Restricted

MARCH 1949

# BUSHIPS Electron

Restricted

NavShips 900,100

# HOME of the Electronics Supply Branch

**N.S.C., Norfolk, Va.**

With its 300,000 square feet of floor space, this building houses the offices of E.S.B. personnel and the ready-issue storage space for electronic material.





**BUSHIPS Electron**

A MONTHLY MAGAZINE FOR ELECTRONICS TECHNICIANS

MARCH, 1949 VOLUME 4 NUMBER 9



**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. Copies 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 the Bureau 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.

**CONFIDENTIAL:** Certain issues of BuShips Electron are classified confidential in order that information on all types of equipment may be included. The material published in any one issue may or may not be classified, however. Each page of the magazine is marked to show the classification of the material printed on that page. The issue is assigned the highest classification of the material included. Classified material should be shown only to concerned personnel as provided in U. S. Navy Regulations. Don't forget, many enlisted men *are concerned* with the contents of this magazine.

BuShips Electron contains information affecting the national defense of the United States within the meaning of the Espionage Act (U.S.C. 50; 31-42 incl.) as amended.

BUREAU OF SHIPS — NAVY DEPARTMENT

UNCLASSIFIED


*Rear Admiral T. Earle Hipp, U. S. N.*

*Commanding Officer, Naval Supply Center, Norfolk, Va.*





# T. EARLE HIPP

## REAR ADMIRAL, U.S. NAVY

Rear Admiral Hipp was born in Newberry, South Carolina, October 28, 1894. He was graduated from the Citadel, Military College of South Carolina, Charleston, South Carolina, in 1914. He was commissioned Assistant Paymaster with the rank of Ensign from June 20, 1917, and advanced in grade until promoted to Pay Director with the rank of Captain June 30, 1942, and advanced to Rear Admiral effective March 31, 1943.

After entering the Supply Corps of the Navy in 1917, Rear Admiral Hipp had instruction from August 1917 until January 1918, at the Naval Pay Officers School, Washington, D. C., and with the Cost Inspector, First Naval District, Boston, Mass.

In January 1918, he joined the *U.S.S. Petrel,* employed in patrol duty, and served as her Supply Officer until January 1919. After a tour of duty in the Bureau of Supplies and Accounts, he was ordered to the *U.S.S. Southard* and, after cruising in her in the Mediterranean, Adriatic, and Black seas, he proceeded to the Asiatic in that destroyer. He was commissioned Passed Assistant Paymaster in the grade of Lieutenant from July 1, 1920. He was Supply Officer on the *U.S.S. Huron,* a flagship of the Asiatic Fleet, from February, 1921 until December of that year when he reported for duty as assistant to the Supply Officer at the Naval Station, Cavite, P.I. After serving as Supply Officer of Destroyer Division Twelve, Asiatic Fleet, from August 1922 until March 1923, he returned to the United States.

Rear Admiral Hipp was attached to the Naval Aircraft Factory, Philadelphia from May 1923 until May 1926, with duty as Inside Superintendent. Following that duty he was Supply Officer of the Presidential Yacht, *U.S.S. Mayflower,* for three years, with additional duty as Aide at the White House. His next duty was in the Claims and Allowances Division, Bureau of Supplies and Accounts, Navy Department, Washington, D. C. He reported there in June 1929 and was commissioned Paymaster with the rank of Lieutenant Commander on January 7, 1930, while serving in that detail. In September 1932, he returned to sea as Supply Officer of the *U.S.S. California,* Flagship Battle Force, U.S. Fleet, and in August 1935 he reported as Supply and Accounting Officer at the Submarine Base, New London, Connecticut. He was Assistant to the Supply Officer in the Navy Yard, Philadelphia from March 1936 until May 1937, and served as Senior Assistant to the Supply Officer at the Naval Gun Factory, Navy Yard, Washington, D. C. from June 1937 until June 1940.

In July 1940 Rear Admiral Hipp reported for duty in connection with fitting out and establishing the Naval Air Station at Jacksonville, Fla. He served as Supply and Accounting Officer of that station from September 1940 until May 1942, when he was ordered to the Navy Department where he was Administrative Officer of the Bureau of Supplies and Accounts. Early in 1945 Rear Admiral Hipp became General Inspector, Supply Corps, Pacific Coast, on the staff of the Commander, Western Sea Frontier, and on January 5, 1946, he was assigned as Chief of the Field Branch, Bureau of Supplies and Accounts, Cleveland, Ohio. Then on January 12, 1948, he assumed command of the Naval Supply Center, Norfolk, Virginia.

Rear Admiral Hipp has the Legion of Merit, Victory Medal, Patrol Clasp, the American Defense Service Medal, European-African-Middle Eastern Campaign Medal, American Theatre Campaign Medal and the World War II Victory Medal.

His official residence is 6301 Greene Street, Germantown, Philadelphia, Pennsylvania.

# ESTABLISHMENT OF THE ELECTRONICS SUPPLY BRANCH AT NSC, NORFOLK

*By* Lieut. Comdr. W. A. Twitchell (SC) USN

Consistent with its fast-growing expansion and long record of excellence of "Service to the Fleet," the Naval Supply Center, Norfolk has added "Electronics" to its list of material available.

Established as an integral part of the Ships Supply Depot within the Supply Center, the Electronics Supply Branch was directed to be activated and fully operative on 1 January 1949 and has been assigned the mission to provide full supply support of electronic material to all active fleet vessels in the Hampton Roads area (except those vessels in the N. N. S. 4); all active vessels of the Atlantic Fleet; Reserve Fleet vessels in the Norfolk area; assigned craft in the Norfolk area as well as shore activities of the Fifth, Sixth, Eighth, Tenth and Fifteenth Naval Districts and other overseas activities in the Atlantic stocking electronic material. This support is to be furnished either directly or indirectly, through ComServLant and/or intermediary continental or overseas supply activities as directed by the cognizant authorities.

Preliminary plans for the establishment of an activity in the Norfolk area for the purpose of providing a supply source for electronic material were initiated at the Bureau level early in February of 1948 and the Electronics Supply Office, Great Lakes, Illinois was charged in a joint directive of BuShips/BuSandA to coordinate the necessary moves to get the ball rolling.

Lieutenant Commander William A. Twitchell, SC, USN was recommended and was ordered to Norfolk as Prospective Officer in Charge. Full-scale planning operations for the establishment of the new depot started in Norfolk on 12 July 1948. Working under the direction of the Planning Department of the Center, basic assumptions were reviewed and progress was charted along lines similar to the already-established Electronics Supply Branch, Ships Supply Depot, Oakland, Calif. The structural organization was laid out in accordance with standardized design. Attacking the personnel situation first, it was quickly ascertained that there was no available source of technical storekeepers in the area and with that in view, it was evident that the operating groups, Control and Material, would have to be adequately supported by an excellently qualified technical division whose application of special knowledge would have to be carefully applied and thoroughly integrated into the operating procedures involved in the receipt, storage and issue of the highly technical material encompassed by "electronics."

Initial stock of "electronics" was established by the Electronics Supply Office and by BuShips and was estimated to be approximately 15,000 line items of maintenance repair parts and approximately 650 line items of BuShips major equipments and components. Two buildings at the Naval Supply Center were designated to accomplish the receipt, storage and issue of this material and immediate plans were initiated to undertake the construction of the necessary bins and storage aids to accomplish this warehousing assignment. A Bin Issue Unit was installed which has a capacity of approximately 45,000 maintenance repair parts items. A Retail Issue Unit for tubes and stock crystals was also constructed. Making full use of pallet racks, major equipments and components were stored as complete units to insure ready and reliable issue.

The Electronics Supply Branch expects to employ approximately 153 IVB's and 69 per diems under the presently assigned mission and is to be the first of the Electronics Depots to enter a full-scale IBM mechanization of stock control and stock reporting.

RECEIPT CONTROL at NSC, Norfolk.





TRAFFIC DIVISION at NSC, Norfolk.

Although many difficulties were anticipated in the mechanization of electronic material, BuSandA considered it highly desirable that the initiation of the Electronics Supply Branch, Norfolk should signal the mechanization of that material for the first time within the system. Electronics Supply Office, Great Lakes, Illinois agreed to limit the descriptive information required in invoicing and came up with approved short titles. Special electronics IBM cards were developed.

The establishment of a permanent supply system for electronic material is predicated fundamentally on maintaining in Naval shipyards and in the supply activity for the Industrial Manager sufficient stocks to cover the needs of the shipyards or Industrial Manager for a reasonable working period. The shipyards and the office of the Industrial Manager will not be used as supply depots as they were during World War II. The large quantities of back-up material will be stored at the inland Naval Supply Depots, and the active stocks for retail issue directly to ships and shore activities and the replenishment for the shipyards and Industrial Managers will be maintained by Electronics Supply Branch, Naval Supply Center, Oakland and Norfolk and the Naval Supply Depot, Bayonne.

The newly formed Electronics Supply Branch at Norfolk looks forward with enthusiasm to being a thorough and reliable source for this most vital equipment. Its officers, to a man, were all former line Communications Officers prior to their entering the Supply Corps and visualize their responsibility from the angle of the end user as well as the supplier.

## OFFICER IN CHARGE

LCDR William A. Twitchell (SC) USN

Lieutenant Commander W. A. Twitchell, SC, USN became the Officer in Charge of the Center's newest addition, "Electronics," at the commissioning ceremonies at the Naval Supply Center, Norfolk on 5 January, 1949. Having been assigned to the Supply Center since July 1948 with orders to establish and put into motion the Electronics Supply Branch, Ships Supply Depot, the Commander built an organization from the ground up and reported his team ready for duty as scheduled on 1 January 1949.

Lieutenant Commander Twitchell entered the Navy with several years of electronics experience and has since had extensive experience in communications and electronics both as a line officer and as a Supply Corps Officer. His service dates back to 1932; first, as a private and non-commissioned officer in the Marine Corps and the Marine Corps Reserve and in 1938 as a commissioned officer in the U. S. Naval Communications Reserve. In 1941, Lieutenant Commander Twitchell was ordered to mobilize his reserve unit for active duty, and to report as Communications Officer to the *U.S.S. Harris*. Serving with the amphibious force throughout the war, he participated in operations in both the Pacific and Atlantic Theaters. After the North African Campaign, he reported to the staff of Rear Admiral R. O. Davis, USN, now Commandant of the Fifth Naval District, and served as the Staff Communications Officer with Admiral Davis' command in far eastern waters and in the Atlantic Fleet until September 1947 at which time Lieutenant Commander Twitchell was transferred to the regular Navy as a Supply Corps Officer. He attended the Supply Corps School at Bayonne, New Jersey and the Special Service School for Electronics Supply. His first assignment as a Supply Corps Officer was as Operations and Planning Officer at the Naval Supply Depot, Spokane, Washington, under the command of Captain A. S. Keeth, SC, USN.

# OUR MISSION AND SERVICE

*By* Lieut. Walter F. Wadewitz (EDO) USN

Yes, we are new, very very new, yet the mission and services for which we strive are as old in themselves as Naval electronics. Strange? No, we don't think so, for our *mission* is to inspect, identify, screen, test and preserve the material you may desire, while our *service* is the assurance that you will receive, expeditiously, the material you requisition.

To achieve these goals our employees, ranging from highly technical personnel through equipment specialists to file clerks, have worked hard in the organization of their respective sections. The results of this effort should be well evidenced in the speed and quality of the material issued to you.

An understanding of the organization and operation of the Technical Division may be obtained by considering the descriptions that follow. Headed by a Technical Officer and Division Chief, its primary function is to properly and efficiently inspect, identify, and advise Ships Supply Depot in all technical matters relative to preservation, storage, and issue of all its electronic material.

To accomplish this function the Technical Division is divided into three sections: (1) The Advisory Section; (2) The Identification & Inspection Section; (3) The Repair, Renovation & Test Laboratory.

These sections, further sub-divided into their respective units, have incorporated within their organization the personnel qualifications and teamwork necessary to show remarkable results. Comprised mainly of veterans, several of whom are "ham" operators, their interests naturally center on electronics. As a result, the issue service of the thousands of specialized parts needed for maintenance of Navy electronic equipment and issued by ESB is assured as the finest quality.

The development and growth of the Navy's electronics system has been tremendous during the past few years. This rapid expansion has created the need for incorporating within the supply system a division of personnel who are highly trained in the field of electronics. Here the material is inspected and identified, tested and repaired, substituted or researched, then shipped to you with minimum delay. With this accomplished, we will have then truly fulfilled our *mission* and *service*.

## ABOUT THE AUTHOR

Lieutenant Walter F. Wadewitz (EDO) USN was born December 3, 1916 in Winona, Minnesota. After graduating from State College, Winona, in 1938 with a B.S. Degree in physics and mathematics, he entered the teaching profession, supplementing his training with post graduate courses at the University of Wyoming and Michigan. He held various positions during this period ranging from high school principal to electronics instructor at Yale University and the University of Texas. Lieutenant Wadewitz remained in this field until entering the Navy in 1943.

After undergoing numerous Naval electronics courses, he served a total of over five years in various shipyards engaged in new construction and repairs. Lieut. Wadewitz joined COMMINPAC in 1945 as Electronics Officer, and in March 1947 was ordered to the San Francisco Naval Shipyard as the Electronics Planning Officer. He assumed his present duty as Electronics Officer, ESB, NSC, Norfolk in October 1948.





# ALPHABET SOUP . . . . . . . ELECTRONICS STYLE

THE TECHNICAL LIBRARY.

*By* James N. Kilpatrick

"FSSC, SNSN, ESO, EMCR, JANAP, IBM, SDC, IR . . . !" Today's special—alphabet soup, electronics style. And this kind of "soup" is ESB Norfolk's particular dish.

This newest member of BuSandA's growing family has been established with the Bureau's famous slogan in mind: "Service To The Fleet!" In order to accomplish this mission most efficiently at ESB, a Technical Division has been incorporated. The staff function of this division centers around aid to the Stores Division in identifying and inspecting electronic equipments. This is where the alphabet soup enters the picture.

Incoming electronic material requisitions are first routed through the Technical Division's "Screening Unit." This is ESB's watchdog for insuring that the end user receives exactly what he ordered—or a reasonable facsimile thereof. This means that in some instances quantities may be reduced or increased to conform with the most efficient insurance policies. In other instances, substitutions may be effected on NIS items.

For example, let us suppose that a dependent activity sends ESB, Norfolk, an urgent request for a 1-ohm, 50,000-watt resistor. A non-technical person might well waste half the day trying to associate such an item with a legitimate stock number. Obviously, some sort of clarification is in order. Accordingly, the screener will refer the request back to the originator with a note as to where the discrepancy or apparent error exists. In the event that stock numbers are not available in Screening's ready index files, so that there is no valid number forthcoming, the item is referred to the Research Unit of the Technical Division for the search for a valid number or for a recommended substitution.

In order to accomplish its mission, the Technical Division has made possible use of the following data sources: Stock Description Cards (SDC); Electronic Material-Cross Reference (EMCR); Federal Standard Stock Catalog (FSSC); Joint Army-Navy Publication 109 (JANAP–109); Navy Type Number Book (NTNB); Inspection Reports (IR's)—and many other reference works.

Alphabet soup, electronics style. . . .

## ABOUT THE AUTHOR

James N. Kilpatrick was born August 18, 1907 in Northern Ireland. He attended Drexel Institute of Technology and Temple University, where he majored in electrical engineering. In the Army, Mr. Kilpatrick served as skipper on auxiliary vessels, and was also chief instructor in navigation.

He was a senior electrical planner and electrical progress engineer on Naval vessel construction for a private shipyard during the early war years.

In the commercial electronics engineering field, Mr. Kilpatrick served as a design and production engineer with Atwater-Kent, specializing in transformers and chokes; and later with RCA-Victor, designing special power transformers to meet Navy specifications. He was senior production planner with SKF Industries, and recently served as special project engineer with the H. L. Yoh Company, industrial consultants. Mr. Kilpatrick is now chief of ESB's Technical Division.

# INSPECTED—OK—ESB

*By* Tom S. Stuart

The quality of outgoing material forms the basis upon which the efficiency of most technical commercial concerns is judged. Consequently, the selection of personnel to staff such a technical unit is of paramount importance, as are the organization and planning methods to be employed.

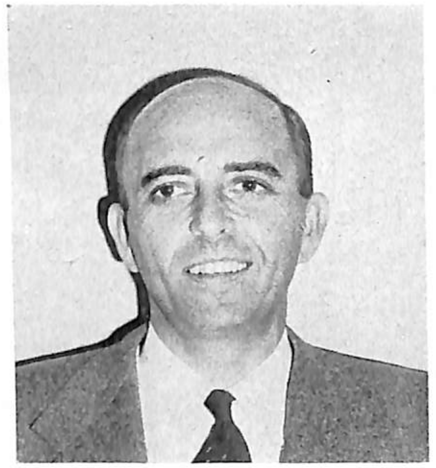
The division of ESB's Technical Division inspection procedures into two specific categories contributes materially toward insuring a top-notch reputation for ESB's quality supply. Under this system, the Inspection Unit is sub-divided into working "teams."

These teams examine incoming electronic material for association with correct stock numbers to avoid possible pollution and verify the physical and/or electrical characteristics concerned. When it is not immediately possible to associate incoming material with valid stock numbers, the Identification Unit enters the picture.

The Identification Unit researchers have more complete and comprehensive data at their disposal than the inspectors. Consequently, they either come up with a valid stock number, or create a local temporary number for the item in question. Such local numbers are then reported to ESO for consideration as to assignment of standard numbers.

The technical library stands by the Identification Unit with shelves of instruction books, manufacturers' catalogues, drawings, etc. Further aid is provided by the Technical Files and Data Section, where complete indices of reference numbers versus stock numbers are maintained. The result of all this adds up to supply service that is intended to insure fast, accurate and complete control. We look forward to serving you.

## ABOUT THE AUTHOR



Tom S. Stuart was born December 16, 1906 in Oak Ridge, North Carolina. He attended North Carolina State College majoring in electrical engineering. He has been an active radio amateur operator for twenty-three years and is a member of the exclusive "DX Century Club," being among the first to be licensed in the fourth call area.

Mr. Stuart also has eleven years experience to his credit as field engineer on radio transmitters and relay stations. Prior to joining the technical staff at ESB, Mr. Stuart was supervisor of Navy airborne electronic equipment at NAS Norfolk. His present position with ESB is supervisor of the Inspection and Identification Section.

# ADVISORY SECTION, EXPERIENCE TALKING

*By* Advisory Section

This unique unit is currently composed of three technicians, each of them a specialist in his respective field of Radio, Radar or Sonar. A closely integrated policy enables these three consultants to exchange ideas and experiences, resulting in marked benefits to everyone concerned.

Recommendations on substitutions or modifications of stock material to fit emergency requisitions are the particular concern of these advisors.

It is obvious that a healthy engineering curiosity is one of the major requirements for membership in this group. In order to satisfy such curiosity, the Advisory Section faithfully studies the BuShips Electron and EIB's, and also all other pertinent trade, research and engineering publications.

But the "tinkerin' an' testin'" lab is nearest and dearest to the hearts of these men. Seeing the necessity for supplying material in absolute working order, BuShips empowered ESB to establish such a lab to test equipment and tubes before airlift shipment overseas.

Even with the aid of directives, manuals, bulletins and similar published technical data, many electronics problems require "that personal touch" for solution.

Experience has shown that such precautions have reduced the percentage of defective material carried by highly expensive transport. Individual components, such as m-g sets, and individual items like Variacs will be tested in this lab when the Advisory Section considers it necessary.

All these functions being designed for better service to the fleet, the ESB Advisory Section would like to go a step further than "the book" and extend a personal cordial invitation to fleet Electronics Officers, technicians and other interested parties to visit the Section whenever they are in the vicinity for a "cracker-barrel" session of technical talk.





# ". . . . . OR OTHER REPAIR FACILITY"

## SAN DIEGO NAVAL STATION

Have you ever wondered what that cryptic phrase might mean in some of the Bureau of Ships directives? That "other repair facility" business is the way the Bureau has of designating the various commands that do not fall in the class of a Naval shipyard at such locations as Guam, Balboa, San Diego, and many other places.

The Naval Station, San Diego, California, down in the very southwest corner of the U. S., is such a repair facility with all the equipment for making repairs that would be found in a shipyard today, but with less personnel, since the present mission of the station is of a limited nature. The Electronics Division is an exception, for it was early anticipated that there would exist a shortage of enlisted technicians, and the mission of the station was accordingly modified to permit "voyage and emergency repairs" to ships of the active fleet operating in these southern waters and the employment of civilian technicians in numbers adequate to meet the demands from the fleet for this service.

Tenders assigned by the various type commanders, of course, perform the bulk of the repairs in this area; however, due to short availabilities between training schedules, the capacity of the various tenders is frequently overtaxed, and the Naval Station Electronics Shop is then available to provide the additional personnel needed. The station is further fortunate in having been assigned three BuShips contract engineers to assist in repairs to fire control radar equipment.

A limited stock of electronic replacement parts is maintained by this station for issue to the fleet. Major electronic equipments are not stocked at San Diego. The Electronics Officer of the Naval Station maintains a library of instruction books and, with a staff of electronics engineers, is available for information to assist forces afloat with their maintenance problems.

**CAPT. BEATTIE is shown the test stand for checking SP stable elements by MR. FRANK THEMER, Electronics Engineer. Radar stable elements constitute a large part of the work load of this shop.**

The shortage of experienced ET rates aboard vessels of the active fleet has placed an added burden upon repair forces afloat in the San Diego area. There are generally several tenders available in this area to assist forces afloat, and, in accord with standard U. S. Pacific Fleet Regulations, vessels operating out of San Diego are serviced by these tenders. Tenders are the main source of technical assistance to effect repairs which are beyond the capacity or ability of ship's personnel at San Diego.

Electronics Inspectors have been provided by the Bureau of Ships (see BuShips Manual, Chapters 67-82 and 67-83) at the U. S. Naval Station to assist com-

**Captain T. T. Beattie, USN**

**Commanding Officer**

Capt. Beattie assumed his present command in January 1948. He first reported aboard in May 1946 as head of the Administrative Department, and in this capacity became thoroughly familiar with the complex workings of the Naval Station and its many varied activities. Capt. Beattie was graduated from the Naval Academy in 1922 and spent seven years aboard Pacific Fleet destroyers. Duty at the Bremerton Navy Yard was Capt. Beattie's next assignment. From 1931 to 1934 he served aboard the *U.S.S. Maryland*, then reported back to Annapolis as an instructor of electrical engineering. Upon completion of this duty, Capt. Beattie was assigned his first command on the *U.S.S. Bittern* at the China station, and later commanded the *U.S.S. Perry* at the station from 1937 to 1939. Returning to the States, he went to the Naval Training Center, San Diego, as Maintenance Officer. In 1940 he reported to the *U.S.S. West Virginia* as navigator, serving in that capacity until she was sunk at Pearl Harbor. He was subsequently on the staff of Commander Service Force, Pacific Fleet, and Commanding Officer of the *U.S.S. Merek*, from which duty he went to the Office of the Chief of Naval Operations, where he remained until 1945. Having spent a year in command of the *U.S.S. Louisville*, Capt. Beattie reported to the U. S. Naval Station, San Diego.

COMDR. SHORT and his Chief Civilian Assistant, MR. W. W. L. BURNETT, inspect work in progress in the modification section of the Naval Station's Electronics Shop.

manding officers in preparing their work requests to be presented at tender arrival repair conferences or during other limited stays in port. These inspectors are available upon request of the vessel's Electronics Officer without the formality of a job order.

Based on information prepared by the ship's personnel and with the additional information furnished by the Naval Station's inspectors, the commanding officer presents his work request to his assigned tender for accomplishment of that work which is beyond the capacity of his force. If the number of voyage or emergency electronic repairs is either too numerous or of a nature that requires facilities or technical assistance beyond tender capacity to accomplish during granted availability, the commanding officers of destroyers may obtain assistance from the electronics facility at the Naval Station by requesting their assigned tender to endorse their requests and pass them on to the Naval Station for action, as is authorized by ComDesPac letter, file S67-11, serial 8298 of 6 May 1947. Where it is realized that time is limited, the commanding officer should request the tender to pass the work request to the Naval Station by dispatch in sufficient time for the accomplishment of the outlined work during tender availability or earlier at the buoy.

Where PhibsPac vessels are concerned, requests are individually screened by that commander and passed to the Naval Station for necessary action. Funds for paying for assistance are provided by the respective type commanders. AirPac work may be charged to ship's quarterly allotment, upon approval by ComFairWest. In the case of DesPac and PhibsPac, a revolving fund has been set up by these type commanders with the Naval Station.

Attention of all officers is invited to that portion of the U. S. Pacific Fleet Regulations which places the responsibility for progress inspections of work on the ship's own inspectors to keep the commanding officer informed, who will in turn follow up on repair activities to assure the satisfactory accomplishment of the approved work requests within the time available or request additional availability or assistance.

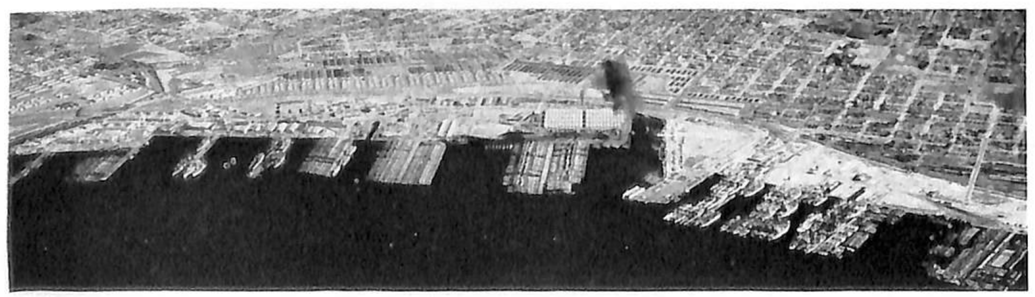
Since the Naval Station utilizes civilian labor, it is important that work requests be submitted in time to accomplish the work before the close of the work week, at 1630 Friday. Weekend work at overtime rates requires special authorization of the authority controlling the funds.

The Naval Station Electronics Planning Officer is located in Building 77, the Electronics Shop facilities of the Naval Station are in Building 172, and the Electronics Parts Supply Section is in Building 78. Navy bus transportation is available from the Broadway Pier to the Naval Station on a half-hour schedule.

**Commander Carl D. Short, USNR**

**Electronics Officer**

With more than ten years' previous "wireless" experience, Comdr. Short was commissioned an ensign in the Naval Reserve in 1926, reporting to active duty at NAS Jacksonville in 1941 as Officer-in-Charge of the Communications Division of Ground School, and was later ordered to Balboa, Canal Zone, as Electronics Officer, 15th Naval District. He was Electronics Officer of Electronics Unit No. 5 and of the first Electronics Repair Ship, *U.S.S. Baham (AG-71)*, to reach Service Squadron 10. Prior to reporting to San Diego, he was Electronics Officer of the Marianas area at Guam.



AIR VIEW of the San Diego Naval Station.





# QUALITATIVE ANALYSIS OF FOLDED DIPOLES

*By* LIEUT. COMDR. CHARLES W. HARRISON, JR., USN
*Electronics Design Division, Bureau of Ships*

## Introduction

Folded dipoles are receiving wide usage at the present time for two basic reasons: First, the input resistance of a two- or three-wire folded dipole at resonance falls within the limits of 250 to 300 ohms or 600 to 650 ohms, respectively. It is entirely feasible to construct an ordinary air dielectric two-wire transmission line having a characteristic resistance of any value within the range 250 to 650 ohms. This fact obviates the necessity for employment of transmission line sections as impedance transformers for matching the antenna to the feed line. Second, a folded dipole used at the lower communication frequencies exhibits a more satisfactory impedance against frequency characteristic than a simple symmetrical center-driven antenna of comparable overall length and wire radius.

The present article presents a qualitative analysis of folded dipole operation. A formula for roughly estimating the input impedance of a folded dipole consisting of N wires is developed.

## Two-Element Folded Dipole

A conventional two-wire folded dipole is shown in figure 1. The wires are of the same radius, and their length approximates one half wavelength. For convenience in this and in subsequent figures the elements are shown unduly separated; however, it is to be understood that the distance between wires is small compared to the wavelength. Figure 2 illustrates a folded unipole. The lower half of the two-element folded dipole is replaced by a large perfectly conducting plane surface. A source of voltage is shown connected between the lower end of one wire and ground. Provided no auxiliary conductors or dielectrics are located in the vicinity of either the folded dipole or folded unipole, the input impedance of the folded dipole is precisely twice the input impedance of the folded unipole.

A quarter-wave base-driven vertical radiator is shown in figure 3. The radius of wire employed is the same as the radius of wire used in the construction of the folded unipole. It is desired to establish a relationship between the driving point impedance of the folded unipole and the vertical radiator. For this purpose it is convenient to replace the single generator shown in figure 2 by the three identical impedanceless generators shown in figure 4. The polarities of the generators at a selected instant in time are indicated. The fact that identical impedanceless generators are not physically realizable is of no import; they are introduced for purposes of discussion only and play no significant part in the final result. The "generator region" of figure 4 and in subsequent figures is deliberately exaggerated to insure space for appropriate labeling of the drawings.

Assume for the moment that no voltage is developed by generator 3. In this case a voltage 2V appears across the sending end of a quarter-wave transmission line which is short circuited at the receiving end. The input impedance of such a line section is very high if it is adjusted to resonance, and accordingly very little current flows into the line at the driving point. However, large currents may exist at other points, particularly in the region of the shorting bar between wires located at the receiving end of the line. Actually, these currents are sinusoidally distributed along the line to a high degree of approximation. They play little part in radiation from the antenna because, at any given distance along the wires, they are of equal amplitude but flow in opposite directions. This is defined as the antisymmetrical mode for currents.

Next, assume that generators 1 and 2 develop no voltage. The unipole now resembles the base driven vertical radiator of figure 3 except that, in lieu of one wire, two wires form the vertical section. Because of symmetry, the total current divides equally between the two elements. Notice that at any given distance along the wires the currents are of equal amplitude and flow in the same direction. This is defined as the symmetrical mode for currents. They play a dominant rôle in radiation from the antenna.

Suppose, now, that all generators are operating. It is immediately apparent that the left element is grounded

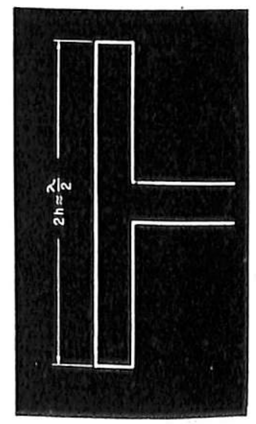



Figure 1.

*Conventional form of folded dipole, showing driving transmission line.*

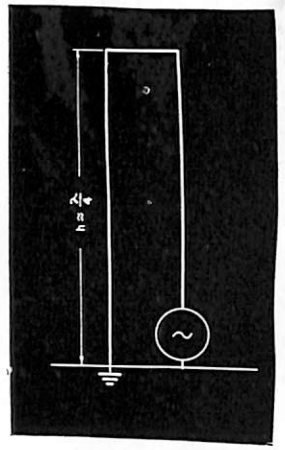


Figure 2.

*Folded unipole. The lower half of the antenna shown in figure 1 is replaced by a large perfectly conducting plane.*

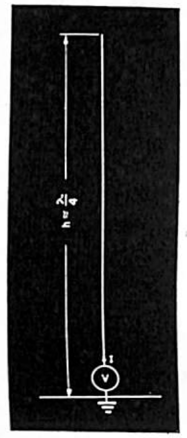


Figure 3.

*Base-driven vertical radiator over a large perfectly conducting plane.*

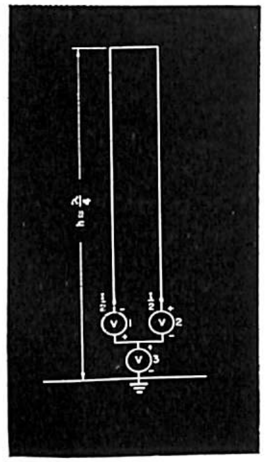


Figure 4.

*Folded unipole like figure 2. The single generator of figure 2 is replaced by three identical impedanceless generators, as shown.*

at its lower extremity because it is connected to ground through two identical impedanceless generators whose voltages oppose. On the other hand, the voltages of generators 2 and 3 develop a voltage 2V between the lower extremity of the right-hand element and ground. The input impedance of a folded unipole is, therefore, $2V/(I/2) = 4V/I$. This result may be correlated with the input impedance of the quarter-wave vertical radiator, it being presumed that wire of the same radius is employed in constructing both, and that the overall length of the vertical radiator is the same as the distance between the driving point and center of the shorting bar of the folded unipole. Obviously, the driving point impedance of the vertical radiator is V/I. Accordingly, the impedance of a folded unipole is approximately four times the impedance of the comparable base-driven vertical radiator. (Observe that for the symmetrical mode for currents the presence of the shorting bar does not significantly alter the current distribution along the wires inasmuch as it is connected between points of equal potential. This is not true for the antisymmetrical mode for currents.)

The limiting value for the input impedance of a base-driven quarter-wave vertical radiator (as the radius of wire approaches zero) is 36.57 + j21.25 ohms. Therefore, the input impedance of a folded unipole comprising two elements is 146.26 + j85 ohms. The input impedance of an isolated center-driven half-wave antenna of vanishingly small radius is 73.13 + j42.5 ohms. Accordingly, the input impedance of an isolated folded dipole composed of extremely thin wires is 292.5 + j170 ohms.

Ordinarily the input impedance of a folded dipole (or folded unipole) with air dielectric is complex; i.e., consists of a reactive as well as resistive component. The total current at the driving point is a superposition of the symmetrical and antisymmetrical currents. It might prove difficult to obtain antenna resonance as well as transmission line resonance simultaneously. Antenna resonance is achieved when the symmetrical component of current entering the driving point (which, except at resonance, is complex *per se*) is precisely in time phase with the applied voltage. Transmission line resonance requires the antisymmetrical component of current to be vanishingly small at the driving point. Undoubtedly, a judicious choice of wire spacing and wire radius is required if one contemplates obtaining a purely resistive input impedance.

It has become common practice to construct folded dipoles resembling figure 1 from twin-lead transmission line, the wires being secured along the edges of polyethylene ribbon. Possibly, the wavelength associated with the antisymmetrical mode is somewhat shorter than that associated with the symmetrical mode under these circumstances.[1] Based on this premise a quarter-wave transmission line section would be somewhat shorter than the section of wire required for antenna resonance. Accordingly, if the input impedance is to be a pure resistance, two adjustments are necessary. First, a rigorous version of the theory of coupled antennas, suitably modified to include the effect of a thin dielectric film surrounding the wires, should be employed for estimating the length

[1] The available theory of biconical antennas having very small angle cones with space between them filled with suitable dielectric material should prove efficacious for estimating the effect of a thin dielectric film on the resonant length of an antenna. An experimental investigation will be made later to determine the difference between the wavelengths associated with the symmetrical and antisymmetrical modes for wires embeded in thin dielectric ribbon. This will be the subject of an article to be published later.



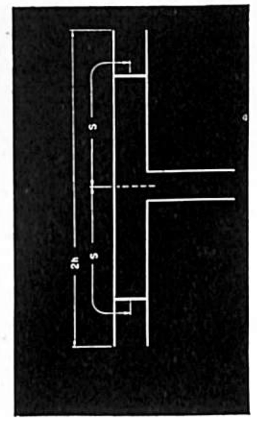


Figure 5.

*Bridged-T antenna. The length 2h is adjusted to obtain antenna resonance. The length S is adjusted to secure transmission line resonance. The wires may be embeded in dielectric media other than air.*

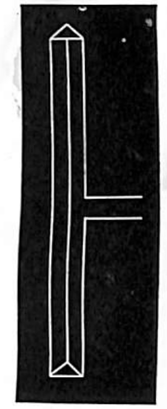


Figure 6.

*Three-wire folded dipole. The wires are secured at the vertices of metallic equilateral triangles.*

of wire required to obtain antenna resonance. Second, the location of the shorting bar for obtaining transmission line resonance must be computed by use of a modified transmission line theory which takes cognizance of the thin dielectric strip between wires.[2] If the wavelength associated with the symmetrical component of currently actually exceeds the wavelength associated with the antisymmetrical component of current as expected, then one way out of the dilemma is to provide for an adjustable shorting bar. An illustration of the resulting "folded dipole", which has now become a bridged-T antenna, is shown in figure 5. It is evident that the length of line section S necessary to obtain transmission line resonance (measured from the driving point to the center of the shorting bar), and the length of antenna 2h necessary to obtain antenna resonance, may be determined experimentally.

A folded dipole antenna inherently possesses a more satisfactory impedance against frequency characteristic than a simple dipole of comparable wire radius. For purposes of explanation, assume that at a given frequency the folded dipole is precisely resonant. If the frequency of the applied voltage is lowered (the wavelength increased) the antenna is too short and the input impedance is capacitive in character; i. e., the symmetrical component of current leads the applied voltage. Simultaneously, the shorted line section becomes too short and the input impedance is inductive in character; i. e., the antisymmetrical component of current lags the applied voltage. The resulting driving point current, which is the vector sum of the two components, remains fairly well in phase with the applied voltage. If the frequency is raised, the symmetrical component of current lags, and the antisymmetrical component of current leads the applied voltage. The reactive parts of the two components of current again tend to compensate one another and the total input current remains fairly well in phase with the applied voltage. Thus the impedance against frequency characteristic of a folded dipole is reasonably smooth over a band of frequencies on either side of resonance.

## Three-Element Folded Dipole

Figure 6 illustrates a three-element folded dipole. The wires are approximately one half wavelength long, and their ends are secured at the vertices of metallic equilateral triangles, as shown. The assumption is made that all wires are of the same radius. One wire of the three-wire antenna is center-driven; the other two are parasitic. Figure 7 portrays a three-element folded unipole. The lower half of the three-wire folded dipole is replaced by the earth. The wires are in the vicinity of one quarter wavelength in length. The antenna is driven by connecting a generator between the lower extremity of one wire and the ground plane.

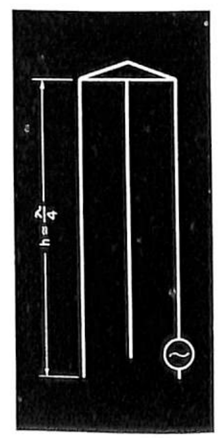


Figure 7.

*Three-wire folded unipole. The lower half of the antenna shown in figure 6 is replaced by a large perfectly conducting plane.*

[2] A transmission line theory for wires immersed in solid dielectric media (extending throughout all space) is available. One should exercise caution in applying the results of this theory to the case of wires embeded in a thin dielectric ribbon. The two cases bear little geometrical similitude.

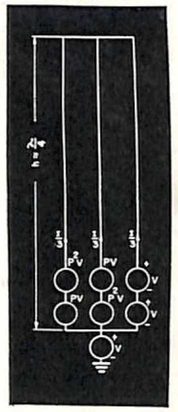
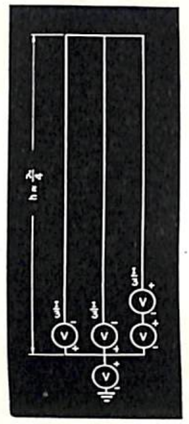


Figure 8.

*Three element folded unipole, showing driving generators. The method of analysis is based on the theory of symmetrical phase components.*

Figure 9.

*Three-element folded unipole being driven by a generator system electrically equivalent to the system pictured in figure 8.*



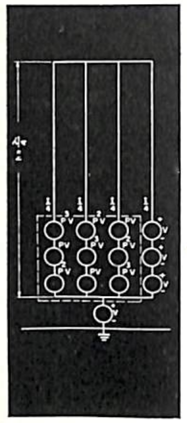


Figure 10.

*Four-wire folded unipole showing driving generators.*

In order to provide a qualitative explanation of the operation of the three-element folded unipole, the single generator of figure 7 is replaced by seven identical impedanceless generators shown in figure 8. A modified version of the theory of symmetrical phase components is employed. By use of the superposition theorem the current entering the driving point of figure 7, or the right-hand wire of figure 8, is determined, and from it the driving point impedance.

The polarities of the various generators at a selected instant in time are indicated. In this case the phase factor P means that as one progresses along a horizontal row of generators (always in the same direction) a progressive phase angle of 120 degrees is introduced between the applied voltages. If the top layer of generators drives the wires in the positive sequence, the next layer of generators drives the wires in the negative sequence.

As mentioned earlier, all applied voltages are of the same amplitude, but considering one layer of generators alone an appropriate phase angle is introduced between the voltages to insure maintenance of electrical symmetry in the three-element antenna. Symmetry cannot be accomplished unless the phase factor P satisfies the equation

$$P^2 + P + 1 = 0 \tag{1a}$$

or

$$P^2 + P = -1 \tag{1b}$$

Multiplying through V gives

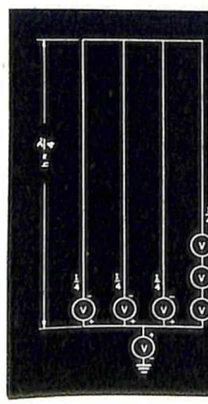
$$P^2V + PV = -V \tag{1c}$$

Thus the two generators in the left-hand wire of figure 8 may be replaced by a single generator of voltage V having polarity opposite to the polarity of the generators located in the right-hand wire. Similarly, the two generators in the center wire are replaced by a single generator. Figure 9, involving five generators, is thus electrically equivalent to figure 8 where seven generators are required. One might say that the three-phase problem pictured by figure 8 has been replaced by the single-phase problem pictured in figure 9. The argument is now the same as that presented for the case of the two-wire folded unipole.

If the generator connected between the earth and the antenna is operative and the others are not, a current I/3 will exist in each wire. This is true provided geometrical symmetry obtains; i. e., the wires are equally spaced on the circumference of a circle. For any other orientation of wires it is not correct to assume that the current divides equally between the wires, as the coupling between them is no longer equal. When the upper generators act alone essentially no current flows in any wire provided the length of the wires is adjusted to achieve transmission line resonance. When all generators are operating, the center wire and left-hand wire are effectively base grounded since the impedanceless generators are connected such that their equal instantaneous voltages oppose. Inspection of the figure reveals that a voltage 3V acts between ground and the lower extremity of the right-hand wire. The input impedance of a three-element folded unipole is therefore $3V/(I/3) = 9V/I$. If one assumes that the input impedance of a quarter-wave vertical radiator is 36.57 + j21.25 ohms, the input impedance of a three-wire folded unipole is approximately 329.1 + j191.3 ohms. Considering that the input impedance of a three-element folded dipole is precisely twice the input impedance of the equivalent three-element folded unipole, one obtains 658.2 + j382.5 ohms as the input impedance of an isolated three-wire folded dipole. If adjustments are made to insure simultaneous resonance with respect to the symmetrical and antisymmetrical components of current, the three-element folded dipole described will present a resistive load of approximately 600 ohms to the driving transmission line.

Figure 11.

*Four-wire folded unipole being driven by a generator system electrically equivalent to the system pictured in figure 10.*





## N-Element Folded Dipole

An analysis of the operation of a folded dipole consisting of N identical wires equally spaced about the periphery of two metallic rings, one wire being center-driven, proceeds as follows: Replace the N-element folded dipole by an N-element folded unipole located over a large perfectly conducting surface. The antenna is driven by a single generator connected between the lower extremity of one wire and ground. Next, a system of idealized generators is introduced in lieu of the single driving generator. The number of them and their phase relationship is readily established, as indicated below. For each horizontal row of generators the phase factor P must always satisfy the equation

$$\sum_{q=0}^{n} P^q = 0 \tag{2}$$

for electrical symmetry to obtain. In (2) $n = N - 1$. Also the number of phase sequences required (and hence the number of generators needed in each vertical wire) is n. Observe that

$$\sum_{q=1}^{n} P^q = -1 \tag{3}$$

so that the vector sum of the voltages effective in each wire (with the exception of the wire containing n generators operating in the same phase) is always the voltage of a single generator having polarity opposite to the generator establishing the reference for phase in the system. Accordingly, the N phase problem is reduced to a single phase problem. Reference is made to figure 10. Here $N = 4$ and $n = 3$. Obviously a total of $N^2 - N + 1$ ($= 13$) generators are needed. The equivalent arrangement of figure 11 requires $2N - 1$ ($= 7$) generators. For this case the input impedance (by inspection) is

$$NV/(I/N) = N^2 \frac{V}{I} (= 16\,V/I)$$

The formula for estimating the input impedance of an N-element folded unipole (or N-element folded dipole) is therefore

$$Z_{in} = N^2\, V/I \tag{4}$$

The ratio V/I is usually taken as 36.57 + j21.25 ohms for an N-element folded unipole, and 73.13 + j42.5 ohms for an N-element folded dipole.

Readers are reminded that (4) is an approximate formula only. Relatively large errors in calculating the input impedance of N-element folded antennas may result when $N > 3$. Also the ratio V/I depends in a very fundamental way on the number of wires involved, on their length and radius, and the gap width at the driving point.

# NETWORK THEOREMS APPLIED TO RECEIVING ANTENNAS

*By* Lieut. Comdr. Charles W. Harrison, Jr., USN

*Electronics Design Division, Bureau of Ships*

Several papers [1,2] have been devoted to an analysis of the receiving antenna when it is oriented in an arbitrary way with respect to a linearly or elliptically polarized field. Specifically, a solution of the problem concerning the voltage developed across a given complex load impedance, in terms of the incident electric field, and the physical characteristics of the receiving antenna, was suggested.

A procedure, involving the use of certain network theorems, was developed for loading an unloaded receiving antenna. The purpose of the present article is to outline a method for inserting the load impedance at the center of a symmetrical receiving antenna, which is believed to be more simple and straightforward than that employed in the earlier work.

Let it be assumed that the current distribution along an unloaded receiving antenna (a straight section of wire of length 2h and radius a) is known. The actual determination of the current flowing along a wire immersed in an electric field (or, more correctly, an electromagnetic field) of arbitrary polarization is a boundary-value problem of electromagnetic theory. An improvement in the analysis of the receiving antenna, over that previously pub-

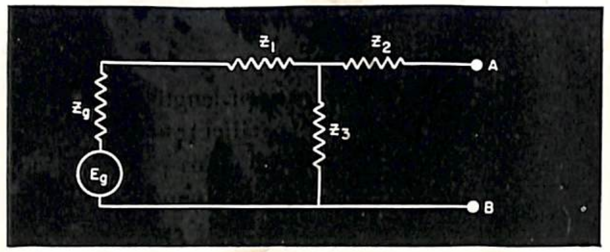



FIGURE 1—*Network consisting of a T section actuated by a voltage source.*

lished,[1, 2] might be effected by following the lines of the improved solution of the problem concerning the driving point impedance of a symmetrical center-driven antenna;[3] viz., one would choose the appropriate expansion parameter and distribution function associated with the receiving antenna.

Now if the distribution of current along the wire is known, the current at the center of the wire is also known, and this may be regarded as the *short-circuit current* flowing between two close-spaced fictitious terminals where ordinarily the load impedance (radio receiver) would be connected.

According to the analysis of the receiving antenna published earlier, the *leading term* in the complicated series for the short-circuit current at the center of the wire is given by

$$I_{sc} = \frac{j\mathcal{E}}{30\beta\Omega}\left\{\frac{1-\cos\beta h}{\cos\beta h}\right\} \quad \ldots\ldots \quad (1)$$

Here $\mathcal{E}$ is the incident electric field; $\beta$ $(=2\Pi/\lambda)$ is the propagation factor, $\lambda$ being the wavelength. ($\beta h$ is the radian half-length of the antenna — h is its half-length in meters if $\lambda$ is expressed in meters.) The factor $\Omega$ is defined by

$$\Omega = 2\log_e \frac{2h}{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where, as stated previously, a is the radius of the wire employed.

If the electric field vector $\mathcal{E}$ is tilted with respect to the axis of the receiving antenna, the phase of the field is not instantaneously the same at all points along the wire. This is of great importance, for the distribution of current depends in a very fundamental way on this progressive phase shift. Equation (1) is valid only when the incident field is

(a) Linearly polarized

(b) Sensibly constant in amplitude over the full length of the wire.

(c) Directed tangential to the axis of the wire.

Additionally, in deriving (1), the assumption of a perfectly conducting wire is made.

[1] Ronold King and Charles W. Harrison, Jr., "The Receiving Antenna," Proc. I.R.E., Vol. 32, pp. 18-34, January 1944.

[2] Charles W. Harrison, Jr., and Ronold King, "The Receiving Antenna in a Plane-Polarized Field of Arbitrary Orientation," Proc. I.R.E., Vol. 32, pp. 35-49, January 1944.

[3] Ronold King and David Middleton, "The Cylindrical Antenna: Current and Impedance," Quart. Appl. Math., Vol. 3, pp. 302-335 (1946).

Of some interest is the expression for the current at the center of a symmetrical center-driven (transmitting) antenna corresponding to (1). It is given by

$$I_o = j\,\frac{2\Pi V_o^e}{R_c\,\Omega}\tan\beta h \quad \ldots\ldots\ldots\ldots \quad (3)$$

Here $V_o^e$ is the externally applied voltage.
$R_c$ is the characteristic resistance of space.

$$R_c \backsimeq 120\,\Pi \text{ ohms.}$$

The input impedance, as obtained from (3), is a pure reactance having the value

$$Z_{in} = V_o^e/I_o = -j60\Omega\cot\beta h \quad \ldots\ldots\ldots\ldots \quad (4)$$

Since (3) is only the *leading term* in a complicated series for the driving point current, (4) must represent only the leading term in a complicated series for the driving point impedance. It is worth mentioning that a base-driven vertical antenna, of full length h and radius a, erected over a perfectly conducting earth, has an input impedance equal to one-half that given by equation (4).

In order to insert a load in the center of the unloaded receiving antenna, it is desired to make use of a network theorem formulated by the writer. This theorem may be stated as follows:

"If two terminals of a network composed of linear bilateral impedances be short-circuited the resulting short-circuit current multiplied by the impedance looking back into the network, with all generators replaced by their internal impedances, results in the open-circuit voltage at the terminals in question."

Proof of this theorem may be accomplished, though possibly not with full mathematical rigor, as indicated below: Reduce the given network to an equivalent T section. This can always be done because at a single frequency any network composed of linear bilateral impedances, having two input and two output terminals, may be replaced by a T section. Figure 1 represents the network reduced to an equivalent T with generator of

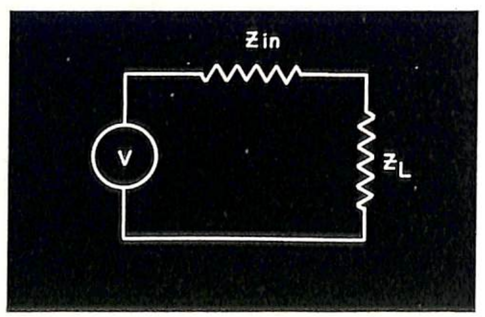



FIGURE 2—*Equivalent circuit of a receiving antenna.*



internal impedance $Z_g$ connected. Find an expression for the open-circuit voltage V appearing across the terminals AB. Short-circuit terminals AB, and find an expression for the short-circuit current $I_{sc}$. Find an expression for the impedance $Z_{in}$ looking to the left from terminals AB. (Short-circuit the generator $E_g$, but leave $Z_g$ in the circuit.)

Then

$$V = I_{sc}Z_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

To apply (5) to the problem of the receiving antenna, one simply multiplies equation (1) by equation (4):

$$V = V_{sc}Z_{in} = \frac{2\mathcal{E}}{\beta}\tan\frac{\beta h}{2} \quad \ldots\ldots \quad (6)$$

Let
$$2h_e = \frac{2}{\beta}\tan\frac{\beta h}{2} \quad \ldots\ldots\ldots \quad (7)$$

then
$$V = 2h_e\mathcal{E} \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

It is evident that V in (6) represents the voltage (open-circuit) that appears across the output terminals of the receiving antenna. (The antenna is open-circuited at its center.) The quantity $2h_e$ is defined as the "effective length" of a receiving antenna for lack of a better term. It is dimensionally a length. The effective length of a base-loaded vertical receiving antenna located over a perfectly conducting earth is $h_e$: For this case

$$V = h_e\mathcal{E} \quad \ldots\ldots\ldots\ldots \quad (9)$$

Equations (8) or (9) by no means constitute a general theory for the receiving antenna. They are restricted in their application as indicated above; the standard references on radio and electronics engineering notwithstanding. Since (8) or (9) depends on $Z_{in}$, it might be well to point out that the impedance looking into the receiving antenna is passive in character, i.e., the incident field $\mathcal{E}$ is presumed to be absent, and corresponds directly to the input impedance of a transmitting antenna having physical dimensions identical to those of the receiving antenna under discussion.

Having determined the open-circuit voltage across the output terminals of the receiving antenna, one employs Thevenin's theorem to determine the voltage developed across the load impedance. This theorem states that the current in the load impedance is the same as though this impedance were connected to a generator whose generated voltage is the open-circuited voltage at the terminals in question and whose impedance is the impedance looking back from the terminals, with all generators replaced by their internal impedances.

For purposes of determining the voltage developed across the load impedance, one develops the "equivalent circuit" of the receiving antenna, as shown in Figure 2. Here the voltage V is inserted in series with the impedance $Z_{in}$ and the load impedance $Z_L$. One solves for the voltage developed across $Z_L$, employing Ohms Law.

## Application of Theory—Numerical Illustration

A vertical receiving antenna of length $h = \lambda/4$ is base loaded by an anti-resonant (parallel resonant) circuit presenting an impedance of 5,000 ohms pure resistance between the antenna terminal and ground. The input impedance of the receiving antenna, if employed for transmitting, is $Z_{in} = 38 + j22$ ohms (this impedance is a function of the antenna length and radius, and therefore involves the physical properties of the antenna). Assume that a vertically polarized electric field $\mathcal{E}$ of 31.42 $\mu$ volts per meter exists in the vicinity of the receiving antenna due to the motion of charge in the distant transmitting antenna. The wavelength $\lambda$ is 250 meters. It is desired to calculate the voltage developed across the parallel resonant circuit. (*Note*: The assumption of a perfectly conducting earth is satisfactory at broadcast frequencies and at longer wavelengths.)

One has

$$\beta h = \left(\frac{2\Pi}{\lambda}\right)\left(\frac{\lambda}{4}\right) = \frac{\Pi}{2}\,. \quad \operatorname{Tan}\frac{\beta h}{2} = 1.$$

Accordingly from (7), $\quad h_e = \dfrac{125}{\Pi}$ meters.

From (9) $\quad V = \dfrac{125}{\Pi} \times 31.42 = 1250\ \mu$ volts.

One now inserts the voltage V in series with the impedance $Z_{in} = 38 + j22$ ohms and the impedance $Z_L = 5{,}000 + j0$ ohms, and solves for voltage $V_L$ across the load. It is given by

$$V_L = \left|\frac{1250 \times 5{,}000}{5{,}038 + j22}\right| \backsimeq 1242\ \mu \text{ volts.}$$

Although it is customary in elementary treatments of the receiving antenna to employ (8) or (9) in the solution of problems, this procedure is not too "scientific" when the impedance (resistance and reactance) of the receiving antenna is specified and employed in forming the "equivalent circuit" of the receiving antenna. It is to be remembered that these expressions are based on the premise that the input impedance of a driven antenna (having dimensions the same as those of the receiving antenna under discussion) is a pure reactance. Accordingly to be absolutely consistent, it appears that only the reactive component of the driving point impedance of the receiving antenna should be used in the equivalent circuit.

No mention has been made regarding the legitimacy of employing network theorems to solve antenna problems, but in the opinion of at least one writer,[4] it is safe to assume that the network theorems apply if properly interpreted.

[4] A. F. Stevenson "Relations Between the Transmitting and Receiving Properties of Antennas," Quart. Appl. Math., Vol. 5, pp. 369-384 (1948).

# MONTHLY PERFORMANCE AND OPERATIONAL REPORT

In conformance with a recent Bureau of Ships request, vessels are required to submit by confidential letter a Monthly Performance and Operational Report on certain communication equipments. These equipments are:

Model TDZ Transmitter
Model RDZ Receiver
Model MAR Transmitter-Receiver
Model RDR Receiver
Model FRA Frequency Shift Converter
Model OCT Frequency Shift Monitor
Model TS-587/U Noise-Field Intensity Meter (only when used during the month)

It is essential that the Bureau receive these reports in order to keep informed on new equipment performance and operation. These reports provide the Bureau with first-hand information under actual operating conditions and are, therefore, of extreme value. Some of the details for the report may be obtained from the ship's Electronic History Cards and installation records, which should be accurately kept. The balance of the form must be filled in from actual operation and performance of the equipment.

One copy of the report should be sent to the Bureau of Ships, Code 980, beginning at once. Coast Guard vessels submitting reports should send one extra copy to Commandant, Coast Guard. Any other copies of the report are to be made as directed by the type or fleet commanders.

An outline of a sample form is included with this article. An explanation of items (A) through (K) inclusive, as referred to in the form, follows:

A—*Total Hours of Operation to Date During This Period.* If possible, indicate the total hours the equipment has been in operation from the date of installation to the date of the report. Also, indicate the hours the equipment has been in operation since the last monthly report.

B—*Total Hours of Operation Lost During the Period Covered by This Report.* The time lost refers to equipment shutdowns due to component and tube failures and other troubles which prevented normal operation.

C—*General Performance.* Comments pertaining to general performance should be noted as "Excellent," "Good," "Fair," or "Poor." This should be followed by a statement of the general reasons which contributed to the description given, such as "Equipment is very reliable, steady, easily tuned and put into operation," or it may be stated that the "Equipment is more dependable since personnel have become more familiar with it," etc. If the equipment has an oscilloscope, state whether the figure was readily-discernible, persistent, clear, etc.

D—*Operational Difficulties.* Give detailed information as to the troubles encountered in operation. This will include not only the failures encountered but also the troubles in getting the gear started, such as time consumed in warm-up, tuning, etc. (The report is not to take the place of the NavShips 383 failure report.) Any exceptional maintenance required should be reported. If any improvement could be made in the operation to eliminate lost time, failures, or unnecessary motion and action on the part of the operator, it should be reported.

E—*Location, Length and Height of Antenna above W.L.* This data can be obtained from installation records and plans. State type of antenna: wire-rope, whip, dipole, etc.

F—*Length and Type of Antenna Lead-in.* This should include only the non-radiating portion of the antenna inside a trunk or coaxial cable.

G—*Maximum Reliable Range for Period of This Report.* State the known maximum range at which reliable communications were maintained together with the frequency used.

H—*Field Changes Accomplished.* This data can be taken directly from the Electronic Equipment History Cards, which should be kept up to date. Give only the numbers of the field changes that have been completed.

I—*Suggested New Applications.* New uses for the equipment or suggested changes in use of equipment to achieve better results, which are not covered in current instructions, should be reported. Some of these uses may be discovered by chance or from proposals by the operators or maintenance men. This is not to be construed as authority to modify the gear in any way.

J—*Electronics Maintenance Personnel.* List the rank or rating and experience of the electronics maintenance personnel assigned to maintain the equipment.

K—*General Remarks.* Add here any remarks not covered in the above items.





*Sample Form*

COMMUNICATION & COUNTERMEASURES EQUIPMENT
MONTHLY PERFORMANCE & OPERATIONAL REPORT

Ship ______________________ Period of Report ______________

Equip.: Model ______________ Serial No. ______________ Date of Instal. ______________

Installed by ______________________

A. Total Hours of Operation to Date ______________ During this Period ______________

B. Total Hours of Operation Lost During Period of this Report ______________

C. General Performance ______________

D. Operational Difficulties ______________

E. Location, Length and Height of Antenna above W.L. ______________
(Indicate Navy Type No., If Any)

F. Length and Type of Antenna Lead-in ______________

G. Max. Reliable Range for Period of this Report (State Freq. Used) ______________

H. Field Changes Accomplished ______________

I. Suggested New Applications ______________

J. Electronics Maintenance Personnel:

K. General Remarks:

Signed ______________

*Initial reports may be prepared on typewriter pending issue of NavShips forms which will be available in district publications and printing offices about April 1, 1949.*


★ In response to this department's query in the December issue of ELECTRON, a little bird (who doesn't want his name mentioned) told us that the December issue of *Electrical Communication,* published by I. T. & T., carried a story on the inventor of the cathode-ray tube. This story gave the credit to Ferdinand Braun, a German who described his invention in a paper published in 1897.

But this isn't enough. We still want a story on the history of the cathode-ray tube, and are depending on someone in the field to submit one. Perhaps the I. T. & T. journal will give someone the needed "inspiration."—Ed.

## How did "Radio" get into Radio?

Sirs:

Most of us are under the impression that the term "radio" was used before the term "wireless." This is not strictly so.

The present use of the word "radio," replacing the older terms "wireless telegraphy" and "wireless telephony," came into use about the time of the First World War. This was not the first use of the word "radio" in radio, however. The principal part of the Popoff-Ducretet receiver of 1900 was a detector called the "radioconductor."

The First World War (1917) therefore did not start the word "radio," as is generally supposed. It was directly responsible for considerable improvement in the established art of "Long Distance Hertzian Radio Telegraphy," however, and in addition, the introduction of voice transmission by radio.

Incidentally, the old Popoff-Ducretet receiver was fitted with a "Morse recorder." This device was equipped with an alarm bell to alert the operator.

M. E. EASON

Code 975 b,
Electronics Shore Division,
Bureau of Ships.

★ Mr. Eason should know. Man and boy, he's been in the radio game since 1902. After finishing twenty years on active duty with the Navy, he entered Civil Service where he has served Uncle Sam ever since.

Mr. Eason is a well-known figure. He operated the first radio equipment procured by Navy contract (*U.S.S. Denver,* 1904); he installed the first remote-control station to be used by the Navy, on the success of which depended the many remote-control stations of the present-day Navy; he was largely responsible for the installation of the Navy's first underground radio transmitting and receiving station at Corregidor Island; he engineered the installation of all the Navy shore radio equipment placed in service between Peiping, China, and Manila prior to 1941.—Ed.

## THAT Singing Palm . . .

Sirs:

The phenomenon of a modulated radio-frequency arc acting as a radio receiver is nothing particularly new. The coincidental circumstances of having a load impedance which acts simultaneously as a demodulating non-linear impedance and as an acoustical transducer is easily satisfied by an electric arc. It is probable that the phenomenon observed was of this nature where the arc produced by the grounded transmission line was sustained because of the rather poor "short" afforded by the palm tree. While this tree was apparently a fair ground return conductor due to its moist, pithy interior (as indicated by its edibility) the continual carbonization of the trunk maintained an impedance sufficiently high to sustain one or more arcs. The function of demodulation normally performed by the non-linear detector of a radio receiver was accomplished by the non-linear impedance of the arc. Once the arc was produced, a relatively low impedance path was provided to ground and the audio-frequency component of demodulation was manifested by altering the power dissipated in the arc. This low frequency variation of the arc power produced corresponding rapid variations in the temperature of the surrounding atmosphere which in turn produced audible sound. This phenomenon of an arc acting as an acoustical transducer was observed in the last century by Tesla and a method of using an arc as a demodulating circuit element was established by W. Duddell as early as 1900. As an indication of the early recognition of this phenomenon, G. G. Blake in his "History of Radio Telegraphy and Telephony" (1928) gives a rather detailed discussion of a proposal to use an electric arc as an elementary form of radio speaker.

JOHN A. CONNOR

Electronics Engineer
Radio Techniques Section
U. S. Naval Research Laboratory

## Naval Reserve in the Third N.D.

Sirs:

Just received the December 1948 issue of Electron and found it full of interesting dope as usual.

However, am slightly irked by the story on the 3rd Naval District Naval Reserve Electronic Warfare Program. Obviously it was not edited by BuPers (Pers–ID6) before publication. There are numerous errors of nomenclature and several of fact!

I suggest you obviate future errors of this nature by checking with several in BuPers or CNO who are in close contact with the Naval Reserve Electronics Warfare Program.

D. S. WICKS
Commander, USN

U. S. Naval Base
Norfolk, Virginia

Sirs:

The article entitled "The Naval Reserve Electronics Program at the Third Naval District" was noted in the December 1948 issue of BuShips ELECTRON NavShips 900,100. This office wishes to express its deep appreciation for this well-written article which gives a comprehensive description of the electronic materiel installation program as conducted in the Third Naval District and the co-ordinated efforts of the District Director of Training and the New York Naval Shipyard toward effecting a successful and efficient Reserve training program. The history of this program is well covered and indicates the efficient and thorough planning undertaken by the New York Naval Shipyard Electronics Officer. He has recently had assigned to his staff as Assistant for Naval Reserve Electronics an experienced electronics officer, formerly Assistant to the District Reserve Electronics Officer under the District Director of Training. Since the inception of the post-war Naval Reserve and during the organizational stages of the Electronics Warfare Program, the District Director of Training was assisted by this officer, who took full responsibility for the procurement and furnishing of electronic materiel to the Organized and Volunteer activities as they became activated.

The District Reserve Electronics Warfare Program Officer has noted with genuine pleasure and satisfaction the ship-shape manner in which the shipyard EO has planned and engineered the installation of several Naval Reserve Training Centers in this District. Electronic items originally in short supply are now being furnished by BuShips and are in readiness in Naval Reserve stocks for immediate installation, shortly after the completion date of the scheduled construction of the Naval Reserve Training Centers and Facilities. Official inspections made by members of the Commandant's staff of completed centers have shown that electronic training equipment installed is being used for training of technicians and operators, who will be well qualified in their specialized rates and who upon mobilization day will be capable of filling billets and taking over duties and watches aboard vessels or shore stations without further indoctrination or training. This is the ultimate aim of the Reserve Electronics Warfare Training Program.

WM. C. BALL
Commander, USNR

District Reserve Electronics Warfare Program Officer
Federal Office Building
90 Church St.
New York 7, N. Y.


GET YOUR FACTS STRAIGHT! Start your preventive and corrective maintenance by studying your instruction books, C.E.M.B., R.M.B., Sonar Bulletin and ELECTRON.

# MODELS QHB/-1

## DRIVER TUNING AND ALIGNMENT

The test procedure described herein is intended for use on all vessels having Models QHB or QHB-1 Scanning Sonar Equipments installed, and for all service activities afloat or ashore performing original installation work or servicing these equipments. It is highly desirable that the procedure given here be carried out at least once every six months on all QHB series equipments. The instruction books referred to are NavShips 900,976, *Preliminary Instruction Book for Model QHB,* and NavShips 900,976(A), *Instruction Book for Models QHB and QHB-1.*

1—Follow through item by item the *Initial Checks and Adjustments* procedure described in Section 3, Paragraph 3 of the instruction book.

2—Make all *Normal Operating Equipment Adjustments* contained in Section 3, Paragraph 4 of the instruction book.

3—Each vessel having a Model QHB/-1 installed has a Model OCP-1 Sonar Portable Testing Equipment on its allowance list. Suspend the hydrophone of this monitor, with a 25-pound weight attached, by a line from the bullnose at the bow of the vessel. The hydrophone should be suspended so that its midpoint lies in the same horizontal plane as the center of the QHB transducer. An inspection of the docking plan of the particular vessel will indicate the depth of the fixed-dome sound window (and, consequently, the depth of the transducer within the dome) with reference to a particular load draft line.

4—Connect the OCP-1 hydrophone to the monitor amplifier unit. Connect the monitor power cord to a convenient source of 115/1/60 a.c. Tune the monitor to approximately 25.5 kc and switch it to TRANSMIT position.

5—Attach the input leads of a vacuum-tube voltmeter (Navy Model OBQ or a commercial Ballantine) to terminals 1A-51 and 1A-52 in the QHB console. Connect the power lead of the v-t voltmeter to a 115/1/60 a-c source. Throw switch S-109 inside the QHB console panel to the RELATIVE position. Turn the QHB equipment on and switch it to the LISTEN position.

6—A noise spoke should appear on the QHB console scope at approximately 000° relative. Train the scope cursor (listening channel) to the point of maximum audio output as indicated by the v-t voltmeter deflection. Set the master gain control on the QHB console at position "3" or "4." Adjust the OCP-1 output attenuator until the v-t voltmeter reads approximately 15 volts, or until a single low-level noise spoke appears on the QHB scope. *Leave the QHB master gain control and the OCP-1 output control at the position just established for the remainder of these tests.* If maximum audio output is not indicated at 000° relative cursor train, reposition the OCP-1 hydrophone right or left as necessary until this condition is obtained.

7—If the scope cursor does not bisect the noise spoke on the scope, it will be necessary to shift the position of B-405 in the scanning switch assembly. This should be done as described on Page 7-67 of NavShips 900,976 and Page 6-4 of NavShips 900,-976(A) until the cursor bisects the scope noise source at 000° relative. Lock B-405 in this position and replace its electromagnetic shield.

8—Disconnect the v-t voltmeter from the QHB audio output terminals 1A-51 and 1A-52. Switch the OCP-1 to RECEIVE. Key the QHB manually and observe the meter deflection on the OCP-1 while an assistant tunes the QHB driver by rotating the MASTER OSCILLATOR TUNING dial in the transmitter-receiver unit very slowly on each side of 25.5 kc. The tuning dial should be locked in the position which gives maximum output as indicated by the OCP-1 meter deflection.

9—Disconnect the OCP-1 monitor and the OBQ v-t voltmeter. Check the wiring and close all cabinets in the QHB units. The QHB equipment may now be assumed to be tuned to maximum driver output and adjusted for optimum bearing.

### Increased Use of TDZ/RDZ

Readers of ELECTRON will be pleased to read the following note quoted from a letter received from the desk of the Commander, Battleships and Cruisers, U. S. Atlantic Fleet:

"The use and reliability of Model TDZ/RDZ u-h-f equipment is definitely increasing. Cruiser Division Ten has continued to use u.h.f. and the C. I. net without a secondary circuit most of calendar year 1948, reporting good success within a reliable range of ten to twelve miles, and has now added a primary tactical maneuvering circuit on u.h.f. Battleship-Cruiser communications within the horizon were satisfactory on u.h.f. during the Midshipmen Cruise. Other ships have isolated their difficulties and in some cases have experienced ranges in excess of TBS."





# MODEL OKA SWITCH ALTERATION

At present, the Navy Type -24814 Keying Interval Switch Symbol S-204 of the CAN-55199 Sound Range Recorder of the Model OKA Sonar Resolving Equipment can be locked in only two positions. To permit locking the switch in three positions, the following procedure, suggested by D. Cree, SO1, of the DD-871, should be followed. The part needed (Part A) is a metal rod approximately 1/2″ x 3/16″ (see figure 1), and the time required is one hour.

1—Remove cursor-range/range-rate panel (4 screws).

2—Remove keying interval control switch S-204 (4 screws).

3—Remove contact assembly from switch (2 screws).

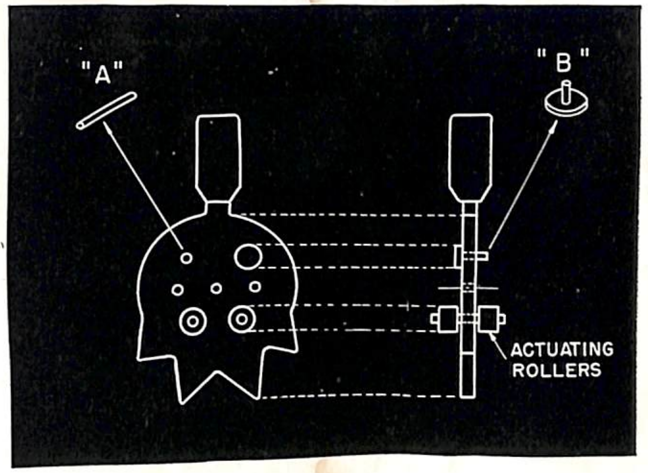
4—Remove blade. Use a center punch to remove axle pin.

5—Remove Part B from blade, and replace it with Part A. Be sure of a tight fit.

6—Reassemble switch and replace in equipment.

This procedure is to be known as "OKA—F.C. No. 1—Alteration to Permit Locking Switch S-204 in Three Positions."

FIGURE 1—*Two views of switch S-204.*




# MODEL TDQ ANTENNA FAILURES

Several reports have been received by the Bureau recently concerning failure of the Type-66095 antenna as used with the Model TDQ Radio Transmitting Equipment. Many of the reports state that the mounting gaskets deteriorate over a period of time, allowing moisture to enter the housing and thereby grounding the antenna. Investigation reveals that these faults can be attributed either to poor installation or a loosening of the bolts due to vibration.

As to the former cause, installing activities are cautioned to install the gaskets and insulators properly and make sure that the bolts are drawn up tight. Glyptol should be applied to the bolts to aid in preventing them from becoming loose.

The cause of the majority of failures is vibration. It is therefore necessary that the type -66095 antennas be inspected for low resistance and grounds more frequently than in the routine maintenance procedure. It is recommended that when low radiation strength and weak reception are experienced, the arrays should be disassembled and inspected—failures of this type cannot be determined by visual inspection alone. After inspection and cleaning, the arrays should be reassembled. Maintenance personnel should use new gaskets and take care that the gaskets and insulators are installed properly and that the bolts are drawn up tight. Glyptol should again be applied to the bolts in each instance to insure against loosening due to vibration.

To illustrate the importance of close inspection and proper maintenance, a number of cases have occurred where alteration requests were made for relocation of the antenna. Investigation disclosed that the antenna had a ground or short. After the antennas were repaired, the efficiency was brought up to such a degree that the need for relocation was unnecessary.

The gaskets are carried as part of the equipment, tender and stock spares. Figure 1 is an illustration of the antenna and shows the gaskets, 0-601, 0-602, and 0-604 that should be checked.

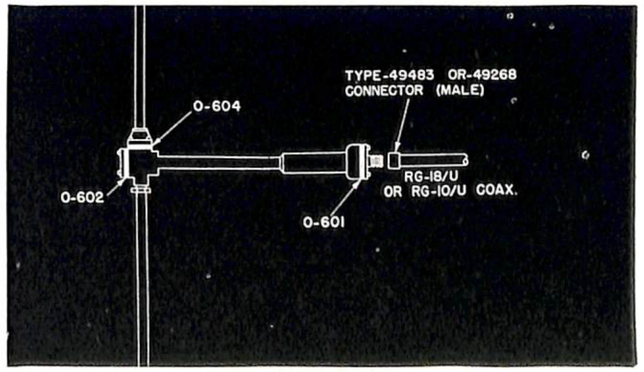



FIGURE 1.

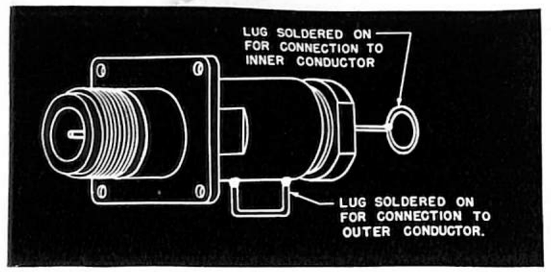
# MEGGER ADAPTER
## FOR CABLE TESTING

Here's another useful beneficial suggestion. It was submitted by Don M. Kinder, civilian worker employed at Puget Sound Naval Shipyard, and has been approved by the Bureau where its use may be beneficial.

Coaxial lines, cable fittings, jumpers, antennas, and similar equipment are often tested with meggers to detect shorts or faulty insulation. Coaxial lines or other equipment with cable fittings must be tested with the cable fittings in place in order to check the entire line. The coaxial fittings are small, however, and many parts are not readily accessible. Two men, therefore, are necessary to operate the megger satisfactorily—one to hold the megger leads so they won't short, and one to crank the megger and note the dial reading.

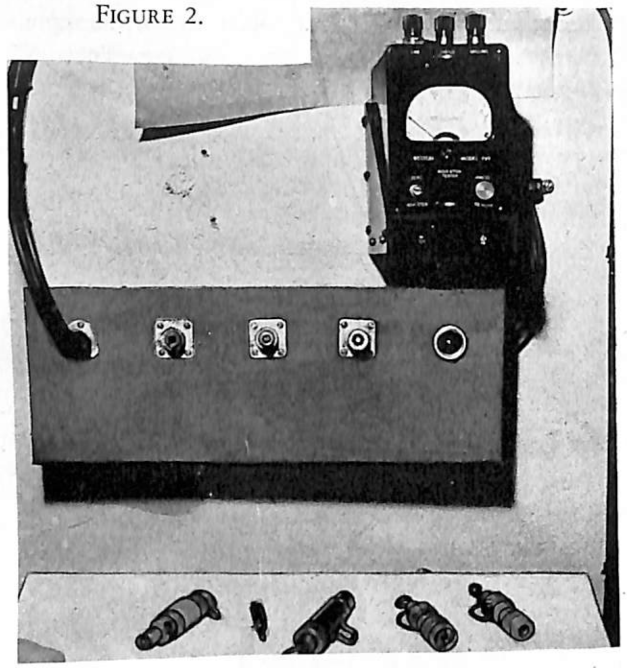
This beneficial suggestion enables one man alone to use the megger so that the other man is released for other service. Moreover, the one man will do the job more quickly and with less trouble. Erroneous readings sometimes obtained when the leads are hand-held are eliminated.

FIGURE 1.




The method is to fabricate special adapter fittings into which the cable to be checked may be inserted, and onto which the megger leads may be easily clamped. These adapters are made from ordinary cable fittings, modified as shown in figure 1. A fitting is chosen which will mate with the cable fitting on the cable under test. A lug in the form of a half-loop is soldered onto the outer conductor of the adapter. A wire is fastened to the inner conductor of the adapter, extending a few inches outside the adapter. This wire is then bent and soldered at the end to form a loop. Thus two lugs are provided (one to the outer conductor and one to the inner conductor). The megger leads will easily clamp onto these lugs, with little danger of shorting out. The technician merely plugs the cable into the adapter, clamps on the megger leads, turns the megger crank, and obtains his reading. These adapters have been in use in Shop 67 at Puget Sound for several months, and have proven highly satisfactory in all respects.

FIGURE 2.



It may be found convenient to have several of these adapters on hand to check coaxial cables with various types of fittings. If many checks are to be made, it may be advantageous to build a panel with a variety of adapters permanently fastened in place. (See figure 2.)

The Bureau suggests one caution in the use of these adapters: *It is imperative that the adapters themselves have no leaks or shorts. Otherwise, a satisfactory cable might be wrongly diagnosed as being faulty. These adapters should be regularly checked with the megger (with no fitting inserted) to insure their reliability.*

## CORRECTION TO QHB/–1 INSTRUCTION BOOKS

The parts lists contained in NavShips 900,976(A), the instruction book for Models QHB/-1 Scanning Sonar Equipments, and contained in NavShips 900,976, the preliminary instruction book for the same equipments, identify driver power transformer T-708 properly except that it is not identified as an oil-filled unit. Information from the A.S.W. field engineers indicates that an oil-filled transformer is supplied. Accordingly, it is requested that all activities add this information to the subject parts lists.





# ELIMINATION OF SPURIOUS OSCILLATIONS IN RDZ RECEIVERS

Recently the Bureau received a report of spurious oscillations in Model RDZ Radio Receiving Equipment. Considerable thought had been given to the problem. The trouble was located and several methods of correcting the condition had been determined.

The first source of trouble was in the scanning amplifier circuit, due primarily to the lack of proper termination of the scanning input receptacle. It was found that by providing proper termination and a shield for the receptacle a large percentage of the interference was eliminated.

A considerable amount of this work would have been eliminated by carrying out Field Change No. 4 for RDZ, which is mentioned in another ELECTRON item on this page. This field change has been made available to all Naval shipyards and regular stocking activities and is applicable to all RDZ's.

Additional oscillations were also reported in the fourth and fifth i-f amplifier stages. The causes of this condition are not corrected by Field Change No. 4 but were found to be as follows:

1—Filament leads, carrying relatively high current, laid closely against the tube grid connections, thereby causing coupling and feedback.

2—Poor grounds of socket clamps of fourth and fifth i-f amplifier tubes caused interstage coupling and regeneration.

Condition 1 was corrected by carefully dressing the leads away from the tube base connections.

Condition 2 was corrected by soldering a short lead between the ground lug on the tube socket clamp and lugs No. 1 and No. 3 of the sockets—particularly V–205 and V–206.

The Bureau solicits information of this character and urges all activities to continue passing it in.

## IMPROVING STABILITY OF RDZ I-F AMPLIFIER

Field Change No. 4—RDZ has been introduced to improve the stability of the i-f amplifier in the Models RDZ and RDZ-1 Radio Receiving Equipment (all models).

The scanning output of the RDZ/RDZ-1 is taken from the high potential side of the cathode resistor of the first i-f amplifier tube and ground, and fed through a length of RG-55/U 50-ohm coaxial cable to the SCAN output receptacle at the rear of the receiver. If a scanning unit such as an RDP is not included in the installation, the receiver SCAN receptacle is not suitably terminated and standing waves are set up in the receiver output cable. As a result, different degrees of phase displacement of the standing wave voltage peaks are present at the I-F and SCAN input terminals which, through stray couplings with other circuits, result in varying degrees of regeneration in various i-f amplifier stages. The stray couplings are materially reduced by installation of a shield and plug-in type dummy load for the SCAN receptacle which comprises a 47-ohm resistor in series with a 0.01-microfarad capacitor which serves to limit the standing-wave ratio.

These field change kits, with complete instructions for carrying out the change, can be obtained from the Electronics Officer of any Naval shipyard or from any Electronics Supply Center. Accomplishment of this change is considered within the capability of ship's personnel.

## TERMINATING COAXIAL LEADS

An improved method of terminating coaxial leads at terminal strips of radio and radar equipments has been submitted in the form of a beneficial suggestion by Ray A. Eaton, Elect. 1/c, of the Puget Sound Naval Shipyard. The present method uses a lug which is soldered to the inner conductor of the coaxial cable with no other support to prevent its breaking loose. This condition is shown in the upper cable of figure 1. On one installation of five coaxial leads in a Model VJ driver unit, all five leads were found broken

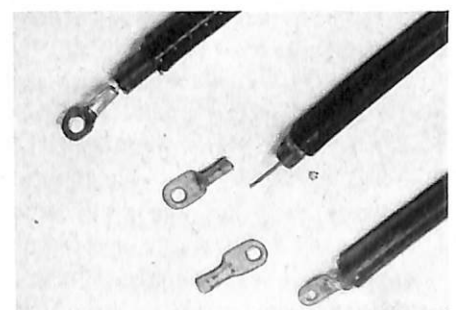


FIGURE 1—*Top, conventional termination showing lack of support for connection; center, terminal before assembly; bottom, new type termination showing additional support for inner conductor and lug.*

after less than 24 hours of operation. During preliminary equipment tests, the entire time of one mechanic has been spent replacing broken lugs caused by opening and closing unit doors.

In the method suggested by Mr. Eaton, a Burndy lug type (20–14) solder lug is slipped over the inner conductor and heated with a soldering iron. As the lug becomes warm, it can be forced under the polyethylene insulation, so that when it cools off it will have the additional support of the insulation. Next the inner conductor is soldered in the usual manner. This method affords a quick permanent connection that is as strong as the coaxial cable itself.

A completed termination is shown on the lower cable of figure 1. This system has been used for three months at the Puget Sound Naval Shipyard without a single failure. An experienced mechanic with a hot soldering iron can complete one unit (5 coaxial leads) in about five minutes—a saving of over three man-hours per unit.

When this method is used, the smallest size lug that will fit over the wire must be employed, so that a layer of polyethylene will remain between the lug and the outside conductor of the cable. When the termination is completed, it should be checked with a 500-volt megger before being used.

# FAILURE REPORT CARDS

During the last year there have been numerous articles appearing in the Electronics Publications on the subject of failure reports. Once again the Bureau desires to emphasize the importance of maintenance personnel submitting Failure Report Cards for every failure in electronic equipment.

Failure reports serve several excellent purposes. They provide the Bureau with a comprehensive presentation of the overall performance of electronic gear. They point out the weakest parts of any particular equipment, and they form a basis on which to procure spare parts. Reported failures are now being tabulated on IBM cards and regular summaries are being made to quickly show the number and type of failures of any component part for any equipment.

All of this goes to prove the necessity of reporting every failure, no matter how trivial, and of equal importance the necessity of reporting each failure accurately by properly filling out the cards (NavShips NBS 383). On the opposite page are shown two of the many failure reports received by the Bureau which are not properly made out and therefore have little value. These are excellent examples of what not to do.

The CAPX-211347 is a motor-generator for general radio use and is in no respect a part of TDZ-RDZ equipment as noted in figure 1. Therefore, naming TDZ-RDZ as the equipment in which the failure occurred is an error. Furthermore, why are two equipments listed? Each card is not only for just one equipment but for only one component in an equipment. Naturally, the TDZ-RDZ serial number is unknown because this equipment is not involved in the first place. The "brief description and cause of failure including approximate life" is the most enlightening of all information supplied. The word "undersize" tells the Maintenance Section in the Bureau actually very little. What happened to the excitor shaft? Did it twist or shear off? and where? What caused it?—lack of lubrication, freezing of bearings from overheating or gradual wear? Of course, we would like to know whether the m-g set operated satisfactorily for one hour or a thousand hours—it really does make a difference when writing design specifications for new motor-generators.

Figure 2 shows a card filled out apparently satisfactorily and it looks very neat but it still does not tell the story desired by the Bureau. It seems that the transformer checked good under no-load condition and no good when a load was applied.

We know it is possible for such things to happen but high resistance connections inside of a transformer are not very common. Did replacement of the transformer correct the trouble or was there a short across the filament of the rectifier tube? How long did it operate satisfactorily? Tell us the actual cause of failure whenever you can, or at least let us know what steps you take to correct it.

After these beautiful examples of what *not* to do, it is only reasonable to show a sample of the type of report *we want*. Here is one of the very few which are filled in completely.

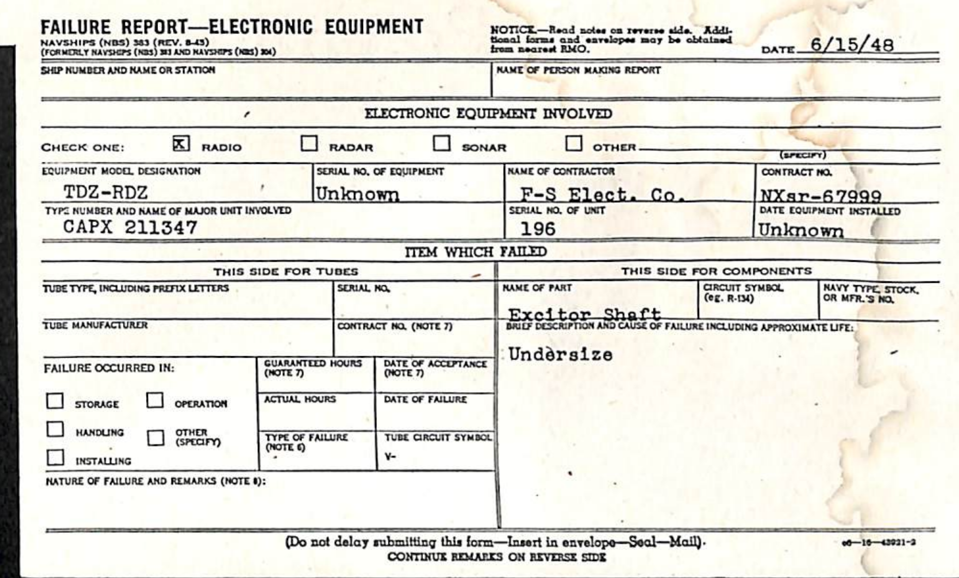
Note that in figure 3 every necessary detail is provided to give a clear picture of the failure, description, cause, corrective measures and approximate life.

A technician may take the attitude that submission of equipment failure reports for all failures reflects unfavorably on his ability to properly maintain the equipment for which he is responsible. Every technician who reads this article should rest assured that such is not the case. The Bureau wants to know about every failure; each failure report card, properly filled out, reflects only favorably on the ability of the technician.

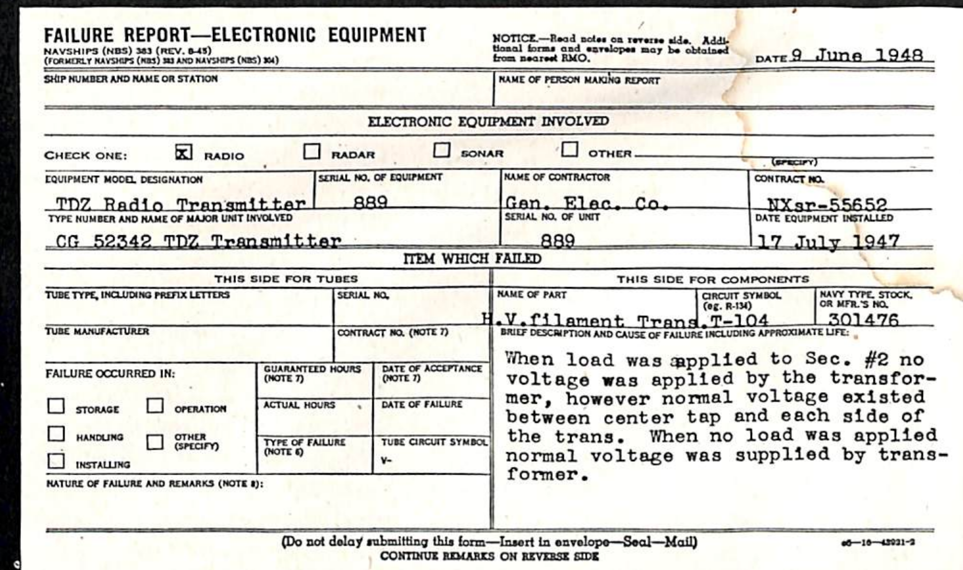




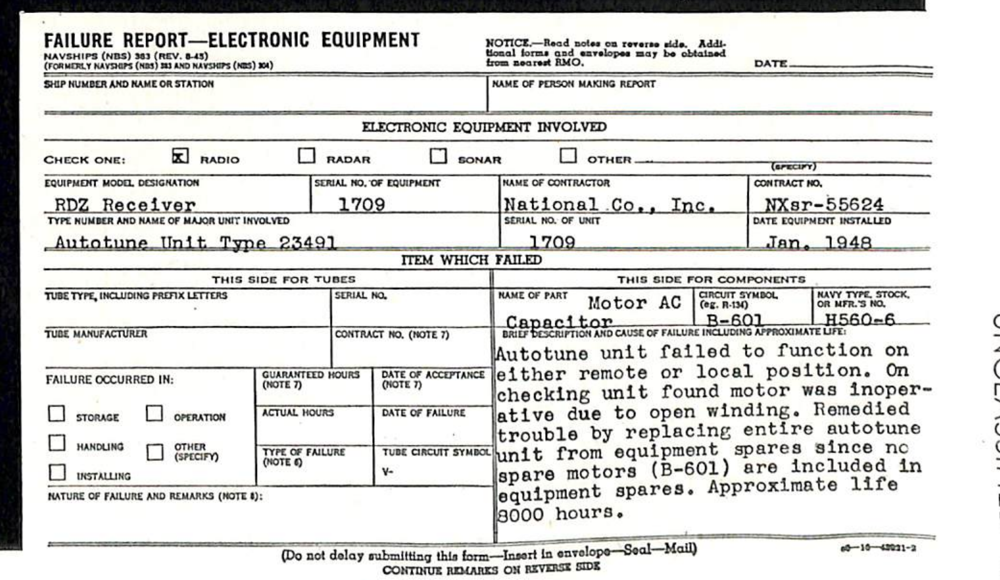
1


FAILURE REPORT—ELECTRONIC EQUIPMENT
NAVSHIPS (NBS) 383 (REV. 8-45)
(FORMERLY NAVSHIPS (NBS) 383 AND NAVSHIPS (NBS) 304)
NOTICE.—Read notes on reverse side. Additional forms and envelopes may be obtained from nearest RMO.
DATE 6/15/48
SHIP NUMBER AND NAME OR STATION
NAME OF PERSON MAKING REPORT
ELECTRONIC EQUIPMENT INVOLVED
CHECK ONE: [X] RADIO [ ] RADAR [ ] SONAR [ ] OTHER (SPECIFY)
EQUIPMENT MODEL DESIGNATION: TDZ-RDZ
SERIAL NO. OF EQUIPMENT: Unknown
NAME OF CONTRACTOR: F-S Elect. Co.
CONTRACT NO.: NXsr-67999
TYPE NUMBER AND NAME OF MAJOR UNIT INVOLVED: CAPX 211347
SERIAL NO. OF UNIT: 196
DATE EQUIPMENT INSTALLED: Unknown
ITEM WHICH FAILED
THIS SIDE FOR TUBES
TUBE TYPE, INCLUDING PREFIX LETTERS — SERIAL NO.
TUBE MANUFACTURER — CONTRACT NO. (NOTE 7)
FAILURE OCCURRED IN: [ ] STORAGE [ ] OPERATION [ ] HANDLING [ ] OTHER (SPECIFY) [ ] INSTALLING
GUARANTEED HOURS (NOTE 7) — DATE OF ACCEPTANCE (NOTE 7)
ACTUAL HOURS — DATE OF FAILURE
TYPE OF FAILURE (NOTE 6) — TUBE CIRCUIT SYMBOL V-
NATURE OF FAILURE AND REMARKS (NOTE 8):
THIS SIDE FOR COMPONENTS
NAME OF PART: Excitor Shaft
CIRCUIT SYMBOL (eg. R-134)
NAVY TYPE, STOCK, OR MFR.'S NO.
BRIEF DESCRIPTION AND CAUSE OF FAILURE INCLUDING APPROXIMATE LIFE: Undersize
(Do not delay submitting this form—Insert in envelope—Seal—Mail).
CONTINUE REMARKS ON REVERSE SIDE
e6—16—43921-2

2


FAILURE REPORT—ELECTRONIC EQUIPMENT
NAVSHIPS (NBS) 383 (REV. 8-45)
(FORMERLY NAVSHIPS (NBS) 383 AND NAVSHIPS (NBS) 304)
NOTICE.—Read notes on reverse side. Additional forms and envelopes may be obtained from nearest RMO.
DATE 9 June 1948
SHIP NUMBER AND NAME OR STATION
NAME OF PERSON MAKING REPORT
ELECTRONIC EQUIPMENT INVOLVED
CHECK ONE: [X] RADIO [ ] RADAR [ ] SONAR [ ] OTHER (SPECIFY)
EQUIPMENT MODEL DESIGNATION: TDZ Radio Transmitter
SERIAL NO. OF EQUIPMENT: 889
NAME OF CONTRACTOR: Gen. Elec. Co.
CONTRACT NO.: NXsr-55652
TYPE NUMBER AND NAME OF MAJOR UNIT INVOLVED: CG 52342 TDZ Transmitter
SERIAL NO. OF UNIT: 889
DATE EQUIPMENT INSTALLED: 17 July 1947
ITEM WHICH FAILED
THIS SIDE FOR TUBES
TUBE TYPE, INCLUDING PREFIX LETTERS — SERIAL NO.
TUBE MANUFACTURER — CONTRACT NO. (NOTE 7)
FAILURE OCCURRED IN: [ ] STORAGE [ ] OPERATION [ ] HANDLING [ ] OTHER (SPECIFY) [ ] INSTALLING
GUARANTEED HOURS (NOTE 7) — DATE OF ACCEPTANCE (NOTE 7)
ACTUAL HOURS — DATE OF FAILURE
TYPE OF FAILURE (NOTE 6) — TUBE CIRCUIT SYMBOL V-
NATURE OF FAILURE AND REMARKS (NOTE 8):
THIS SIDE FOR COMPONENTS
NAME OF PART: H.V. filament Trans.
CIRCUIT SYMBOL (eg. R-134): T-104
NAVY TYPE, STOCK, OR MFR.'S NO.: 301476
BRIEF DESCRIPTION AND CAUSE OF FAILURE INCLUDING APPROXIMATE LIFE: When load was applied to Sec. #2 no voltage was applied by the transformer, however normal voltage existed between center tap and each side of the trans. When no load was applied normal voltage was supplied by transformer.
(Do not delay submitting this form—Insert in envelope—Seal—Mail)
CONTINUE REMARKS ON REVERSE SIDE
e6—16—43921-2

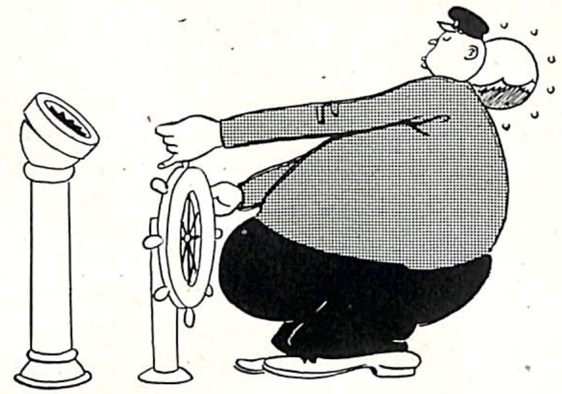
3


FAILURE REPORT—ELECTRONIC EQUIPMENT
NAVSHIPS (NBS) 383 (REV. 8-45)
(FORMERLY NAVSHIPS (NBS) 383 AND NAVSHIPS (NBS) 304)
NOTICE.—Read notes on reverse side. Additional forms and envelopes may be obtained from nearest RMO.
DATE
SHIP NUMBER AND NAME OR STATION
NAME OF PERSON MAKING REPORT
ELECTRONIC EQUIPMENT INVOLVED
CHECK ONE: [X] RADIO [ ] RADAR [ ] SONAR [ ] OTHER (SPECIFY)
EQUIPMENT MODEL DESIGNATION: RDZ Receiver
SERIAL NO. OF EQUIPMENT: 1709
NAME OF CONTRACTOR: National Co., Inc.
CONTRACT NO.: NXsr-55624
TYPE NUMBER AND NAME OF MAJOR UNIT INVOLVED: Autotune Unit Type 23491
SERIAL NO. OF UNIT: 1709
DATE EQUIPMENT INSTALLED: Jan. 1948
ITEM WHICH FAILED
THIS SIDE FOR TUBES
TUBE TYPE, INCLUDING PREFIX LETTERS — SERIAL NO.
TUBE MANUFACTURER — CONTRACT NO. (NOTE 7)
FAILURE OCCURRED IN: [ ] STORAGE [ ] OPERATION [ ] HANDLING [ ] OTHER (SPECIFY) [ ] INSTALLING
GUARANTEED HOURS (NOTE 7) — DATE OF ACCEPTANCE (NOTE 7)
ACTUAL HOURS — DATE OF FAILURE
TYPE OF FAILURE (NOTE 6) — TUBE CIRCUIT SYMBOL V-
NATURE OF FAILURE AND REMARKS (NOTE 8):
THIS SIDE FOR COMPONENTS
NAME OF PART: Motor AC Capacitor
CIRCUIT SYMBOL (eg. R-134): B-601
NAVY TYPE, STOCK, OR MFR.'S NO.: H560-6
BRIEF DESCRIPTION AND CAUSE OF FAILURE INCLUDING APPROXIMATE LIFE: Autotune unit failed to function on either remote or local position. On checking unit found motor was inoperative due to open winding. Remedied trouble by replacing entire autotune unit from equipment spares since no spare motors (B-601) are included in equipment spares. Approximate life 8000 hours.
(Do not delay submitting this form—Insert in envelope—Seal—Mail)
CONTINUE REMARKS ON REVERSE SIDE
e6—16—43921-2

# Bridge Circuits & Potentiometers

## BASIC PHYSICS

## PART 16



### The Law of the Conservation of Energy as Applied to Electrical Circuits

The transformation of potential energy to kinetic energy in an electrical circuit is brought about when the source of e.m.f. forces a current through the effective resistance of the load. Kinetic energy may become evident by the production of heat, chemical change, light, mechanical energy, or combinations of several of these or other forms. Around a closed electrical circuit the algebraic sum of the voltage-drops and the source of e.m.f. is *always* zero. If $E$ represents the algebraic sum of all the e.m.f.'s in the circuit, the energy supplied by these may be expressed as $EI$ units per second. If $R$ is the total effective resistance represented by the circuit, the energy expended in heating the circuit is $I^2R$ units per second. Then, by the Law of the Conservation of Energy,

$$EI = I^2R$$

or, $$E = IR$$

This is recognized as Ohm's Law, which expresses the relationship of voltage, current, and resistance in any electrical circuit. In other words, the sum of the e.m.f.'s in the circuit, which represent potential energy, equals the sum of the $IR$-drops in the circuit, which involve transformations to kinetic energy.

### Internal Resistance

Every device in practical use for supplying electrical energy to an electrical circuit has some internal resistance. This is often called the ohmic resistance of the device, although it is not a constant that can be defined by Ohm's Law. The internal resistance is determined by the chemical or electrical nature of the generating device, and varies from several hundredths of an ohm in large-capacity storage batteries to several ohms in electromechanical dynamos. Nevertheless, under given conditions, a portion of the energy supplied is used in heating the device through the heat energy developed as a result of current flow in the internal resistance.

As a result (see figure 1), when a current $I$ flows through a source of electromotive force in the direction in which the e.m.f. of the device tends to produce current, the potential difference across its terminals is found to be equal to $E - Ir$, where $r$ is the ohmic or internal resistance of the generating device, and the power delivered to the external circuit is $EI - I^2r$. However, if the current flows in the opposite direction to that in which the source of e.m.f. tends to produce current, the potential difference between the terminals of the device is then $E + Ir$, and the power delivered to the source of e.m.f. is $EI + I^2r$. This example is encountered in everyday life in the automobile storage battery, which gives up energy in supplying the requirements of the starting and lighting circuits. Energy is received by the battery when it is being charged by either an automobile generator or an external charging machine.

In general, when a current $I$ passes through an e.m.f.-generating device from its negative to its positive terminal, the device receives from the outside source of energy an amount of power equal to $EI$, although part of this power will be dissipated within the device. When the current passes through the device in the opposite direction, it gives up $EI$ units of power which are transformed from electrical power to some other form, such as mechanical power if the device is an electric motor.

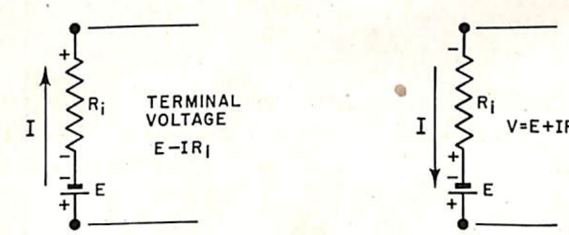



FIGURE 1—*Showing how the direction of current flow through the internal resistance of a battery affects the terminal voltage.*

In addition, $I^2r$ units of power are dissipated in heat within the device. From this example it can be taken that the transformation of energy involving the e.m.f. of the circuit is a reversible process, depending upon the direction of flow of current, but the transformation of energy involving $Ir$ is not reversible. The power dissipated in the internal resistance $r$ of the device is $I^2r$ and independent of the direction of the current in accordance with Joule's Law of electrical heating.

This is true in the devices such as batteries and dynamos which have been considered; thus, between the terminals of the e.m.f.-generating device, the measured potential difference may be expressed as

$$V = Ir \pm E$$

where $V$ is the potential difference, $I$ is the current, $r$ is the internal resistance of the device, and $E$ is the e.m.f. produced by the device.

### Voltage Drops in Electrical Circuits

When an electric current flows in an electrical circuit energy transformations occur in each component. Heat energy is developed that is proportional to the ohmic resistance of the component and the square of the current flow. At the same time, according to Ohm's Law, there will exist a potential difference across the component equal to the product of the current and the resistance, which is commonly referred to as the $IR$-drop. The polarity of this potential difference is always in the direction of the current flow, i.e. negative to positive, through the component.

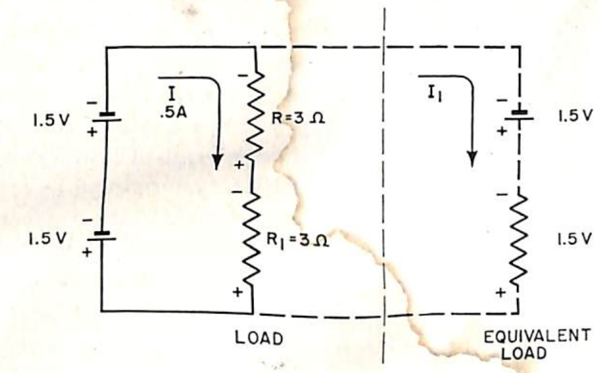



FIGURE 2—*An example of the numerical equality between the potential difference of an IR-drop and an equal source of e.m.f. across the component.*

For example, figure 2 shows a simple series circuit consisting of two ordinary dry cells which serve as sources of e.m.f., and two 3-ohm resistors as the load. The current caused to flow in the resistors as calculated by Ohm's Law is 0.5 ampere, and by applying Ohm's Law to each resistor it is found that the $IR$-drop across each resistor is 1.5 volts; the polarity, as indicated, is in the direction of current flow. If the algebraic sum of the voltages around the entire circuit is taken, it will be found to equal zero.

There is a theorem in geometry that states in effect: "Things equal to the same thing are equal to each other." This may be applied in the analysis of the circuit in figure 2. One of the 3-ohm resistors of the load is replaced by an identical dry-cell (The proper polarity is observed). Then a measurement, supplemented by calculation, will show that the $IR$-drop across the remaining 3-ohm resistor is unchanged. This indicates that potential difference is numerically the same whether measured across a source of e.m.f. or the resistive com-

---

*Within past months there have been many requests for reprints of certain chapters of Basic Physics or for back issues of* ELECTRON *containing them. Such requests can not be complied with for budgetary reasons.*

*These chapters on Basic Physics are written by the Training Section of the Bureau of Naval Personnel. When all chapters have been completed they will be published together as a BuPers training manual. For the present, as a chapter is finished it is published in* ELECTRON *for the benefit of the many readers who find it interesting and educational.*

*Personnel who "missed" certain chapters are urged to wait until BuPers completes work on this manual and publishes it in finished form.*

ponent in this electrical circuit, provided the internal resistance of the dry-cell is neglected.

In practice, the internal resistance can never be neglected, because the larger the current supplied by the device, the greater the loss within the device itself; however, for the purposes of circuit analysis, any e.m.f.-generating device is accompanied by its characteristic internal resistance as shown in figure 1.

In order to accurately determine the value of the e.m.f. of a generating device, it is necessary to perform the measurement without allowing the device to produce a current flow, as explained by figure 1. The common methods of voltage measurement may be divided into two classes; those that measure potential difference without the flow of current, and those that require a current flow.

Instruments that require no current from the generating device are divided into those actuated by electrostatic attraction or repulsion, and those that compare the unknown potential difference with the *IR*-drop in a wire of known resistance through which a constant current flows. The latter is the *potentiometer* type of instrument.

The instruments of the other class are actuated by the magnetic or the heating effect of an electric current. These instruments draw a small current, and can be used only when the potential is maintained as by a battery or dynamo. Thus the terminal voltage is decreased by the *Ir*-drop caused by the current demand of the instrument, since this current flows through the internal resistance of the generator. These instruments are generally classed as voltmeters. The resistance is great as compared to the internal resistance of the e.m.f. generator, so the current demand is usually small.

## The Principles of the Potentiometer Method

The e.m.f. of a cell is not given exactly by the reading of a voltmeter connected across the cell terminals, because even a high-resistance voltmeter takes some current, and, however small, this causes an *IR*-drop in the internal resistance of the cell, thus reducing the terminal voltage. Cell e.m.f.'s can be compared accurately with the known e.m.f. of a Weston standard cell by means of a potentiometer. An advantage of the potentiometer method is that the measurement is made when the cells are not supplying any current, and since there is no potential drop in the cells, the value measured is truly the e.m.f.

The potentiometer method of comparing potential differences or electromotive forces is credited to Poggendorf, and is now in common use for many purposes. The actual comparison is accomplished by utilizing the *IR*-drop along a wire of known resistance through which a constant current flow is maintained. There is a voltage drop along the wire that is proportional to the length; and accurate calibration is possible. Each unit of length will represent a unit *IR*-drop, and the total of these *IR*-drops will equal the applied e.m.f. A potentiometer is simply a series circuit constructed with a variable arm that permits contact to be made at any point between the ends of the resistance. Therefore, any value of potential difference less than the applied e.m.f. may be obtained by suitably moving the arm.

The Weston standard cell is a precise source of e.m.f. that is used internationally as a standard for the volt. It will maintain a constant voltage of 1.0183 volts over extended periods of time, provided that it is not required to supply current. Therefore, the Weston cell is perfectly suitable as a comparison standard with the potentiometer method, since this method does not require that the cell furnish current.

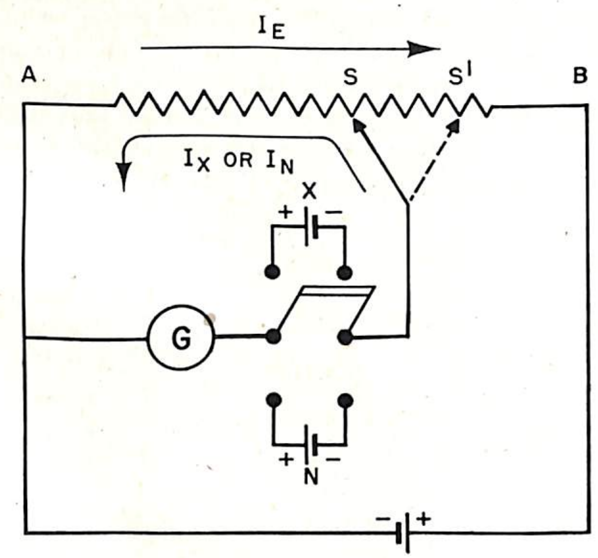



FIGURE 3—*Potentiometer arrangement to enable comparison of an unknown e.m.f. against a standard Weston cell of known e.m.f. by utilizing the* IR-*drop along* AB

The operation of the potentiometer method is illustrated by figure 3. A current $I$ from a battery $E$ flows through the potentiometer wire $AB$ and back to the battery. The battery $E$ usually has an e.m.f. of three volts, and this should be as constant as possible. The potential drop along this wire is $IR$, where $I$ is the current and $R$ is the resistance of the wire. A shunt circuit consists of a sensitive current-indicating galvanometer $G$ and a double-pole, double-throw switch to a variable contact on potentiometer wire $AB$. The switch permits the comparison of a cell of unknown e.m.f. $X$, against a standard Weston cell of known e.m.f. $N$.

To establish an *IR*-drop in the potentiometer wire equal to that of the known e.m.f. of the Weston cell $N$, the contact is moved along the wire to $S$ until the galvanometer indicates zero current. Then, since an equal potential difference exists across each section of the shunt circuit, e.m.f. $N = IR_s$. The switch is then thrown to the unknown cell $X$ and the contact moved on the potentiometer wire to point $S'$, until the galvanometer again indicates no current. When the potential drop along the wire $AS'$ is exactly opposed by the e.m.f. of cell X, we have e.m.f. $X = IR_s'$. Since the current in the shunt circuit is zero at each final setting $S$ *and* $S'$, the current $I$ in the potentiometer wire $AB$ is unaffected. No current is drawn from either the Weston cell $N$ or the unknown cell X. When the comparison is made, therefore, the actual e.m.f.'s of $N$ and $X$ are compared without being affected by the internal resistance of either cell; hence, we have

$$\text{e.m.f. } X = \frac{R_2}{R_1} \times (\text{e.m.f. } N)$$

where $R_2$ is the resistance of the potentiometer wire $AS'$ and $R_1$ is the resistance represented by length $AS$.

The voltage of the unknown cell $X$ is expressed in terms of the Weston standard cell $N$, which is the international standard of voltage.

## Measurement of Resistance

The electrical resistance of any substance may be determined by calculations involving the chemical and physical properties, or through the relationship of voltage, current, and resistance in Ohm's Law. The latter method of measurement is more commonly encountered in the field of electronics. This method is based on the potential difference (*IR*-drop) developed across the resistance when current flows through the resistance. The value of resistance may be found by measuring the magnitude of current flow through the resistance and the voltage across the resistance, and using Ohm's Law for calculation.

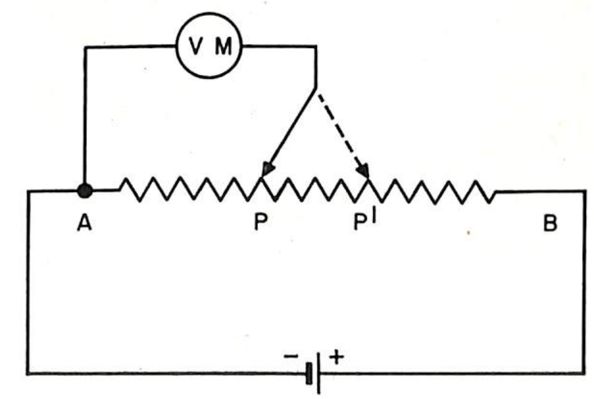



FIGURE 4—*A method of showing the proportionality between potential drop and resistance.*

Resistance values may also be determined very accurately by a comparison method similar to the potentiometer method of comparing e.m.f.'s. The circuit in figure 4 may be used to illustrate the relationship of potential drops and resistance. The voltmeter has one terminal permanently connected to $A$ and the other terminal free to move along the resistance $AB$. The voltmeter reading will be zero when both terminals are at $A$, and will gradually increase as the point $P$ is moved toward $B$. It will be found that the potential drop measured between the points $A$ and $P$ is always proportional to that part of the resistance between $A$ and $P$, and may be written

$$\frac{AP}{AP'} = \frac{V}{V'}.$$

The quantity $V'$ is the potential drop measured between $A$ and any other point $P'$.

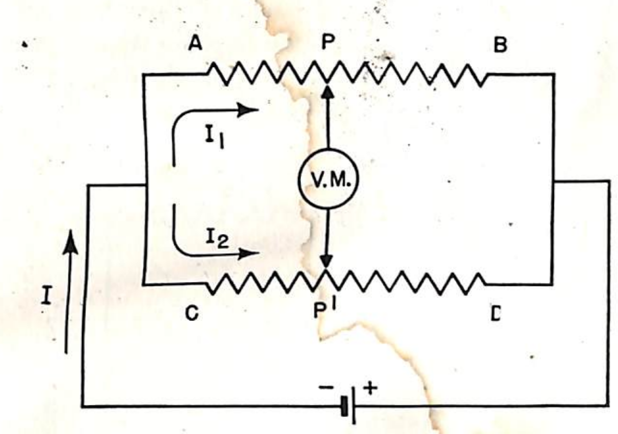



FIGURE 5—*A method of indicating equal potential drops between two resistance branches.*

If, instead of having one resistance as shown in the previous figure, we have two parallel resistances as shown in figure 5, and one terminal of the voltmeter is moved along resistance $AB$, while the other terminal is moved along the resistance $CD$, we shall find that when the portion of the resistance $AB$ between the points $A$ and $P$ is proportional to that part of the resistance $CD$ between the points $C$ and $P'$, the difference in potential between points $P$ and $P'$ will be zero and there will be no reading on the voltmeter. The proportion may be expressed as

$$\frac{AP}{CP'} = \frac{AB}{CD}$$

Likewise, a similar expression may be used for the remaining part of the two branches.

$$\frac{PB}{P'D} = \frac{AB}{CD}$$

And from these two relations, by equating to the total resistance in each branch, we may write

$$\frac{AP}{CP'} = \frac{PB}{P'D}$$

This shows that the potential drop always distributes itself proportionally along one or more resistances in a parallel circuit. Since this is true, such a device may be used to compare unknown resistances with known resistances (in terms of ratios) with a great deal of accuracy.

## The Wheatstone Bridge

The Wheatstone bridge is an instrument used to obtain precise measurement of resistance, and utilizes the principle just explained. The bridge is said to be balanced when the meter indicates zero-current flow or a "null." In figure 5 the voltmeter was used to show that points $P$ and $P'$ were at the same potential therefore indicating zero. Current flow is always from negative to positive or from a lower to a higher potential; for example, if point $P$ were less positive than point $P'$, the current in the meter branch would be from $P$ to $P'$; conversely, if point $P$ were more positive than $P'$ the meter current would be in the opposite direction. The null-indicating meter is usually a zero center-scale instrument.

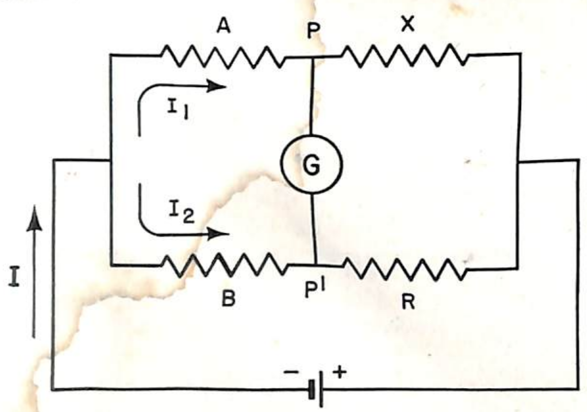



FIGURE 6—*The galvanometer method of indicating equal potential drops by a null or zero current.*

In figure 6 let us assume that the resistance represented by branch $A$, branch $B$, and branch $R$ are known and that the resistance shown as the branch $X$ is unknown. Inasmuch as the meter connected between the points $P$ and $P'$ is merely being used to determine that these two points have the same potential, a sensitive galvanometer can be employed instead of a voltmeter, and will be preferable since it is more sensitive. Under conditions when there is no deflection in the galvanometer needle, we can write a similar relation to that given in the previous equation:

$$\frac{A}{B}=\frac{X}{R} \quad \text{or} \quad \frac{A}{X}=\frac{B}{R}$$

expressed in terms of the unknown $X$, $X=R\left(\frac{A}{B}\right)$

In analyzing the above equations which hold true only when there is no deflection of the galvanometer, note that $A$ and $B$ may have an infinite number of actual values so long as the same ratio is maintained. For example, if $A$ were 10 ohms and $B$ were 5 ohms, the ratio would be 2; therefore $X$ would have a resistance twice the value of $R$. Quantities $A$ and $B$ could each be twice as large (20 ohms and 10 ohms respectively) and still maintain a ratio of 2, although in practice multiples of 10, 100, 1000 and their reciprocals are used for ease of operation and calculation.

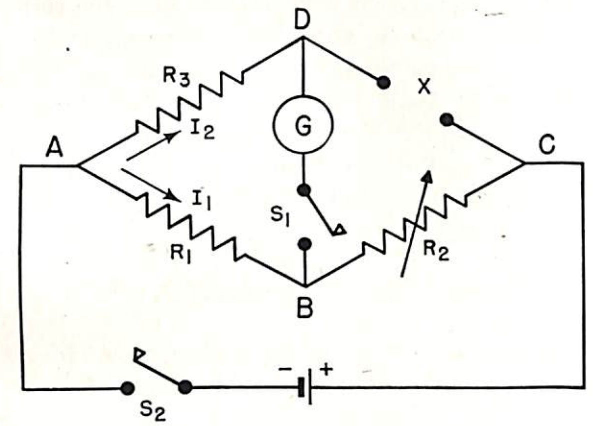



FIGURE 7—*Fundamental Wheatstone bridge circuit.*

Figure 7 illustrates the conventional schematic diagram for the Wheatstone bridge. It is almost identical to the arrangement shown in figure 6, but has the resistances connected in a diamond-shaped hook-up in the diagram. Switches are incorporated to disconnect the battery when not in use and also for disconnecting the galvanometer. The resistors $R_1$ and $R_3$ are called the ratio arms of the bridge, and are usually made to have ratios of 1:1, 1:10, 1:100, 1:1000, which may also be reversed to obtain ratios of 1:1, 1:0.1, 1:0.01, and 1:0.001. Resistance $R_2$ is called the rheostat arm. Resistance $X$ is the unknown resistance to be measured. Resistances $R_1$, $R_2$, and $R_3$ are usually resistance boxes containing precision resistors with tolerances of 0.01% or better. Each resistance box has switches to vary the resistance to obtain the desired values.

## Theory of the Wheatstone Bridge

Still referring to figure 7, let us ascertain how the fundamental proportion is derived. When the battery circuit is closed, the current at $A$ divides as in any parallel circuit, part going through the circuit $ABC$ and the remainder through the circuit $ADC$. When the bridge is balanced, there will be no indication of current through the galvanometer. Therefore, points $B$ and $D$ must be at exactly the same electrical potential. It will then be evident that the fall of potential from $A$ to $B$ is exactly the same as the fall of potential from $A$ to $D$. In other words, the voltage across $AB$ must be numerically the same as the voltage across $DC$. The current in $AB$ is the same as the current in $BC$, since this is a series circuit; therefore let this current be designated $I_1$. The other series circuit $AD$ and $DC$ has the same current flow through $AD$ and $DC$; call this current $I_2$.

The points $B$ and $D$ are shown to be at the same potential. Therefore, the voltage drop in $AB$ is equal to the voltage drop in $AD$; thus,

$$I_1 R_1 = I_2 R_3,$$

and since the voltage drop in $BC$ is equal to the voltage drop in $DC$, it follows that

$$I_1 R_2 = I_2 X$$

In order to eliminate current values from the equations since we are interested only in resistances, the first equation is divided by the second:

$$\frac{I_1 R_1 = I_2 R_3}{I_1 R_2 = I_2 X}.$$

Then, the current values cancel from each equation and we have,

$$\frac{R_1}{R_2}=\frac{R_3}{X} \text{ or } X=R_2\left(\frac{R_3}{R_1}\right)$$

A comparison of figures 5 and 6 and their respective equations, for the unknown resistance $X$, will show that both are identical relationships.

The Wheatstone bridge is extremely accurate and has a very wide range for resistance measurement. Accuracy is attained through the use of precision resistance boxes and a sensitive galvanometer to indicate exact balance of the bridge when the meter current is zero. A shunt is usually used across the galvanometer during the preliminary adjustments to protect the meter from the relatively large values of current that exist under conditions of bridge unbalance. The ratio arms permit resistance measurement from values of a thousandth to a thousand times the resistance of the standard rheostat arm.

Since the primary use of the Wheatstone bridge is for precision measurement, the approximate value of the unknown generally is known before utilizing the bridge so that setting of the ratio arms is facilitated.

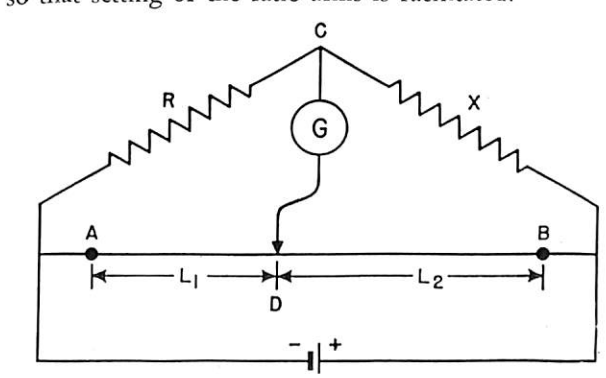



FIGURE 8—*Slide-wire form of the Wheatstone bridge, often called the Varley or Murray Loop when the unknown resistor X is a cable or long wire.*

## The Slide-Wire Wheatstone Bridge

In the slide-wire form of Wheatstone bridge the resistance $R_1$ and $R_2$ of figure 7 are replaced by a uniform wire $AB$ as shown in figure 8. $R$ is the standard known resistance and $X$ is the unknown resistance. The wire should be of low conductivity, uniform cross section, and should have a low temperature-coefficient of resistance. Manganin or German silver is commonly used. The current supplied by the battery divides, part going through branch $ACB$ and the rest through the slide wire $ADB$. The bridge is balanced by sliding the contact along the wire $AB$ until the galvanometer indicates no current—say at $D$. The theory of the slide wire bridge is exactly the same as that of the regular bridge. Hence, when the bridge is balanced,

$$\frac{R}{X}=\frac{\textit{Resistance } AD}{\textit{Resistance } DB},$$

and since the wire is of uniform cross section, the resistances of $AD$ and $DB$ are directly proportional to the lengths $L_1$ and $L_2$ respectively; expressed:

$$\frac{R}{X}=\frac{L_1}{L_2} \text{ or } X=R\left(\frac{L_2}{L_1}\right)$$

The lengths of $L_1$ and $L_2$ are usually determined by mounting the wire on a yard stick or meter stick, the only requirement being that the graduations be linear.

Two modified forms of the slide-wire bridge are currently used in telephone and long-line cable work to locate grounds and faults in cables. They are called the Varley and Murray Loops but actually are merely modified forms of the slide-wire bridge.

The Wheatstone bridge is also used in making precision measurements of capacitance and inductance as well as resistance. Such application will be fully covered in connection with alternating-current methods of measurement. The familiar bridge circuit will be encountered many times during the course of electronic study. Therefore, it behooves the student to thoroughly understand the basic principles when applied to direct-current circuits.

QUESTIONS ON BASIC PHYSICS, Part 16.

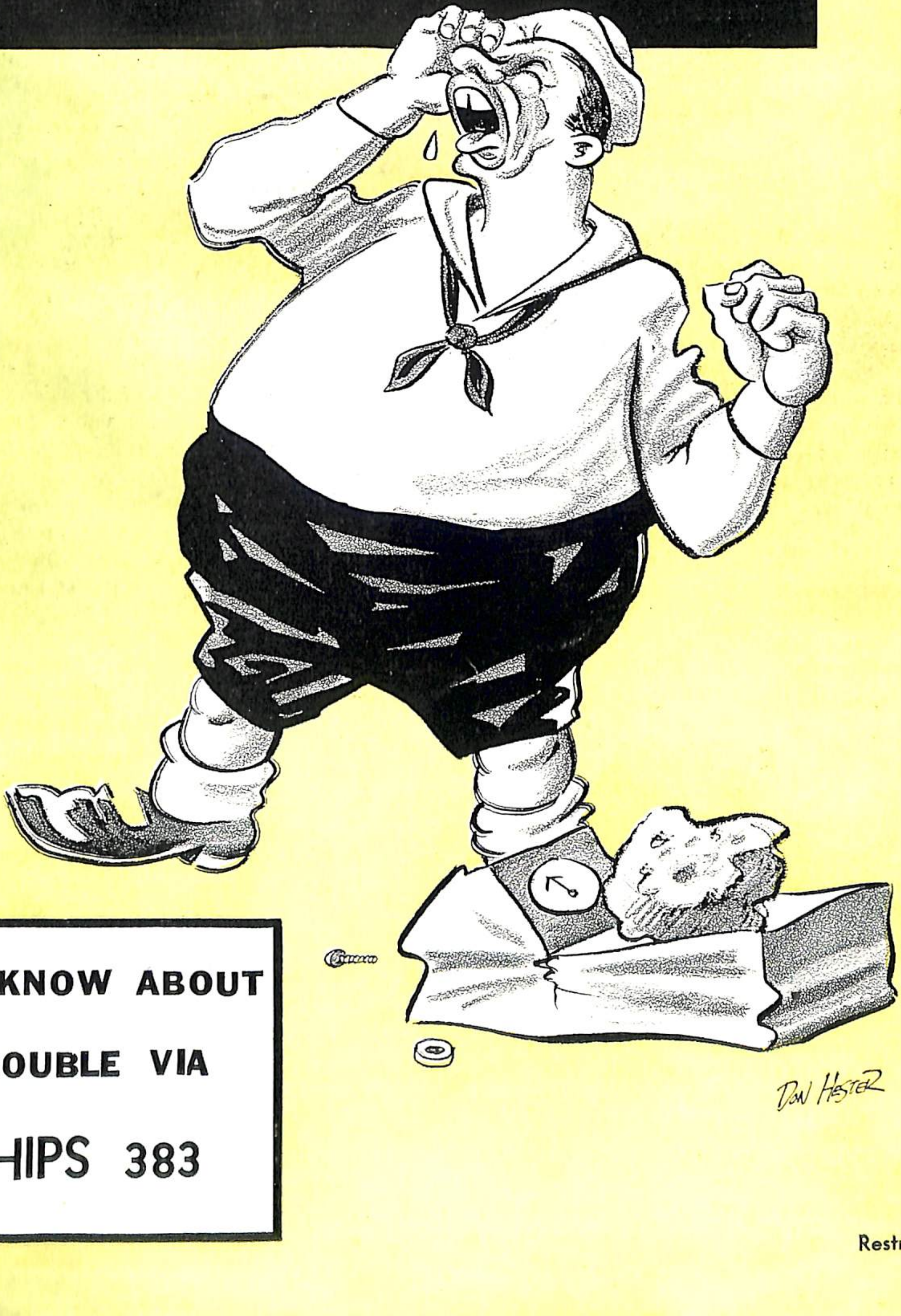
1—Find the internal resistance of a storage battery if the terminal voltage drops 1.7 volts when a load current is measured at 18.4 amperes.

2—The greatest power is delivered to a load when the load resistance is (*twice, equal to, one half*) the internal resistance of the generator of e.m.f.

3—In the circuit shown in figure 6, the unbalance current is from $P$ to $P'$. Resistance $R$ should be (*increased, decreased*) to attain bridge balance.

4—The unknown resistance $X$ in figure 7 is found to be 7.14 ohms when the bridge is balanced. What is the ratio set by $R_1$ and $R_3$? What is the resistance setting of the rheostat arm $R_2$? Quantities $R_1$, $R_2$ and $R_3$ are each resistance boxes variable in one-ohm steps from one to 1000 ohms.

# Dont Cry Over It All Alone




**LET US KNOW ABOUT**

**YOUR TROUBLE VIA**

**NAVSHIPS 383**