conventional direction of an electric current*. In everyday electrical work, the conventional direction may be utilized at all times without experiencing undue difficulty. However, considerable difficulty arises when the conventional direction is used to explain electronic phenomena, particularly the theory of conduction in electronic tubes.

Since a movement of electrons constitutes a current, it is logical to assume that the direction in which the electrons move is the direction of current. But consider this: electrons may move with or be moved against an electric field. If the electrons move under the impetus of an electric field they accomplish work; in this case, electrons always move from *negative* to *positive*. However, before electrons may accomplish electrical work they must be given potential energy by being forced to move against an electric field: in this case, where work is done upon electrons, they are moved from *positive* to *negative*. Sooner or later the student will encounter the statement "electrons always flow from negative to positive." The experienced engineer accepts it because he is familiar with the implications. As mentioned previously, utilization has wider application than generation. When electrons flow from negative to positive, electrical energy is being utilized, not generated.

The Electric Circuit. In figure 3, G indicates an electric generator, a machine that functions as an electron pump which, by means of the electric force which it generates, forces electrons to move from one terminal to another. Let the direction of this generated electric force be such that electrons are removed from terminal A and deposited at terminal B. The instant one electron leaves terminal A, the terminal ceases to be neutral and becomes plus or positively charged; at the same time, terminal B becomes negatively charged the instant an electron is added to it. Each electron removed from A is compensated for by an excess electron appearing at B, so that the positive charge developing at A is at every instant equal in magnitude to the negative charge developing at B.

Mechanical energy supplied to the generator is utilized in moving electrons from A to B. Every electron removed from A and deposited at B will tend to generate counterforces at both A and B that oppose the movement of additional electrons. As the magnitude of the charges at A and B increases, the counterforce—resulting from the attractive force exerted by the charge at A and the force of repulsion exerted by the charge at B—eventually becomes so great that the mechanical force supplied to the generator is incapable of moving any more electrons. When this condition is attained, the generator ceases to accomplish any further work in moving electrons, and a constant difference of potential will then exist across terminals A and B. *Potential energy has been stored in the two terminal charges in equal amounts but of opposite polarity.*

Now let a conductor be connected across terminals A and B as shown in figure 4. The negative charge at B will exert a force of repulsion while the positive charge at A exerts a force of attraction on all the free electrons in the conductor. In effect

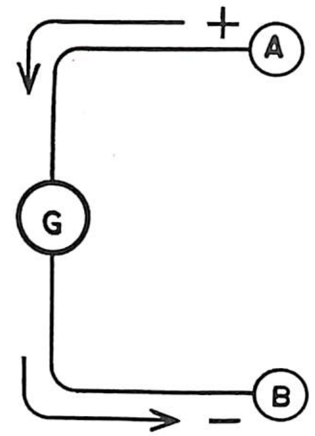


FIGURE 3.

electrons will enter the conductor at B and move toward A in an attempt to neutralize the two charges. If the generator continues to pump electrons from A to B, the electrons will continue to flow from B to A through the external conducting path. A continuous current or drift of electrons will be established throughout the entire length of the closed circuit or conducting path, with electrons flowing from positive to negative on the generator side and from negative to positive in the external conductor side. Work is done on the electrons as they move through the generator, and in turn the electrons moving through the external conductor accomplish work. An electric field exists in the circuit. The direction of the field is from A to B through both the load and generator. Electrons move under the impetus of this field through the load but the generator must force them to move against the field in moving them from A to B.

Electrons moving through the circuit increase the temperature of the conductor which indicates that electric energy is being converted to heat energy. Any conductor carrying an electric current will be

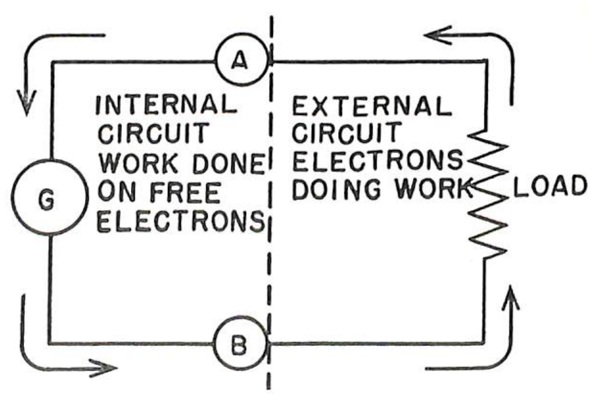


FIGURE 4.

heated. The theory of this conversion will be discussed later.

On the basis of this introduction to a simple electric circuit, several important ideas may be formulated.

The first is that on the basis of direction of electron movement, the circuit may be divided into two parts. On the left side of the vertical dashed line in figure 4 work is done on the electrons and they move from positive to negative. This section is called the internal circuit of the generator or, more simply, the source. To the right of the dotted line is the external or load circuit. In the study of electrical principles, maximum interest will center in load circuits. Remember that the statement "electrons always flow from negative to positive" refers to the direction of the current *in the load*.

The second idea is that when electrons move always in the same direction around a closed path, the current is called a *direct current*. Note that electrons passing from A to B or vice versa move in opposite directions in the load and source; but when the internal and external circuits are connected to form a closed conducting path the electrons move around the loop only *in one direction*. If the closed loop is opened at some point, the flow of electrons will be interrupted. The conducting path is then said to be *open-circuited*. The potential difference across A and B will be transferred to the points where the circuit is opened.

The third idea is that the closed conducting path in figure 4 is called a series circuit because there is only one path around which the electrons may move. An ammeter connected at any point in a series circuit will indicate the same average time rate of electron flow. The concept, *the current is the same in all parts of a series circuit*, is very useful.

Electromotive Force. The term "electromotive force" means the force sustained by the source when the source is supplying a certain quantity of electrical energy per unit time.

Since the "difference in potential" between any two points in a circuit is used to measure electromotive force, the two terms are used interchangeably in electrical work. In electronics, however, it is important to distinguish one term from the other, and to understand what each term implies.

First, consider a simple case illustrating difference of potential. If two bodies having charges of equal magnitude but opposite polarity are connected by a conductor, a current will flow from negative to positive *until the charges are equalized*. The magnitude of the current will be maximum at the instant the electrons begin to flow and will gradually fall off to zero at the instant the two charges are equalized. The decay of current with time is shown in figure 5. Note that the use of the term "difference in potential" between two bodies carries no implication that a continuous current will flow if these points are electrically connected.

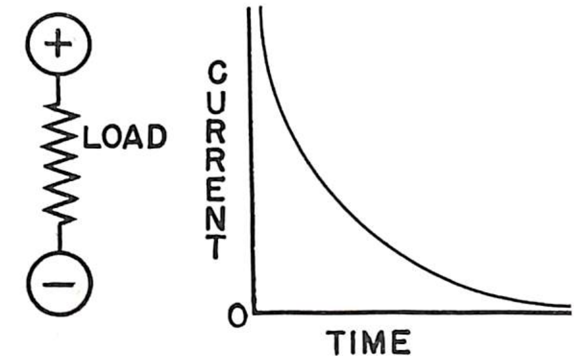


FIGURE 5—*Decrease of current with time as two unlike charges are permitted to neutralize.*

Now consider a case illustrating electromotive force. Starting again with two charged bodies, this time let them be connected to opposite terminals of a generator. Under these conditions if a conductor is now placed between the two bodies, a current will flow from negative to positive as before, but this time instead of the charges equalizing and the current decaying to zero, the source or generator acts to sustain the charge or difference in potential. It does this by continuously moving electrons from positive to negative in the source while electrons are moving from negative to positive in the load. In other words, the source exerts an electromotive force that acts to sustain the difference in potential. "Electromotive force" is measured simply by measuring the difference in potential, but use of the term implies that the difference of potential will be sustained if the two charged bodies or points are electrically connected.

Generators are rated according to their power output. For example, a rating of 5 amperes, 220 volts, means that the generator is capable of generating and sustaining a difference of potential of 220 volts as long as the current passing through the load does not exceed 5 amperes. If the current passing through the load slightly exceeds 5 amperes, the generator may be incapable of doing work rapidly enough to sustain the 220 volt difference of potential in which case the voltage will drop. This will be indicated by a decrease in the electromotive force across the output terminals of the generator. If the current in the load becomes far greater than 5 amperes, the difference of potential across the output terminals may fall to a very low level. A very heavy current overload is customarily referred to as a *short-circuit.*

RESISTANCE

The concepts of electromotive force and difference of potential lead to an understanding of potential electrical energy. The concept of electric current explains how potential electric energy becomes kinetic electric energy. The picture of electrical energy will be complete when it is understood how the kinetic energy is transformed to other forms of energy, or, in other words, how moving charges accomplish electrical work. This concept begins with the study of electrical resistance.

In elementary studies of electrical principles it is customary to consider resistance as a property of matter. Later, in the study of electrical work and power, resistance is redefined as a concept rather than an actual property. In this text, the word "resistance" will be used to mean a property of matter, and the expression "equivalent resistance," to mean the abstract concept of resistance. In time the student will learn to select the proper meaning by the way in which the word "resistance" is used.

According to Newton's law of action and reaction, a force cannot be exerted against a body unless that body exerts a force in opposition. In electricity, consider resistance as that physical property of matter which, working in conjunction with a current, produces the counter-electric force against which the applied electric force is exerted.

One definition of resistance is "that property of matter by virtue of which matter opposes the movement of free electrons." Since the movement of electrons through a substance always generates heat, another definition of resistance is "that property of matter by virtue of which kinetic electrical energy is converted to heat energy." The second definition is preferred because there are other forms of electrical counter-forces in addition to resistance.

Nature of Resistance. It is customary to explain resistance as the opposition offered by atoms and molecules in a substance to the movement of free electrons. The heat generated by an electric current is assumed to result from the electrons colliding with atoms and molecules. It is rather difficult to visualize how an electron can mechanically collide with an atom. Two electrons cannot collide because at the instant of the impact the force of repulsion between like charges approaches infinite magnitude. In a normal atom the planetary electrons rotate about the nucleus at such enormous velocities that the nucleus is practically enclosed in an impregnable negative field of force. To penetrate such a field and reach the positive nucleus the free electron must attain an extremely high velocity. An explanation of resistance on the basis of mechanical collision between electrons and atoms is, of course, not very logical.

It has been explained that in a normal atom electrons rotate about the nucleus in stable orbits. If an electron is accelerated it absorbs energy by jumping to an outer orbit. An outer orbit electron must, therefore, be given energy in order to remove it from the atom; hence, a free electron must have an energy content greater than one occupying a stable orbit. When the free electron is captured by an adjacent atom, this excess energy causes the electron to fall into an unstable orbit. In time it will jump to a stable orbit by radiating a little packet of high frequency energy in the form of an electromagnetic wave. The frequency of this wave may be such as to place it in the spectrum of radiant heat. If an adjacent atom receives this form of energy it may become excited and if it is sufficiently excited, an outer electron may escape from the atom. However, it is possible that the atom might absorb the energy by virtue of an increase in the motion of the entire atom. An increase in atomic (or molecular) agitation is perceived by our senses as an increase in temperature. *When the energy of the free electron is utilized to increase the agitation of an atom or molecule, electrical energy is converted to heat energy.*

Another way of explaining resistance is to consider it as a measure of work that free electrons must do as they move against the negative fields surrounding atomic nuclei. The applied force compels the free electrons to move against the repulsion of these planetary electron fields, and work must be done to overcome the forces of repulsion. Resistance, then, is a form of electrical friction between electric fields of electrons, rather than the result of mechanical collision of electrons with atoms and molecules.

The resistance offered by matter to the movement of electrons depends upon the nature of the matter. It is customary to explain this on the basis of the number of free electrons per unit volume. A good conductor has a large number of free electrons per unit volume—hence, a relatively low resistance.

The radiant energy theory, however, also offers an excellent explanation quite different from that based on the number of free electrons. The energy emitted by an excited atom when an outer electron jumps to an inner, more stable orbit varies directly as the frequency of the radiated electromagnetic wave. In some substances the radiated frequency is higher than others, depending, of course, upon the exact nature of the inward jump made by the electron. In substances in which an excited atom radiates a comparatively large packet of energy in returning from an excited to a normal state more heat per unit current is generated than in a substance in which a smaller packet per atom is radiated. The greater the quantity of heat produced by an individual excited atom, the greater will be the resistance of that substance.

Regardless of these theories of resistance, there is irrefutable experimental evidence that a movement of electrons through any substance will generate heat, the quantity of heat generated by unit current in unit time being a function of the nature of the material. The definition that resistance is that property by virtue of which kinetic electrical energy is converted to heat energy may be substantiated in so many ways that it must be accepted. In the so-called purely-resistive circuit, all the electrical energy is converted to heat. Later it will become evident that *any* electrical circuit has an equivalent purely-resistive counterpart, insofar as generation of heat is concerned. This is an important concept because electrical devices such as motors, incandescent lamps, etc., can be analyzed mathematically as resistances.

Unit of Resistance. The practical unit of resistance is the *ohm.* It may be defined in a variety of ways, because it is intimately related to such concepts as charge, potential, current, electrical work and power. At this point particular interest lies in finding its relation to potential and current. The following definition points the way to that relationship: Unit resistance is that resistance in which unit difference of potential will establish unit current. In the M. K. S. system *one ohm is that resistance in which a difference of potential (or electromotive force) of one volt will establish an average current of one ampere.*

An ohm is a unit of intermediate magnitude. The student will encounter in everyday electrical work electrical resistances ranging from several million ohms to a few millionths of an ohm. A good insulator or non-conductor may have a resistance of many millions of ohms. A good conductor may have a resistance much less than one ohm. Therefore, the expressions "high resistance" and "low resistance" are relative. In general, a high-resistive circuit is one in which the applied potential establishes a current considerably less than one ampere. A low-resistive circuit is one in which a comparatively small difference of potential may establish a current of several amperes.

Ohm's Law. George Simon Ohm, celebrated German physicist of the eighteenth century, first formulated the basic relation between potential, current and resistance. Ohm's law is the fundamental law of all electric circuits.

Electrical potential may be thought of as the capacity of electric charges for doing work. A potential although measured in terms of work and energy is, in effect, a force or pressure that acts to move electrons. It is through the medium of the electric current that potential accomplishes electrical work. Potential establishes the current, the current does electrical work in overcoming the opposition or counterforce of resistance. If one volt establishes a current of one ampere in a resistance of one ohm, then two volts, which represent a force or pressure twice as great, should establish a current of two amperes in the same resistance. When the resistance is constant, the current established in that resistance will vary directly as the applied electromotive force; conversely, if the potential applied across a resistance is constant, then increasing the resistance means greater opposition to electron movement, resulting in a reduction in current amplitude. Two ohms will offer twice as much opposition as one ohm so that if the potential is constant the amplitude of the current in a resistance of two ohms will be only one-half that established in a resistance of one ohm. These conditions are summarized in *Ohm's Law* which states *the current in any resistive circuit varies directly as the applied electromotive force and inversely as the circuit resistance.*

$$\text{Current} = \frac{\text{Electromotive force}}{\text{Resistance}}$$

$$I = \frac{E}{R}.$$

When E is in volts and R in ohms, I will be in amperes.

By rearrangement of Ohm's law it is found that

$$R = \frac{E}{I},$$

which indicates a circuit has a resistance of 1 ohm when one volt establishes a current of 1 ampere in the circuit. It should be noted that one ohm is equivalent to *one volt per ampere.*

Another form of Ohm's law is

$$E = IR.$$

This indicates the product IR is in the nature of an electromotive force. The product IR is called a resistive voltage drop (the so-called "IR-drop"), and constitutes the opposing force against which the applied electric force operates. It will be remembered that one of Newton's laws of motion specified that a force accomplishes work by operating against an equal but oppositely directed force. The voltage drop IR is often called a counter-electromotive force. This counter force is generated by the current as it flows through the resistance. *The electric current in any resistance will always adjust itself instantly to such a value that the product of the current and resistance is always exactly equal to the electromotive force applied across the resistance.*

Ohm's law describes the state of electrical equilibrium in a circuit. It will be remembered that when forces are in equilibrium the "effective" force is zero. If

$$E = IR$$

then

$$E - IR = 0$$

The applied force E is just balanced by the counter force IR, resulting in zero effective force.

Conductance. Experience indicates the average student will grasp the concept of resistance much more readily than the concept of conductance. Resistance is a measure of the *difficulty* in establishing a given current in a circuit. Conductance is a measure of the *ease* with which a given current may be established in a circuit.

A series electrical circuit is one in which the current must follow a single conducting path. A parallel circuit is one in which two or more paths exist for the current to follow. The concept of conductance is particularly useful in analyzing multiple-path circuits. Resistance is the more useful concept in dealing with series circuits.

The resistance of a circuit expressed in ohms describes the electromotive force in volts that must be applied to establish a standard current of one ampere. For example, if there are 10 ohms of resistance in the circuit, 10 volts must be applied across the circuit in order to establish a current of one ampere; if 20 ohms, then 20 volts are required, etc. In other words *resistance is measured in terms of the potential required to establish unit current.* (1 ohm = 1 volt per ampere.)

In analyzing conductance this idea is reversed. Conductance of a circuit describes the current in amperes that will result from the application of an electromotive force of one volt. One volt is taken as the standard potential; the current established by this standard represents the circuit *conductance.* In other words *conductance is measured in terms of the current established by unit potential.* (Unit conductance = 1 ampere per volt.)

The ohm is equivalent to one volt per ampere whereas the unit of conductance corresponds to one ampere per volt. It should be evident that conductance is the reciprocal of resistance. By Ohm's law

$$R = \frac{E}{I} = \frac{\text{volts}}{\text{amperes}}$$

$$\frac{1}{R} = \frac{I}{E} = \frac{\text{amperes}}{\text{volts}} = G$$

where G represents the conductance of resistance R.

Since the number of units of conductance equals the number of units of current established in a circuit by an applied e.m.f. of one volt, the current established by any other potential is readily calculated, since the current in any circuit varies directly as the applied potential. For example, if one volt establishes a current of 3 amperes in a given circuit, then ten volts must establish a current ten times greater, or 30 amperes. Therefore, if the conductance of a circuit is known, the current established by any potential may be determined without the necessity of calculating the circuit resistance.

$$I = EG$$

The unit of conductance is called the "mho," obtained by reversed spelling of "ohm." The logic whereby

$$\frac{1}{\text{ohm}} = \text{mho}$$

surpasses all understanding. It is often a source of confusion when, without adequate explanation, conductance is defined as the reciprocal of resistance. The student should thoroughly memorize the following: *WHEN A CIRCUIT HAS A CONDUCTANCE OF X MHOS AN ELECTROMOTIVE FORCE OF 1 VOLT WILL ESTABLISH A CURRENT OF X AMPERES IN THE CIRCUIT.*

ELECTRICAL WORK AND POWER

Strictly speaking, work is done upon an electric charge when energy in some form other than electrical is converted to electrical energy. For example, the generator converts mechanical energy to electrical energy by moving electrons from positive to negative. Mechanical work is done in the generator and appears as electrical energy. Also, for example, in a storage battery, chemical energy is converted to potential electrical energy by the movement of electrons from the positive to the negative terminal of the battery. Chemical work is done in the battery. Electrical work is done when electrical energy is converted to some other form of energy. Electrical work is done when a current generates heat in a resistance. Electrical work is done when a current forces a motor to rotate. Electrical work is done when a battery discharges.

Since energy is measured in terms of the work it may accomplish, a unit of work is also a unit of energy. A volt represents one unit of work done upon one unit of charge, hence the volt is a unit of potential electric energy. Work is done by a force acting through a distance, hence potential energy provides the force by which work is done. For that reason, the volt is a unit of electromotive force as well as a unit of potential energy.

The unit of work in the M. K. S. system is the *joule.* A mechanical joule is the work done by a force of one newton acting through a distance of one meter. It can be shown that the work done on a charge of one coulomb when its potential energy level is raised one volt is equivalent to one joule. Since energy can be neither created nor destroyed, it follows that one coulomb moving through a difference of potential of one volt must accomplish one joule of electrical work. Therefore, when a charge of Q coulombs moves through a voltage drop of E volts a total of QE joules of work is done.

$$w \text{ in joules} = (Q \text{ in coulombs}) \times (E \text{ in volts})$$

$$w = QE.$$

Table I lists the common units of energy and work and their values with respect to each other. Resistance is that property of matter by virtue of which the conversion of electrical energy to heat energy is carried out. When one coulomb of charge is moved through a resistance of 1 ohm, one joule of heat energy appears. This heat energy would increase the temperature of one cubic centimeter (one gram) of water 0.2389° C. One joule of electrical work, if completely utilized, will do 0.7376 ft-lb of mechanical work.

TABLE I

	joules	*ft-lb*	*gm-calories*	*B. t. u.*
joules	1	0.7376	0.2389	9.482×10^{-4}
ft-lb	1.356	1	0.3240	1.286×10^{-3}
gm-calories	4.185	3.087	1	3.968×10^{-3}
B. t. u.	1055	777.9	252	1

Power. In general, machinery is rated in terms of how rapidly it can accomplish work rather than by how much work it can accomplish. The more powerful the machine, the more work it can accomplish during any given period of time. *Power is the time-rate of doing work* or

$$\text{Power in watts} = \frac{\text{work in joules}}{\text{time in seconds}}$$

$$P = \frac{w}{t}$$

The work in joules done in a period of t seconds is equal to w/t joules per second. The joule per second is called the *watt.*

Since $w = QE$, then $P = w/t = QE/t$.

However, Q/t is the time rate of flow of electrical charge, which has been defined as the electric current; hence,

$$P = \frac{QE}{t} = IE.$$

The product of the electromotive force (in volts) applied across a circuit, and the current (in amperes) established by that force, represents the rate in watts at which electrical work is being done in the circuit. The total work done in any circuit in any time t is given by

$$w = EIt$$

where w is in joules; E, in volts; I, in amperes; and t, in seconds.

The practical units of electrical work are the *watt-hour* and the *kilowatt-hour.* The work done in one hour at any average rate of 1000 joules per second is equivalent to 1 *kilowatt-hour.* The horsepower-hour is equivalent to 746 watt-hours or 0.746 kw-hr.

By the use of Ohm's law, the equation for electrical power may be defined in terms of I and R, or E and R.

Since $P = EI$ and $E = IR$, then $P = (IR)\,I = I^2R$. This particular form of the power equation is very useful in electronics work, much more so than the EI form. A current of 4 amperes in a resistance of 2 ohms will convert electrical energy to heat energy at the rate of $4^2 \times 2$ or 32 watts.

Since $I = \frac{E}{R}$, another form of the power law is

$$P = EI = E\frac{(E)}{(R)} = \frac{E^2}{R}.$$

An electromotive force of 8 volts applied across 2 ohms of resistance will convert electrical energy to heat energy at the rate of $\frac{8^2}{2}$ or 32 watts.

The next two chapters will be concerned with how the various electrical formulas developed in this chapter are used in solving simple electrical circuits. In order to provide a ready point of reference the important formulas are here summarized:

$I = \frac{Q}{t}$ (I in amperes, Q in coulombs, t in seconds.)

$E = IR$

$I = \frac{E}{R}$ (I in amperes, E in volts, R in ohms.)

$R = \frac{E}{I}$

$I = EG$ (I in amperes, E in volts, G in mhos.)

$P = EI = I^2R = \frac{E^2}{R}$ (P in watts, I in amperes, E in volts, R in ohms.)

$w = Pt = EIt = I^2Rt = \frac{E^2t}{R}$ (w in joules, E in volts, I in amperes, R in ohms, P in watts, t in seconds.)

TEST QUESTIONS

1. What constitutes a conduction current?
2. Convert an electron movement of 10^{16} electrons per second to milliamperes.
3. If 10^5 electrons are moved through a circuit in 10^{-8} second, what is the average current in microamperes?
4. (a) When R = 6.4 ohms, then G = ____ mhos.
   (b) When G = 0.00036 mhos, then R = ____ ohms.
5. Convert:
   (a) 0.35 v to mv.
   (b) 45,600 a to ma.
   (c) 3768 w to kw.
   (d) 6.27 kv to v.
   (e) 3 hp-hr to kw-hr.
6. (a) In most metals, resistance can be expected to (increase, decrease?) with increase in temperature.
   (b) In most non-conductors, conductance can be expected to (increase, decrease?) with increase in temperature.
7. Which is the correct statement? The power in an electric circuit may be doubled by:
   (a) doubling the applied electromotive force.
   (b) halving the circuit resistance.
   (c) increasing the circuit current by 50%.
   (d) increasing the applied electromotive force 41%.
   (e) decreasing the resistance 67%.
8. Is this statement true or false? A generator rated at 220 volts, 50 amperes, is more powerful than one rated at 440 volts, 30 amperes.
9. What current in amperes will be established in a conductance of 0.15 mho by an electromotive force of 8.5 volts?
10. Convert to joules:
    (a) 326 ft-lb.
    (b) 1000 gram-calories.
    (c) 350 B. t. u.
    (d) 1.6 hp-hr.
    (e) 0.75 kw-hr.

ANSWERS TO TEST QUESTIONS, CHAPTER 7

1. 2.3×10^{10} tons.
2. 13.7 dynes.
3. 8.67×10^{-9} coulomb and -8.67×10^{-9} coulomb.
4. 4×10^{-42} dyne.
5. 36.9, and 1.44 lines/cm².
6. 1800, 450, and 72 dynes.
7. 1700 volts.
8. −10 volts.

☆ U. S. GOVERNMENT PRINTING OFFICE, 1945 751500

Frequency-Shift-Keying Spread

By Comdr. E. H. Conklin

It is desirable for both the technician and the operator of a radio circuit to be able to listen to a signal, and determine the existence or cause of peculiarities that are detrimental to communications. The emission of a clear signal without spurious frequencies or undesired modulation will clearly be recognized; but the proper spread between the "mark" frequency and the "space" frequency of frequency-shift-keying requires experience or instruction.

Some operators have found it to be sufficient to tune a receiver until one of the signals is in "zero beat," and then to estimate the tone of the other signal which should be 850 cycles—a slightly lower tone than the one that would peak on the 1000-cycle audio filter in a model RBC receiver. However, when it is desirable to inform a distant transmitting station that he should check his spread, it it helpful to give a closer indication of the spread by actual measurement. Frequently it will be obvious from the measured spread that the transmitting station technician permitted his control of the spread between the "mark" and "space" frequencies to remain at the normal position for 850 cycles, but that he set the "multiplier" switch at a point that differs from the frequency multiplication used in the transmitter.

Any receiving operator can measure the spread between the two frequencies of frequency-shift-keying by the following relatively simple means:

Using a receiver such as model RBC, tune the signal until the beat note obtained from one of the two frequencies of an FSK signal passes down through the zero beat point and starts up again; at this time, of course, the other frequency of the signal will still be going down in tone. Continue tuning, very carefully, until the "mark" tone and the "space" tone fall at the same frequency; this will remove the sound of keying; and what appears to be a continuous whistle, with some key clicks, will be heard. The tone of this signal is exactly half of the spread between the "mark" and "space" frequencies.

To measure this half-spread tone, hold two headphones up to one ear, with one phone operating from the receiver and the second from an audio oscillator such as model LO. When the constant tone of the receiver is matched by that from the audio oscillator, the dial setting of the oscillator is one-half the spread.

A visual comparison system involves using the vertical and horizontal amplifiers of an oscilloscope instead of the two headphones. When an ellipse is formed on the CRO tube screen, the frequencies are the same. Generally, this method is used in a slightly different manner—by not making any careful adjustment of the receiver but putting it in the normal FSK receiving position, with both the "mark" and "space" beatnote tones on the same side of the zero beat. The audio oscillator is then matched first to the "mark" and then to the "space" frequencies, and the difference between the two measured audio frequencies taken as the measured spread.

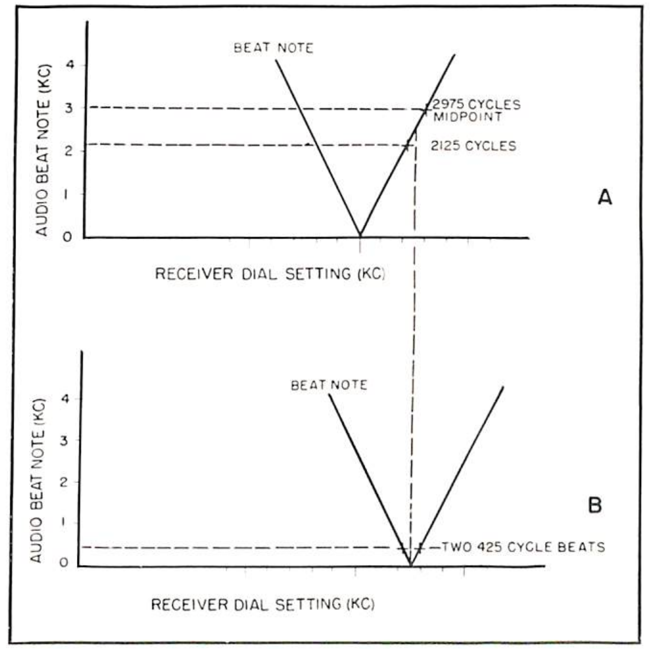


Figure 1—*Two methods used in measuring frequency-shift-keying spread, as explained in text: A—two audio frequencies are measured, and their difference taken; B—one frequency measurement is made.*

Punch Performance in a small package

The PT-boat, a tiny, fragile thing with powerful engines and high speed, combines a high standard of performance with small size when maintained properly.

The navy's electronic equipment, occupying only a small amount of space in a ship, also combines punch performance with small size by providing vision through darkness, hearing over great distances, and many other features unobtainable without it. We must strive constantly to keep it in perfect working order.