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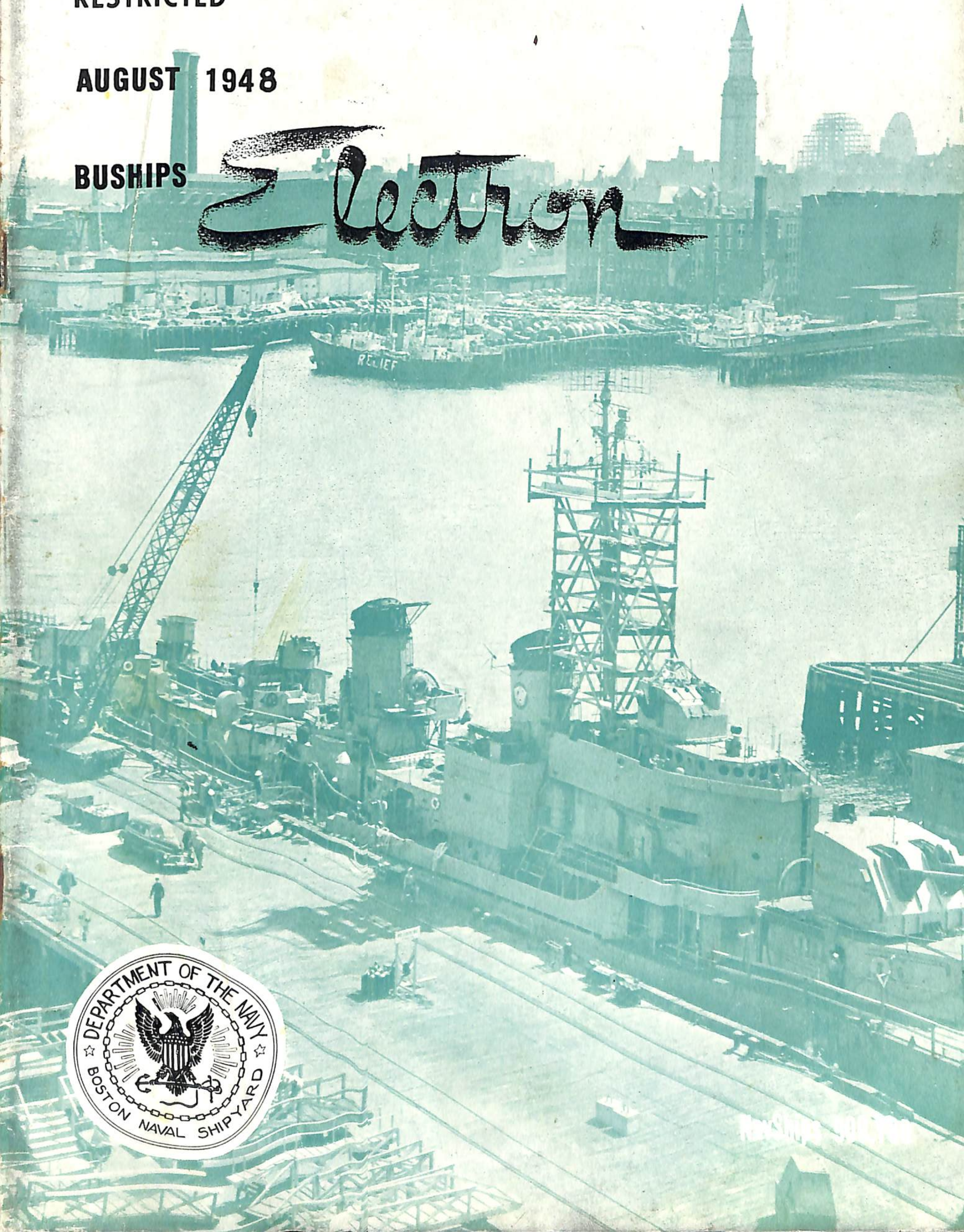
BUSHIPS Electron



Captain Wesley McLaren Hague, U.S.N.
Commander Boston Naval Shipyard

Wesley McLaren Hague
Captain, U.S.N.

Captain W. McL. Hague, USN, was born in Chicago, Ill., 2 May 1897. He enlisted in the Navy in February 1915 as an apprentice seaman, and was appointed to the Naval Academy in 1916, while serving on the armored cruiser SAN DIEGO. *He graduated from the Naval Academy in 1919, and served one year on the* OKLAHOMA *as an Ensign. In 1920, he started postgraduate work in Naval Construction and Marine Engineering at the U. S. Naval Academy. He entered M.I.T. in 1921, and in 1923 was granted an MS degree in Naval Construction by that institution.*

During the summers of 1921 and 1922, he worked in the Boston Navy Yard as a student officer, receiving his first practical experience in ship construction and repair under the tutelage of some of the present-day masters and foremen of the shipyard.

He served in the Puget Sound Navy Yard as Ship Superintendent and Office Superintendent from 1923 to 1927. The next four years were spent as Assistant to the Superintendent of the Mechanical Division, Panama Canal.

Then followed a tour of sea duty on the Staff of the Commander, Submarine Force, U. S. Fleet. Later, from 1933 to 1937, he served as Shipbuilding Superintendent at the Navy Yard, Mare Island, and from 1937 to January 1943 as Hull and Shipbuilding Superintendent of the Norfolk Navy Yard.

From January 1943 to September 1945 he was the Senior Assistant Fleet Maintenance Officer for the Pacific Fleet. There followed a year in the Bureau of Ships as Planning Officer of the Maintenance Division, from which he was detached to relieve Commodore A. R. Marron as the Commander, Boston Naval Shipyard.

The Boston Tea Party—Boston, 1774

The Boston Naval Shipyard

On April 25, 1800, the Secretary of the Navy wrote to the President: "At Charlestown there is a very proper situation for a building yard, but it can not be obtained for less than $18,000."

He was referring to a site at Mellon's Point, in Charlestown, the present site of the Boston Naval Shipyard. This new yard was to be one of five established for the purpose of building six 74-gun frigates for the young United States Navy.

DEPARTMENT OF THE NAVY BOSTON NAVAL SHIPYARD

Thus was the Boston Naval Shipyard conceived, just 26 years after the Boston Tea Party, 25 years after Paul Revere's famous ride through the Boston area. This makes the Boston yard one of the oldest of the Naval shipyards.

Throughout the years this yard has upheld the traditions of New England and the United States Navy. Hard working and efficient, the Boston Naval Shipyard has served this country loyally through many wars and done its share in peace and in war to develop Naval vessels from the cumbersome frigates of 1800 with their smooth-bore cannon to the modern counterpart of steel with great fire power and the ability to seek out the enemy in fog, smoke or darkness.

The stories on the following pages were written by the personnel currently employed at this yard. They deal with the organization, the facilities and the problems of the yard, and with some of the installations in the Boston area associated with the shipyard or directly a part of it. Thus ELECTRON brings to its readers another in the series of stories about the Naval shore activities, designed to promote a better understanding among the components of the Navy by enabling them to become more familiar with each other's work.

The Electronics Office

The Electronics Office required a minimum of adjustments to comply with the new standard organization and Chapter 6, Shipyard Regulations. Commander G. L. Countryman, the Electronics Officer, with Deputy status as Planning and Production Officer for Electronics, has as his assistant for Shore Electronics Commander W. P. Oury, USNR, who has been here since 1942. The present Assistant for Naval Reserve is Commander H. D. Kaulback, USNR, the District Reserve Electronics Officer, who maintains offices in the Electronics Office as well as at the First Naval District Headquarters. Supervising ship matters, with additional duty orders as Assistant Electronics Officer, is Lieutenant Commander F. H. Cunnare, USN, Assistant Repair Superintendent for Electronics, who maintains liaison with the Production Department. Lieutenant (junior grade) E. R.

The Electronics Officer

Commander G. L. Countryman started his Naval career by joining the U. S. Naval Reserve in 1927. It was while he was connected with the Naval Reserve that he received a commendation from the Secretary of the Navy for outstanding services in connection with the search for the ill-fated dirigible, the *Akron*.

He has been on active duty continuously since 1935. The outbreak of the last war found him Executive Officer of the U. S. Naval Section Base, Cape May, New Jersey. In 1942 he was ordered to take charge of the Aviation Radioman School at Jacksonville, Florida. Following a short tour of duty at OPNAV he became the Communication and Tactical Officer on the *USS South Dakota*. Later he became the Navy Communication Materiel Officer for CINCPAC. Then came more duty with OPNAV, this time as O-in-C of the Communication Materiel Group.

Commander Countryman received his commission in the regular Navy in October, 1946, and was designated for Engineering Duty in May, 1947. He assumed the duties as Electronics Officer, Boston Naval Shipyard, in February, 1948.

Comdr. G. L. Countryman, U. S. N.

Captain Hague, Commander Countryman, and group of electronics engineers.

Knickel is assistant to Lieutenant Commander Cunnare as Ship Superintendent for Electronics.

Liaison with the Planning Department is maintained through Lieutenant (junior grade) F. G. Hogg, USN, Assistant Planning and Estimating Superintendent for Electronics.

Chief Civilian Assistant to the Electronics Officer is Mr. B. M. Mitchell, with a total of 57 IVb personnel under his direct administration for both ship and shore work.

Two of the groups attached to the Electronics Office wear "two hats," covering necessary work for both the Ship and the Shore Section. These are the Teletype and CRF Group, under the supervision of Mr. F. L. McCutchen, and the Material Group, which maintains liaison with the Supply Department, under the supervision of Mr. W. E. Holdich.

The Electronics stockroom, under Mr. R. E. O'Neil, has recently been transferred to a Shop Store, under Shop 67. The acting foreman of Shop 67 is Mr. William Ferguson. At present all shop work is carried out in the remodeled fifth floor of Building 197, and the second floor of Building 16, South Boston Naval Drydocks. There is ample room for any future expansion at the latter location. A large ground floor area, complete with overhead crane to facilitate handling antennas, etc., is shortly to be made available, probably in Building 197.

The recently completed Transducer Repair Facility is separately housed in Building 10, selected after a Yard survey to determine a vibration-free location adjacent to the waterfront. The facility operates under Shop 67, with engineering services available at all times from the Sonar Group of the Electronics Office Ship Section.

Boston has been designated as the east coast manufacturing yard for electronics, and all manufacturing is, of course, under Shop 67 as lead shop, with other trades participating as necessary.

Captain Guy Chadwick, USN, Planning Officer, examines plans in Electronic Design Drafting Section.

Electronics Library

Chief Civilian Assistant

Mr. Burrell M. Mitchell was born in Salem, Oregon, 13 September 1906. He attended Oregon State College and Stanford University, and received the degree of Bachelor of Science in Electrical Engineering in 1929.

Mr. Mitchell's first employment was with the Radio Division of the General Electric Company, Schenectady, N. Y., as student engineer and engineer during 1929 and 1930, working on radio transmitters, sound-on-disc, and sound-on-film recording equipment. In 1930 he was transferred to the Jamaica Plain, Mass., plant (formerly the Wireless Specialty Co.) of the RCA Victor Manufacturing Company as resident engineer in charge of sound-on-film recording equipment. In 1931 he was transferred to the Camden, N. J. plant of RCA Victor, where he was employed for nine years, most of the time being responsible for test equipment, facilities and procedures used in producing government, commercial, and special-order electronics apparatus.

Mr. Mitchell became affiliated with the Electronics Office at the Boston Naval Shipyard in 1940, and was designated as a supervisor in 1942.

Mr. B. M. Mitchell

Ship Section

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Radio Communications and Countermeasures Group

The original inception of radio for communication purposes at the Boston Naval Shipyard occurred in 1906. The first radio civilian aide position was established in 1915.

The radio group, through the intervening years, has been the fore-runner of the present Electronics Office and as such has installed, maintained, and experimented with many prototype equipments.

At present the group consists of six electronics engineers and one temporarily assigned electronics engineer. These men form the Communications and Radio Countermeasures Group. They are well versed in the present-day shipboard requirements for communications.

A large laboratory affords space for the fast-moving familiarization program and repair facilities. This program presents for operation and maintenance a complete shipboard installation including radio countermeasures and test equipment.

The following items refer to representative technical experiences met by this group.

COMMUNICATION INTERFERENCE

By C. Z. Kleczek

The following case of interference encountered in communications radio equipment which originated in radar equipment may be of interest to anyone who may have occasion to locate similar interference:

The SR-a radar equipment on the *USS Gyatt* (DD–712) developed considerable pulse noise in all radio communication receiver outputs. The amount of noise suggested that something in the radar equipment was developing a great deal of power at all radio frequencies; when it was discovered that the interference was sufficient to block the signals on the RAK (a low-frequency radio receiver) it became a serious threat to the radio security of the vessel.

The Radio Communications Group was notified and the following observations were made:

The amount of noise input to the receiver varied as a function of SR-a antenna rotation. The noise was at the pulse rate of the radar equipment. Improving the shielding of the radar transmitter compartment had little if any effect on the interference. When a dummy load was inserted on the output of the radar equipment the noise was reduced considerably. Shielding of the radar transmitter compartment then helped to reduce the noise even more.

From the above it was concluded that the noise originated in the radar transmitter. Further, an investigation of the transmitter disclosed that the coaxial joint connecting the oscillator compartment with the transmission line matching units and the duplexing tuner in the transceiver frame was broken at the flexible elbow joint of the inner conductor.

The harmonics generated by a spark gap in the inner conductor directtly in the path of the output of the SR-a radar were of sufficient strength to pass along the transmission line to the antenna and be radiated by the antenna structure.

Examination of the broken section showed that considerable energy had been dissipated there. The sylphon bellows arrangement of the joint was replaced with a copper sleeve, the joint reassembled, and the equipment put into operation. The high level pulse interference had disappeared, and all equipments operated normally.

A SHIP THAT KNOWS

By C. J. Kleczek

Where do you stand in the rating of efficiency?

You have the finest electronic equipment in the world.

The most able and widely experienced personnel are available to assist you in keeping it so.

The ship that knows the importance of electronic equipment delegates the care of electronic equipment to its ET's—personnel specially qualified for qualitative analysis of equipment function.

Too often ships report to other Naval activities and when the Engineering Officer, Communications Officer, Electronics Officer, Chief ET, or the ET are questioned for a report on the condition of electronic equipment aboard, answers are misleading and not too definite.

Hats off to the *USS Richard E. Kraus* DD–849.

When this particular vessel reached port and the inspection party from the electronics office contacted the vessel's personnel, log books of equipment were opened and definite indications on the efficiency of each and every piece of electronic gear were apparent.

There was not one answer such as, "The TCS works 'pretty good.' "

Instead, "The TCS has a sensitivity of 45 microvolts at the high end of each band and we suspect that it requires replacement of the r-f coils. We have attempted to improve its sensitivity by alignment and the replacement of tubes but it is impossible to get a peak in the tuning adjustments." Now there is where the shore facilities can help.

Energy is not wasted on the examination of the vessel's equipment. Sensitivity, echobox ring time, sonar hydrophone output readings will tell you—and well.

Electronic equipment is a silent force. It reflects the morale of the ET. It is always functioning. How well it functions is another thing. Perfect functioning has avoided many a collision at sea and countless numbers of other mishaps that occur in this fast-moving world of today.

Intelligent cooperation can be best guided by intelligent data. Know how well your gear is working—there *are* ships that *know*.

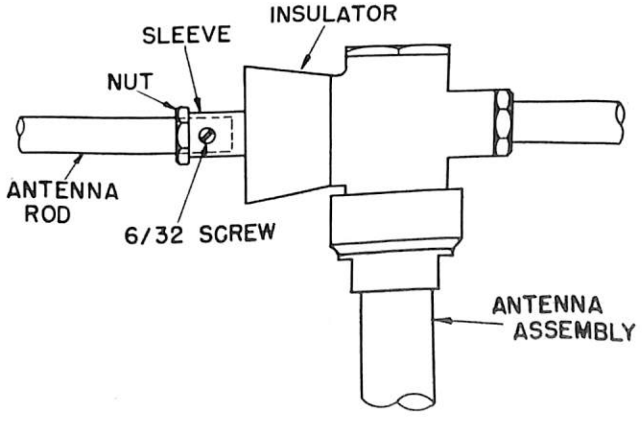
MODIFICATION TO 66147 ANTENNAS

By H. H. Goodman

In many instances the installation of Type 66147 antennas on various types of Naval vessels has resulted in failure of the TDZ/RDZ/MAR to maintain communications. In almost all the antenna failures the cause has been the loss of the radiating rods, and usually the antennas are located in inaccessible places on extreme end of port or starboard yardarms or outriggers.

Although considerable time, thought and effort must have been given to the design of the antenna, a slight change would eliminate much future trouble.

Before the antenna is installed, the radiating rod should be assembled and a small hole that takes a 6/32 machine screw should be drilled and tapped through the rod assembly where threads make up to insulator. A 6-32 brass screw ¾ inch long should be put through the rod assembly and the end swedged in place. Glyptal should then be applied. (See cut.) This procedure will prevent the rods from vibrating loose, and reducing radiation efficiency. The cost of this modification is negligible and more than offset by the benefits to be derived.



Modification to –66147 antenna.

Fire Control Radar Group

The Fire Control Radar Group of the Electronics Office, Boston Naval Shipyard, is responsible for all Fire Control Radar electronics work on new construction and vessels assigned availabilities at the Boston Naval Shipyard and Annexes, under the jurisdiction of the Electronics Officer and Ordnance Officer. In addition, the testing and calibrating of fire control radar installed by other building yards in the First Naval District are also the responsibility of this group.

This group consists of seven electronics engineers, including the group supervisor who also has technical supervision over seven radio mechanics, three Western Electric Field Engineers and one Submarine Signal Field Engineer. These engineers make arrival inspections of vessels that arrive at the shipyard for an overhaul availability. During the vessel's availability, they direct or assist in the repairs and modifications of all the fire control radar equipment. When all repairs and modifications have been completed, they make the necessary tests and adjustments to place the equipment in first-class operating condition. Finally, before the vessel leaves the shipyard and usually during the vessel's RFS period, the engineers who have worked on the ship go to sea with the vessel for one or two days and calibrate the fire control radar equipments using a slow plane as a target.

In addition to the engineering work, these engineers instruct the ship's personnel in the operation, maintenance, circuits, tune-up and calibration procedure of the various types of equipment.

Personnel in the Fire Control Radar Group are also charged with the responsibility of having all fire control radar work including installations, repairs and modifications completed within the vessel's assigned availability. The engineers have considerable authority over the work performed by the various shops in the shipyard. Besides being representatives of the Production Officer, they also are representatives of the Planning Officer and as such have authority to issue "on-the-spot" planning which greatly aids the installation and repair work aboard ship.

FAMILIARIZATION PROGRAM

The Fire Control Radar Group has participated in a training program for the past eight months. This program has been temporarily suspended because of the heavy work load at the shipyard.

Before curtailment of the training program, lecture courses had been completed on the Mk 34 radar and Mk 63 Gun Fire Control System, Mk 12 Mod 1 radar and the Mk 25 Mod 2 radar equipment.

The complete training program includes lecture courses in the Mk 22 Mod 1 radar, Mk 32 Mod 1, Mk 13 Mod 0, Mk 39 Mod 3 radar, Mk 57 Gun Fire Control System and Mk 56 Gun Fire Control System including Mk 35 Mod 2 radar.

This program will be resumed in the early fall of this year.

FIRE CONTROL RADAR LABORATORY

The Fire Control Radar Laboratory has at present two Mk 34 Mod 2 radars, one Mk 28 Mod 2 radar and one Mk 22 Mod 0 radar installed. A Mk 39 Mod 3 radar is available and will be installed in the near future. In pursuance of the current familiarization program, additional equipments will be installed shortly.

The laboratory is also equipped with various types of test equipment that is used for testing fire control radar equipment.

These equipments installed in the laboratory are used for checking the operation of repaired units and for instructional purposes.

The facilities of the laboratory are available to the radio mechanics and the engineers.

REARRANGEMENT OF BELOW DECK UNITS OF THE MK 25 RADAR ON DD-692 CLASS DESTROYERS

A new arrangement of the below deck units of the Mk 25 Mod 2 radar on the DD-692 class destroyers is being prepared by the Design Section of the shipyard. This will be an alternate arrangement to the Gibbs and Cox plans. This rearrangement was necessitated by the fact that the Mk 25 Mod 2 radar compartment on one destroyer was thirteen inches narrower fore and aft than other destroyers of this class.

This rearrangement is being followed on all future Mk 25 Mod 2 radar installations on DD-692 class destroyers at this shipyard and will improve the overall installation by allowing more space for servicing of the units.

Granted, it is a little more difficult to install the equipment in these new locations, but the equipment is installed only once while it is serviced innumerable times.

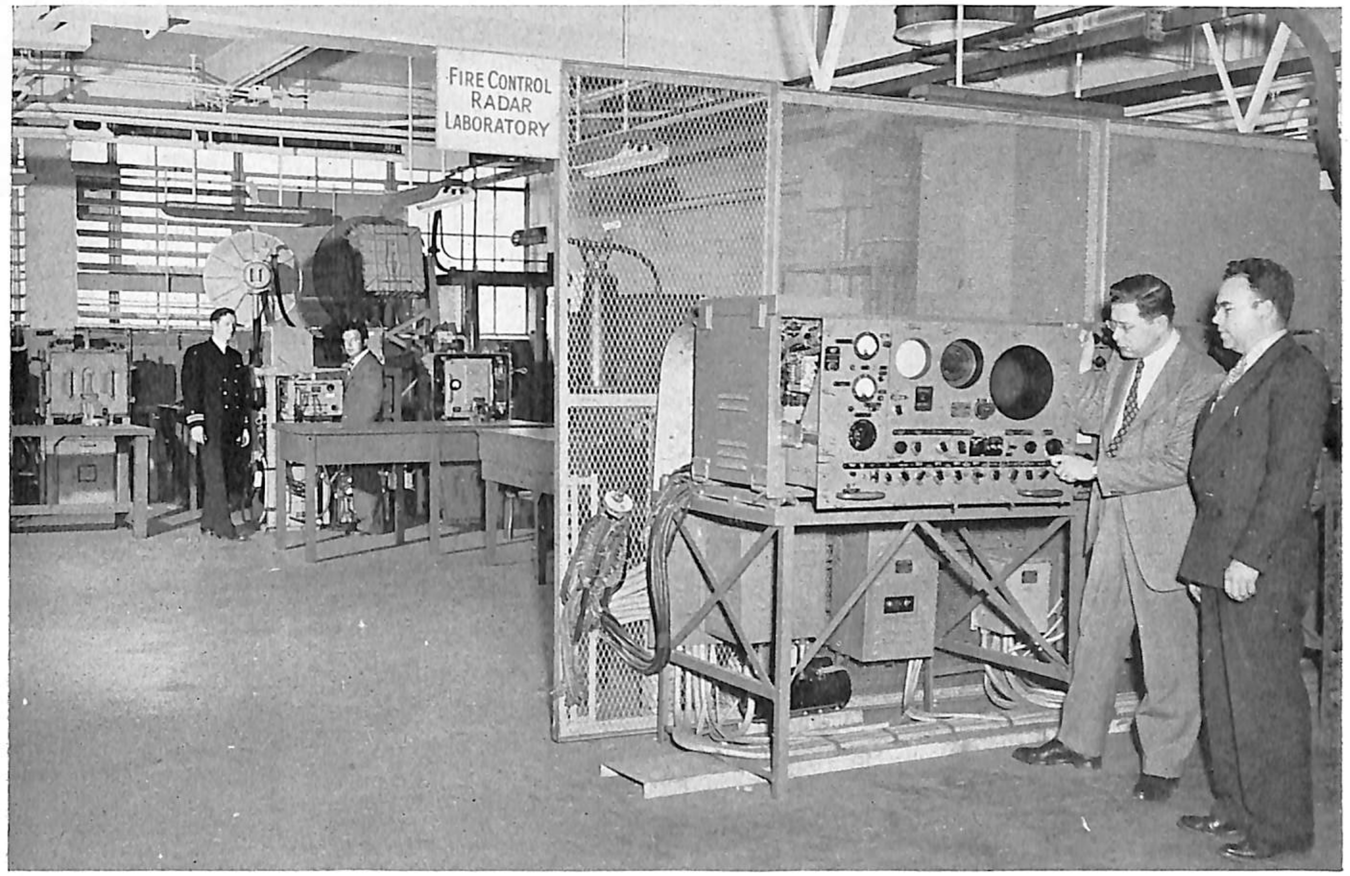
This new arrangement plan is to be distributed to all other activities, and it is strongly recommended that this alternate arrangement of the Mk 25 Mod 2 radar compartment be used in lieu of the Gibbs and Cox plan.

IMPROVED METHOD OF GROUNDING SHIELDS ON TTRS AND TTRSA TYPE CABLES

An improved method of grounding the shields on TTRS and TTRSA type cables is being used by this shipyard.

In lieu of the method shown on Bureau of Ships plan *RE49AA 272 B,* a "wedge-on" grounding sheath connector is used.

These "wedge-on" connectors are far superior to any other method of grounding the shields of the TTRS and TTRSA types of cable that have been used at this shipyard. They speed up the installation, provide a neat and uniform installation, and greatly eliminate the troubles that have been experienced while testing new installations.



Fire Control Radar Laboratory.

KEEPERS FOR MARK 25 MOD 2 MAGNETRON

Do you recognize these symptoms of trouble while initially testing a Mk 25 Mod 2 radar?

1—AFC not operating
2—Ring time low
3—Overall sensitivity low
4—Double moding

If you do, then you probably know the cause. If you don't, then a word to the wise: *Make certain that the keepers have been removed from the magnetron.* These keepers appear to be a part of the magnetron; even though the magnetron packing box instructs the installing personnel to remove these keepers, they have on occasion been overlooked.

Search Radar, I.F.F. and Loran Group

The Search Radar, I.F.F. and Loran Group of the Ships Section, Electronics Office, tell an interesting story. This story serves to exemplify the difficulties surmounted by the energetic engineers of that group.

The *USS Corduba* (AF-32) came into this shipyard recently with an unusual trouble. The SU radar seemed to lose all targets when the ship's air whistle was sounded. This situation, while unusual, had a very serious effect, as it resulted in the ship being involved in a collision at sea.

After considerable effort it was disclosed that the Motor Generator Servo Unit B-401 and the Gyro Stabilizer Unit, Westinghouse 1280532-B, were not functioning properly. In addition to this, it was discovered that excessive vibration was transmitted up the ship's mast to the SU antenna. This vibration was of great enough amplitude to close the silver-stat contactors in the Gyro Stabilizer Assembly, and the antenna would elevate to the extreme upper position every time the whistle was sounded.

The defective units were replaced, and as a further precaution, the whistle itself was shock-mounted to produce a satisfactory and lasting solution to the difficulty.

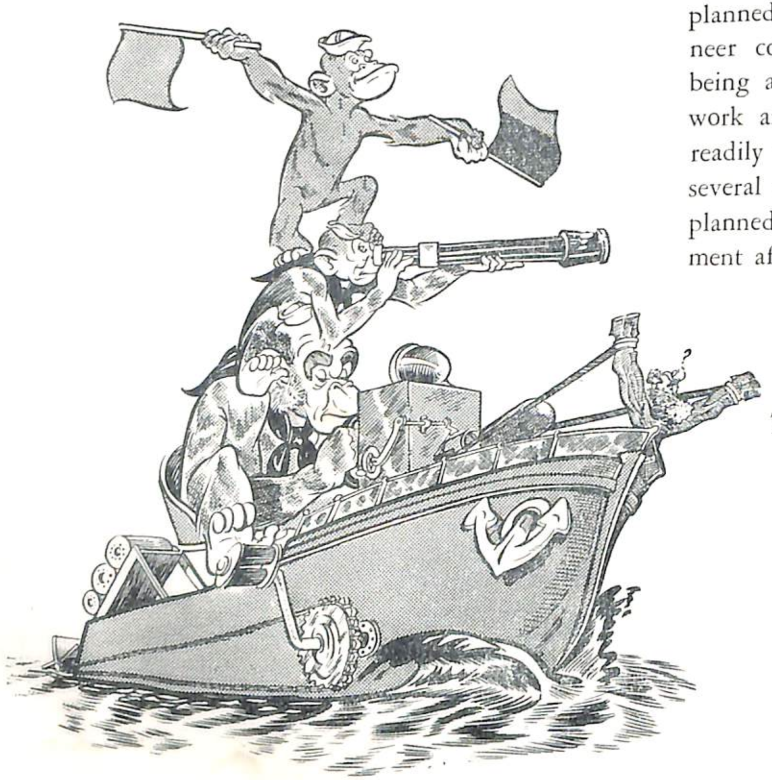
Sonar Group

During the war, the Sonar Group's work was planned and progressed by several Naval Officers with the technical assistance of two shipyard electronics engineers, N.D.R.C. field engineers, contractors' field servicemen (Submarine Signal Co., R.C.A., Western Electric Co., and Bludworth, Inc.), Electronics Field Service Group Officers, and enlisted men. Since October 1946 the work has been completely taken over by civilian engineers of the shipyard. The group now consists of a supervisor and four electronics engineers. The engineers coordinate the work through the planning and production stages with technical control of the work on vessels having shipyard availabilities. They also complete the electronic tests to the satisfaction of the Electronics Officer and the vessel.

In general, the type of work performed by the Sonar Section since the war has changed from new construction and fitting out work to overhaul, maintenance, repair and conversion work. The regular overhaul, maintenance and repair work has been mainly on the 692 class destroyers with some destroyer escorts. Several PC and YMS type vessels including a destroyer have been put back into active condition for the Naval Reserve program.

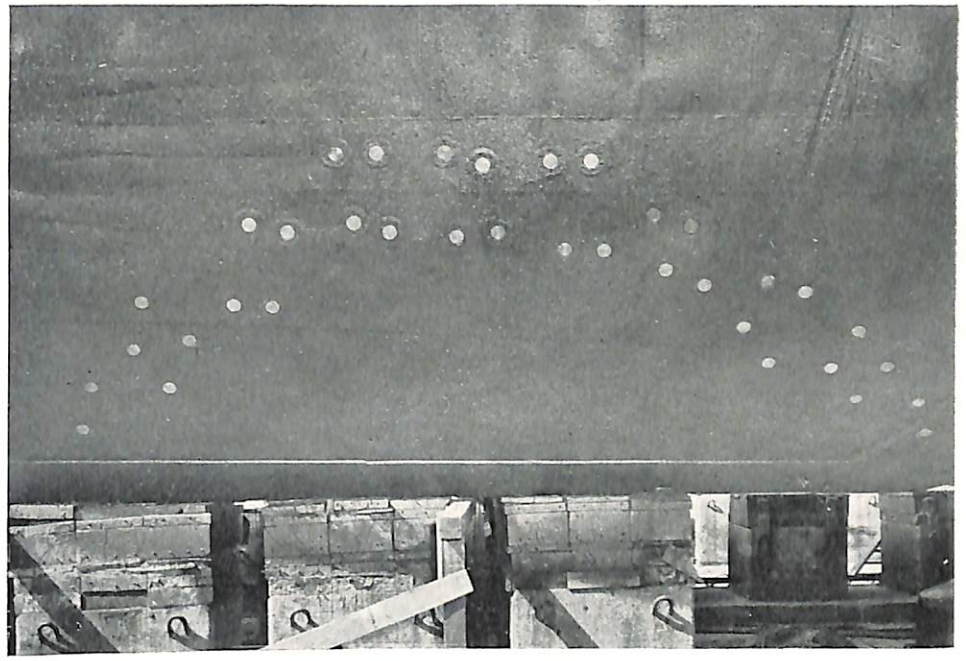
Extensive sonar conversion work has been undertaken, such as the initial conversion of the *USS Witek* (DD-848) in 1946 with a prototype installation of an integrated ASW system. The system includes equipments such as QDA, OKA, QGB, XQHC, attack plotters, Mk 23 computers, and fire control accessories. This was followed by the conversion of two E-PCE(R) vessels to sonar laboratory ships for the U. S. Navy Underwater Sound Laboratory, New London. The modification of three CVE's and four DD's with the new type QHB Scanning Sonar Equipment was interesting work. The *Witek* presented a second opportunity for this shipyard to perform an initial sonar installation of Model XQHD Scanning Sonar Equipment and Model GHG Listening Equipment including the overhaul of the previously installed equipment. The conversion or modification of two destroyers, and a destroyer escort, with the installation of a complete integrated ASW system, has presented a busy session of sonar work to this shipyard.

The sonar engineer has many complex duties. Beginning with the arrival inspection of a vessel, which is in compliance with existing directives, the ship's personnel is provided detailed technical information on the status of the vessel's electronic equipment with special instructions as necessary for each piece of equipment. The arrival inspection information is relayed to the shipyard's Planning Department to provide necessary details of the work to be accomplished so that an intelligent estimate of the requested repairs may be forwarded to the vessel's type commander. When the authorization to proceed with the work or repairs is received, the man with the threefold duty takes up the responsibilities of a ship superintendent in coordinating the trades to do the work to meet the technical requirements. Having planned the work instructions and schedules, the engineer continues by supervising the work and repairs being accomplished and reporting the progress of the work and material to the group supervisor. One can readily understand that if an engineer must look after several ships at one time, his work has to be carefully planned to allow the necessary time to test the equipment after the work of the various trades is completed.



The Integrated ASW Attack System

Courtesy the U.S. Fleet Sonar School
San Diego, Calif.



G.H.G. Hydrophone installation on USS Witek

Sonar Domes and Retracting Mechanisms

Sonar domes are streamlined housings for echo-ranging transducers designed to reduce noise and turbulence around the transducers, and to provide mechanical and acoustical protection and, in the sealed type, freedom from marine growths. These domes, shields, or boots, as they are sometimes called, are appendages to the ship's hull and are usually located on the centerline or near the keel at approximately one-third the distance from the bow to the stern.

Before continuing the discussion on domes, one should perhaps explain the significance of the transducer unit which has also been identified as a projector or oscillator. The transducer utilized in sonar systems is a power-transforming device which converts electrical energy for the transmission of underwater signals. It is also capable of receiving echoes of these signals and reconverting them to electrical currents which activate indicating devices which in turn compute ranges. These signals are in the supersonic range from approximately fifteen thousand cycles per second to about one hundred thousand cycles per second. Ranges are computed by timing devices that measure the time interval between the outgoing transmissions and the echoes received from the surfaces of reflecting objects.

Domes are classified into three general types: the "fish" (football or torpedo) type, the retractable type and the fixed or welded-on type. The "fish" type is retractable either against the hull, or into a sea chest, and is used on the SC and YMS type small craft. It is identified with its model equipment. The size is approximately 3½ feet long, and 16 to 20 inches in diameter, weighing up to 90 pounds. The retractable type dome is used on DE's, PC's, PCE's, AM's, PF's, and some DD's. This type dome is identified by its length (fore and aft) which is either 50 inches or 54 inches. It weighs up to 600 pounds. The fixed domes used on DD's, AVD's, APD's and CVE's are also identified by their lengths along the keel. They are 57 inches or 100 inches long, and they weigh from 670 to 1256 pounds. The foregoing are steel domes but there are also two new types of domes such as the 60-inch and the 120-inch rubber domes. The smaller is at present being used as a fixed dome, and the larger one is intended as a retractable type. The Boston Naval Shipyard is designing and manufacturing two 120-inch steel retractable domes under Bureau of Ships project orders since the rubber types are not available. These are to be utilized on CVL type vessels.

The domes are characterized by "window" area. The transducers housed within the domes operate in this area to provide maximum transmission and reception of signals. The steel domes usually have only a restricted "window" area in the forward part of the dome. The present rubber dome is designed with a strong steel frame and metallic screen or grid vulcanized over with a special rubber that presents suitable transmission qualities in all directions. This makes it suitable for the new type scanning sonar equipment which simultaneously presents a visual picture of a number of targets surrounding a vessel or even under the vessel. The later type transducers have a so-called maintenance-of-close-contact feature so as to retain contact with a deep submarine at close quarters.

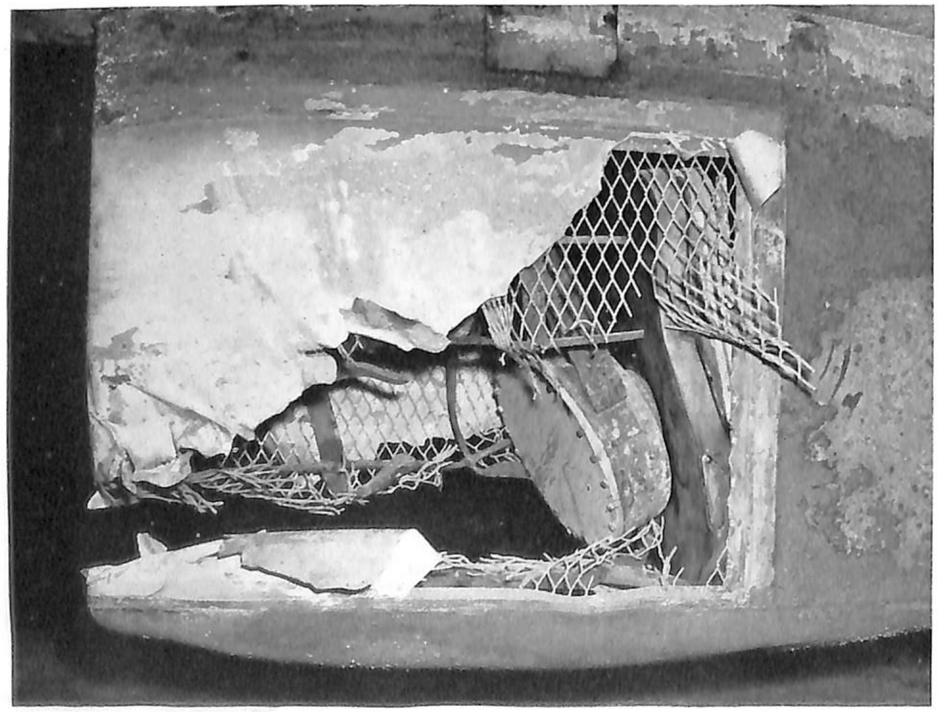
Prior to World War II and during the early part of the war, the sonar transducers were part of a spherical ball which could be retracted within a sea chest opening when secured. The spherical shape was mainly for the mechanical strength that it afforded. A vertical banjo-shaped section through the center of the ball approximately 20 inches in diameter forms the active element of the transducer. Sometimes both faces of the unit are active, providing a choice of two types of transducers in one unit. The magnetostrictive type on one side is covered with a hemispherical shell of thin stainless steel filled with ethylene glycol or some other solution which has suitable transmission qualities for supersonic energy and will not freeze at operating sea water temperatures. The crystal type on the other side is sealed in oil by a hemisphere of special rubber, whose density equals that of sea water. This ball type transducer is impractical to use for echo ranging when the vessel's speed begins to exceed ten knots. The eddying and cavitation at the unit causes such a great amount of noise pickup as to obliterate any echoes that may be received. Furthermore, turbulence producing air bubbles and cavitation forms a sound screen to reduce the amount of outgoing as well as incoming signals in the water.

The British, having to cope with the submarine menace before we did, have done much to make the use of sonar equipment practical at speeds in excess of ten knots. They designed a streamlined retractable dome to house the transducer. They used domes made of plastic materials, but their practical solution was a 5/16" nickel and cast iron dome which had a lateral "window" of 20-mil stainless steel, eighteen inches wide all around the dome, and bolted to cast aluminum reinforcing ribs. The banjo-shaped transducer was housed within and trainable in the "window" area. The dome was 54 inches long and protruded approximately three and one-half feet below the keel of their destroyer escorts. The materials used and the shape of the dome provided equipment that was efficient in operation at high speeds.

Our Navy started to use the dome and retraction gear as manufactured by the British when we entered the war. Soon we manufactured our own domes and retraction gear. Having benefited by British experience, we discovered the noise-reducing qualities of domes. These qualities increase as the ship's speed increases to approximately 18 knots; they then decrease until, at about 27 knots, the dome gives no noticeable improvement over the bare projector.

Since 1942 we have had considerable experience with domes, mostly as a result of failures experienced. Dome failures fall into three general classifications: mechanical, acoustical and marine growths.

The principal mechanical failures are due to collisions with obstructions such as floating debris, large fish, the bottom, or fouled anchor chain. Excessive stresses resulting from rough seas in which the dome may rise out of the water and be pancaked down upon it may destroy a dome. Excessive stresses resulting from swift turns by the ship cause damage to the dome. Vibration causing a gradual parting of the window from the expanded metal reinforcement at the welding points ruins a dome. Improper installation and careless operation contribute to a short life of a dome.



Damage to sonar dome and QGA transducer mechanism of a destroyer caused by chain on mooring buoy encountered during practice run. This damage was repaired at the Boston Naval Shipyard.

Acoustical failures usually follow mechanical failures from oil fouling the "windows," from dents or tears in the window, or from sludge deposited inside the dome.

Marine growths take place in all waters. These growths on the window area reduce the transmission quality of the window, and add to the noise pickup encountered.

To minimize these failures the domes have gone through a series of improvements and the Boston Naval Shipyard has contributed much to the tests and improvements that have taken place.

The fixed domes were first sealed and filled with a solution of Prestone or ethylene glycol and water. The action of this solution caused a furry coating to form on the face of the transducer and the window area of the dome, however, resulting in an appreciable transmission loss. Accordingly, the solution was changed to another containing sodium chromate, salt and water, which was practically equivalent to sea water; the sodium chromate was added as a rust inhibiter. Experience with this finally resulted in the decision to make the dome free flooding to the sea.

Free-flooding holes on fixed domes were spotted after tests and computations by the David W. Taylor Model Basin in Washington. The Boston Naval Shipyard was engaged in these tests. Originally the hole to permit free flooding was placed at the bottom of the dome, but was found to set up disturbing pressure within the dome. Next, two 1¼-inch holes were recommended, port and starboard, about 4 inches above the sound window and near the center line. Later, a hole in the nose and a smaller one at the tail were tried; but at high speeds excessive pressures were set up inside the dome, to the extent of causing leakage into the ship via the vent pipe from the top of the sea chest. The final result was to locate two ½-inch holes port and starboard, 10 inches from the nose, and one ⅝-inch hole on the tail. Tests conducted from this shipyard showed this last arrangement to be satisfactory from the standpoint of equalizing pressures within and without the dome at operating speeds.

The mechanical structure of the fixed dome has undergone numerous changes in an effort to satisfy acoustical requirements and still retain rigidity and strength. The first fixed domes of the 57-inch size, as made by the E. G. Budd Manufacturing Company and the Boston Naval Shipyard, had window material ⅛ inch thick. Although this thickness was desirable from the standpoint of mechanical strength, it was undesirable because of the transmission loss to the signal and the resulting reflections within the dome. This dome was superseded by the 57-inch corrugated dome having a 50-mil stainless steel window of 0.8-inch-deep corrugations. These domes had advantages in manufacture but were noisy due to "washboard" effects in moderate and heavy seas.

The steel domes finally resulted in the present type with a window of highly polished 20-mil stainless steel with a reinforced backing of expanded metal. The window is spot welded to the expanded metal at each intersection of the diamond design. This window only extends around the forward sides of the dome permitting an operating arc of 300 degrees centering at the bow. The after portion is acoustically shielded by a baffle installed within the dome. This baffle minimizes interference from the ship's own propellers. To provide additional rigidity to the dome, horizontal and vertical stiffeners have been added in the window area.

During the war a considerable number of mechanical dome failures were experienced before design changes minimized the failures. Until 1944 all damaged domes were scrapped, usually because of window failures. This shipyard initiated a method of repairing the domes by renewing the window material and adding necessary stiffeners and in this manner saves $600.00 for each dome repaired and replaced. To date approximately 400 domes have been repaired by this shipyard. The method used in repairing these domes was initiated by Emilien Beaumier of this Yard who received a beneficial suggestion award of $250.00 for his ideas. Later the Bureau of Ships awarded an additional $250.00 to Mr. Beaumier.

Because of the numerous retracting gear failures due to corrosion, loosening of mechanical parts, and design deficiencies, Lieutenant Meyer (Sonar Section Head during 1944-1945) initiated the design of a new type of retracting gear. This design was to utilize the previous type of chain hoist for the retracting mechanism of the 54-inch dome. When this proposal was submitted to the Bureau of Ships for action, this yard was requested to re-design it for a 120-inch retractable dome for use on capital ships. This was shortly after the sinking of a cruiser whose captain indicated that if the ship had had sonar equipment, it would not have been lost. In September 1945 the Bureau of Ships authorized the Boston Naval Shipyard to proceed with the design and manufacture of a retracting gear for a 120-inch dome.

The retracting gear was designed for two separate sonar transducers mounted in tandem. The dome is free flooding and the provisions allow replacement of transducers while ship is waterborne or at sea. The massive construction, weighing approximately 15,000 pounds, provides sufficient strength and rigidity to minimize the design deficiencies and mechanical weaknesses of previous retracting mechanisms.

The retracting gear was developed to incorporate the 120-inch rubber dome designed by the Naval Research Laboratory and the David W. Taylor Model Basin. Since the rubber dome will not be available for the first two retracting mechanisms, the Boston Naval Shipyard is manufacturing two 120-inch steel domes patterned after the 100-inch QGA dome. It appears now that the steel domes may eventually be replaced by the rubber types designed by the Naval Research Laboratory.

Electronics Planning and Estimating Group

The Electronics Planning and Estimating Group at the Boston Naval Shipyard consists of five electronics planners, and as a part of the Electrical Planning Group, is under the supervision of the Electrical Planning Group Supervisor.

The Electronics Planning and Estimating Group can look back from its present position as a well-organized and recognized unit of the Planning and Estimating Department, to the time six years ago when neither rating nor group existed.

The fact that such a group exists today is a tribute to the foresight of the Planning Department in realizing in advance the need for an Electronics Planning Group, and then keeping pace with the great expansion in Naval electronics work during the last several years.

As a result, ships entering the Boston Naval Shipyard for repairs or overhaul benefit by having electronics work handled by planners who, because of their experience and familiarity with electronics work, can speedily process the screening of vessel's work requests and alterations; make labor and material cost estimates; order material; prepare work specifications for the trades involved, and get the job order briefs "on the street" promptly, which is always appreciated by the Production Department and Electronics Office. A well-organized Advance Planning Group materially assists the Electronics Planning and Estimating Group in progressing all work as much as possible before the actual arrival of a vessel.

Coordination with other trade planners and estimators and the Electronics Office is stressed, in order to obtain complete coverage of electronics planning including all phases of electronics work and associated work such as general electrical, fire control, ordnance, machinery, and structural.

Beneficial suggestions have been submitted by the Electronics Planning and Estimating Group pertaining to practical and paper work problems, ranging from methods of expediting and simplifying fabrication of radar wave guide and fittings, to changes in the method of publishing the Electronics Installation Bulletin. Several suggestions are now under consideration for adoption, and every effort is being made to increase the quota of suggestions.

Although not now included in the Electronics Familiarization Program, due to the currently heavy work load and the shortage of personnel, it is hoped that in the future the Electronics Planning and Estimating Group will be able to participate in this program, in order to keep abreast of the many new changes and new electronic equipments.

Electronics Planning and Estimating Group

Naval Reserve in the First Naval District

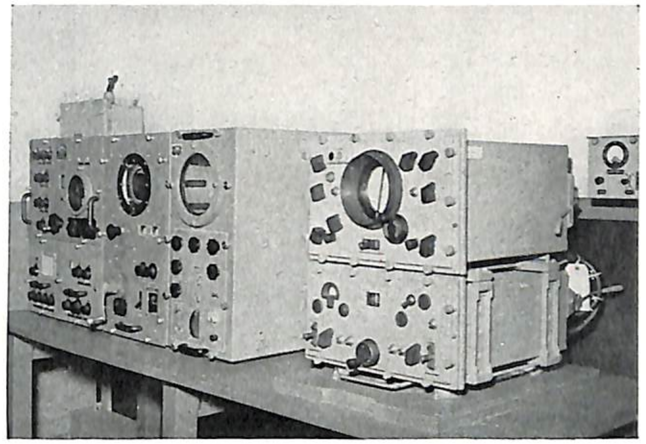
Twenty-one Naval Reserve and Naval and Marine Corps Reserve Training Centers will be in operation in the First Naval District by 1 January 1949.

These Naval Reserve and Naval and Marine Corps Reserve Training Centers are located at Bangor and Portland, Maine; Portsmouth and Manchester, New Hampshire; Lowell, Salem, Lynn, Lawrence, Brockton, Boston, Hingham, New Bedford, Fall River, Springfield, Pittsfield, and Worcester, Massachusetts; Burlington, Vermont; Newport, Providence, Woonsocket, and Pawtucket, Rhode Island.

The electronic warfare installations comprise four radio transmitters of various types, one air search and surface search radio, PPI unit, radio operators' desks and code practice tables, IFF equipment, sonar equipment, radio direction finders, frequency meters, antenna and ground systems and miscellaneous associated equipment in C.I.C. and other training spaces.

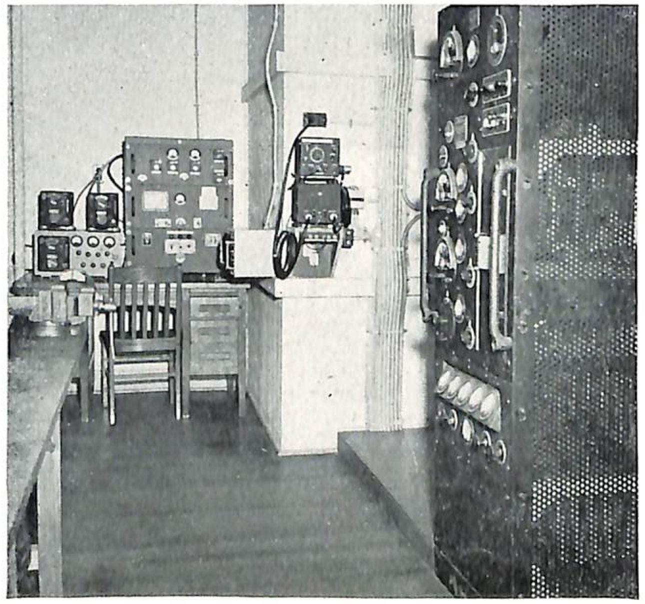
Panels and cables are provided for patching the output of any radio receiver or oscillator to any or all code practice positions.

All electronic installation work on the above projects is performed by personnel from the various shops of the Boston Naval Shipyard under the immediate supervision of the District Reserve Electronics Officer and project engineers from the shipyard Electronics Office.

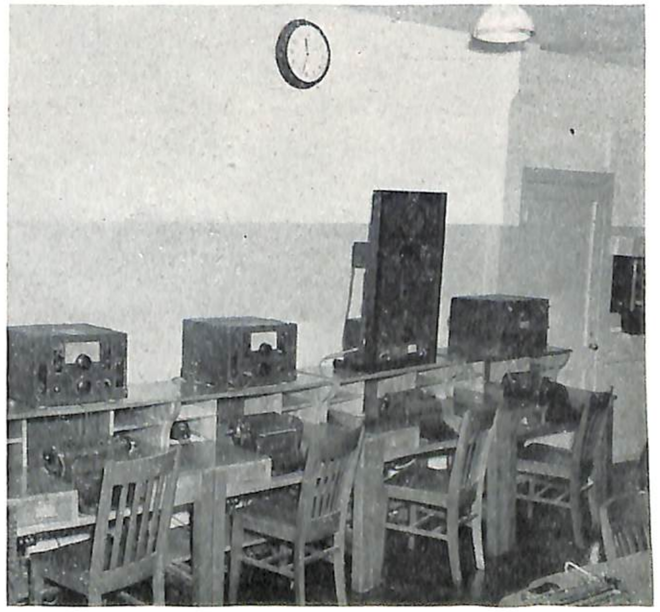


Bingham, Mass.

In addition to the facilities provided above, eighteen vessels of various types are provided for the training of reserve personnel. These vessels comprise five AMS, one DD, three LCI, one LCS, one LST, one PC, one PCE, one PCE(R) and four SS. The YFN-1151 (sonar barge) is also in commission for training of sonar men. This barge is the ex-YC-792 and was used extensively during World War II for training purposes. The deck house contains a large compartment amidship in which is installed the major sonar equipment consisting of the following: QCQ-2, QJA, QCB, QCS, QCL-8 complete with projectors and hoist and training mechanism. Also installed are an NMC and NJ-8 fathometers. Two attack plotters are also attached. Several stacks for instructional purposes are provided for some phase of material instruction. A Model JK sonic listening equipment is available and so rigged that the transducer may be lowered over the side and used on passing vessels.



New Bedford, Mass.



Lawrence, Mass.

Brockton, Mass.

A recent acquisition has been a Model QFG Shipboard Sound Operator Trainer Equipment. This equipment provides for additional operational sonar training.

Classroom, workshop, watch stander's bunk room, head and shower are also provided. A diesel power plant provides power when dock power is not available, and an oil-fired boiler provides heat and hot water. Due to the similarity of actual shipboard conditions, ideal training is provided.

A number of Model SCR-299 equipments and radio-equipped jeeps have been reconditioned and are available for any emergency. These units are distributed throughout the district at strategic locations.

Sonar Transducer Repair Facility . . .

About a year ago, the Bureau of Ships came to the conclusion that something should be accomplished about having the Navy repair its own sonar transducers. With this in mind, the Boston Naval Shipyard was chosen as the location for a Sonar Transducer Repair Facility on the East Coast.

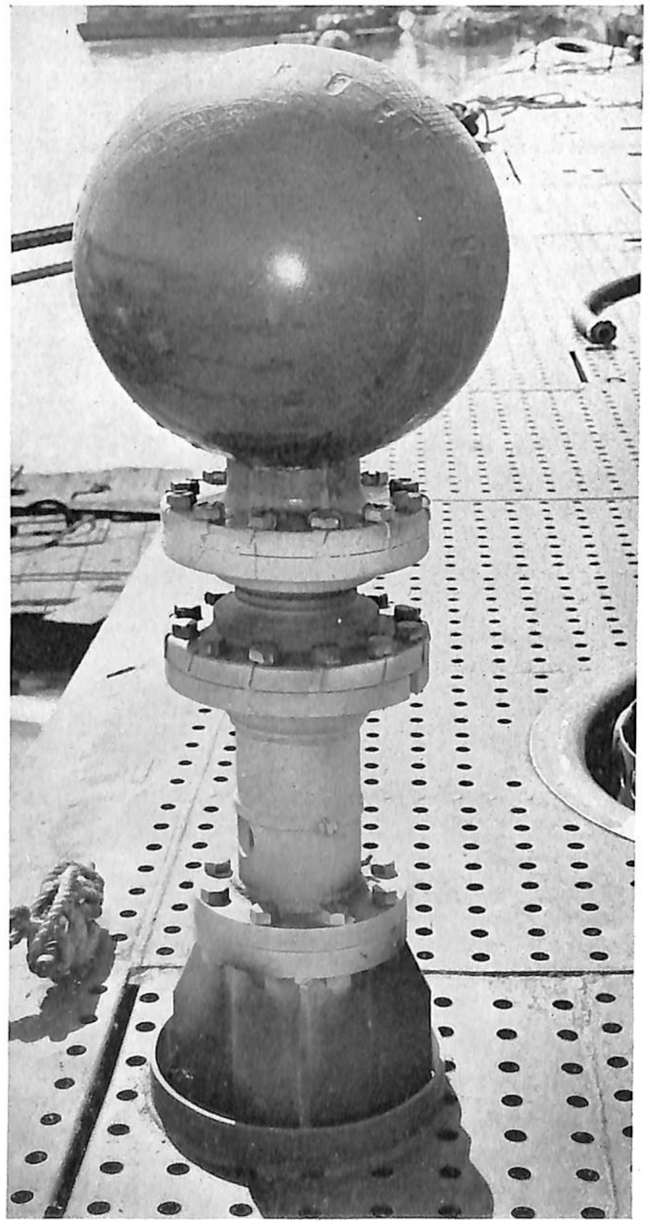
Several locations in the shipyard were tested for noise and vibration interference, and found to be wanting in one respect or another. Finally, one building was found to be suitable and it was decided upon as the location for the Sonar Transducer Repair Facility.

With a location settled, and a ready-made structure to modify, plans were drawn to convert this building into an ideal Sonar Transducer Repair Facility. The Naval Research Laboratory in Washington, D. C., was consulted and has provided many helpful suggestions.

The laboratory spaces are completely air-conditioned. Facilities include a 16'x16'x16' test tank, vacuum pumps, small machine tools, and special test equipment.

The Repair Facility was completed and ready for business on 1 June 1948. One electronics engineer and two radio mechanics were sent by the shipyard to the Naval Research Laboratory, Washington, D. C., and then to Mare Island Shipyard for specialized training on transducer repairs. The Boston Naval Shipyard now stands ready to undertake the repair of any Navy-type sonar projector, magnetostriction or crystal.

This shipyard has also been assigned as the Bathythermograph Repair Facility for the East Coast. It is currently planned to incorporate bathythermograph repairs as part of the work to be accomplished in the Sonar Transducer Repair Facility, with the assistance of the Materials Laboratory.

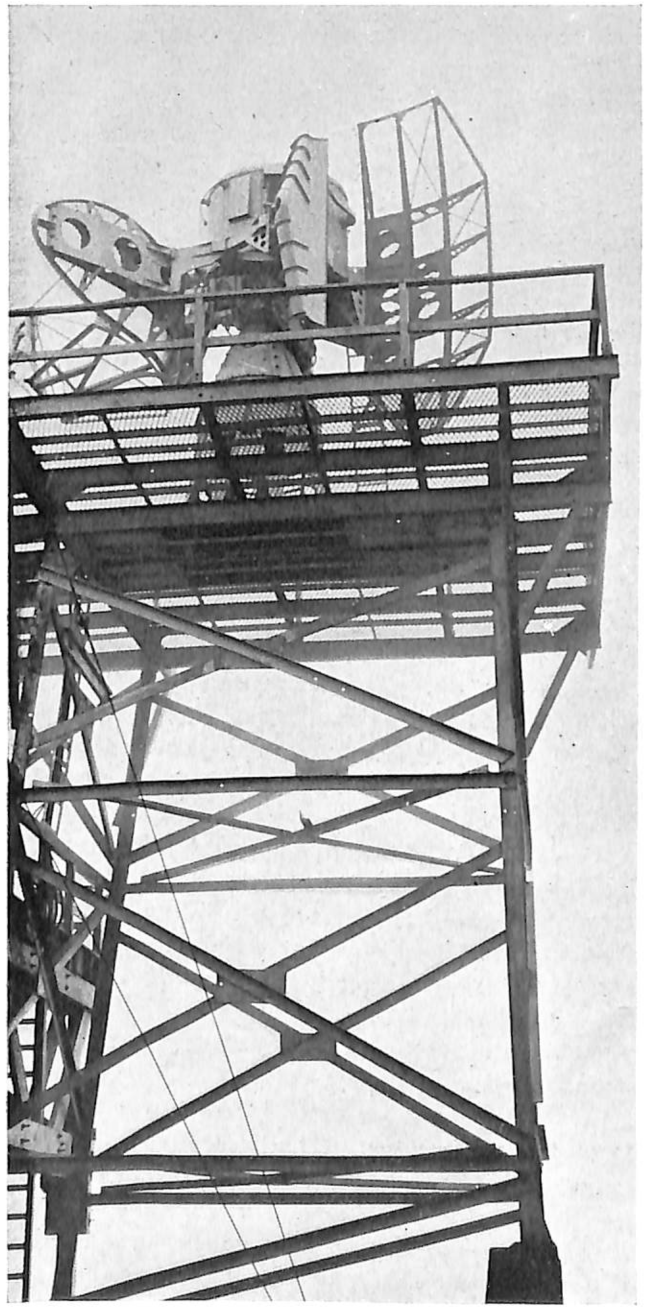


Topside QB transducer.

Boston Schools . . .

C.I.C. TEAM TRAINING CENTER

This school has a large amount of electronic equipment in the six rooms which make up the simulated Combat Information Centers of the various type vessels. In addition, a large room is used for problem generating equipment in order that field problems may be simulated when it is not practicable to provide the real thing. Two other rooms are assigned and equipped for countermeasures. Real and simulated radio communications are provided also.



SX antenna platform atop Navy Building.

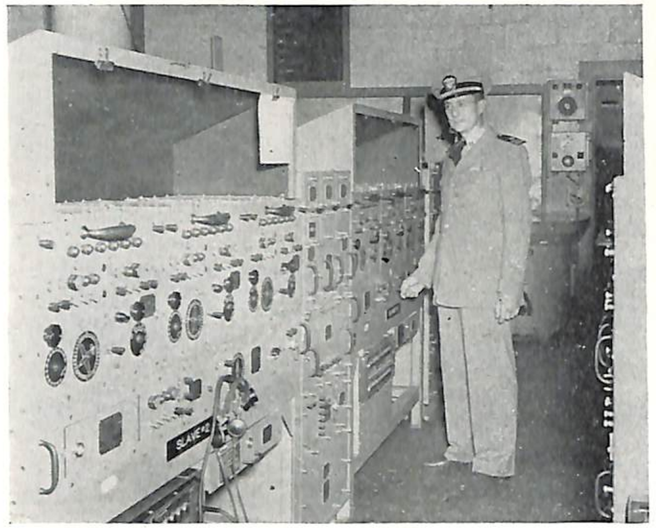
The roof of the Navy Building was not originally designed to carry the many tons of radar antennas and equipments which have been placed thereon. As a consequence, it has been necessary to provide platforms which place the large stresses into the main vertical members of the building.

The SX antenna, weighing 5500 pounds, is nine floors and thirty-one feet above the street level. The platform on the antenna's pedestal was built sufficiently large to make servicing of the antenna as easy as possible, with the result that this valuable equipment receives constant preventive maintenance attention even in this very high place. In this installation, it was found that the two high voltage pulse cables from the modulators will break down due to the extremely sharp bend necessitated by the shape of the bottom cover plate and it was necessary to alter this plate to reduce the curvature of the pulse cables.

The "CV Room" is the largest of the C.I.C. mock-up rooms. The picture shows about two-thirds of the whole room. There are two more SX consoles directly behind the one on the right. At the far end of the room is the A.E.W. equipment and to the deep left are the SG and SR-a consoles. The left foreground shows the VF and VG-2 radar repeaters. Behind the camera and out of the picture are a status board and a vertical plotting board, near which are located a VJ radar repeater and a polar plot table. The radar repeaters connect to a radar distribution switchboard located in the Problem Generating Room.

The OCZ radar trainer picture shows these equipments installed with their fronts facing each other. A total of four of these are available for providing a dozen controllable targets to the SR console which, in turn, is connected to the radar distribution switchboard and thence to any of approximately 15 radar repeaters in the establishment. The officer in this picture is Lt. A. W. Barnes, who is charged with the large responsibility of maintaining all of the electronics equipment at this activity.

CV room.

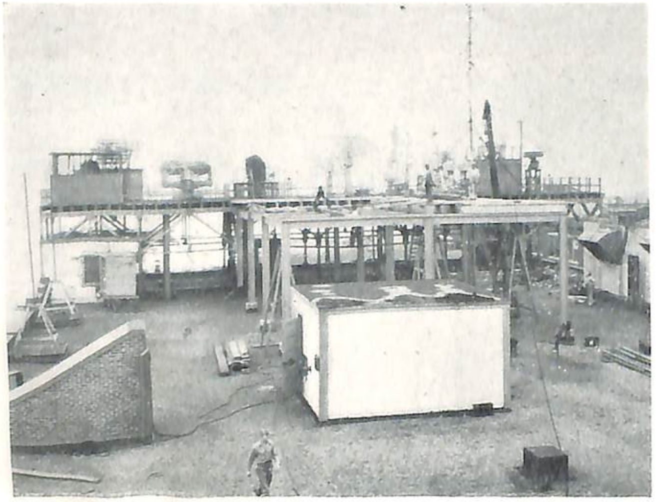


OCZ radar trainer.

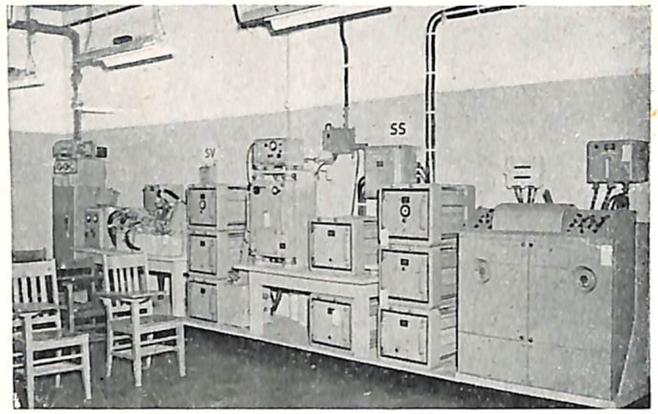
As would be expected in a C.I.C. school, a large part of the equipments are radar repeaters and plotting devices for use in connection with two air search, two surface search and two fighter director radars. Fire control radar has not been neglected, however, and three equipments are available for operation as well as a fire control radar trainer. Dummy director houses on the roof provide good simulation of shipboard operations.

U. S. NAVAL SCHOOL, RADARMEN— NAVY BUILDING

The radarmen's school is located in the same building and on the same floors as the C.I.C. Team Training Center, but operates to accomplish a different mission. Hundreds of enlisted men go through this school each month or six weeks to learn operational maintenance of a wide variety of radar equipments. Hence some of the problems are different. Here radar equipments are provided by the dozens and therefore aggravate the problem of providing antenna support and space.



Antennas at the Radarmen's School.



Classroom at the Radarmen's School.

The picture taken from atop the superstructure at C.I.C. shows the antenna platform at the radarmen's school. You will note that an extension is in the process of construction in the foreground which will accommodate about twelve more radar antennas. Peculiar to this school will be the provisions made for the submarine types of radar, the Models SS and SV. The shipboard installation places the antenna drive mechanisms within the skin of the vessel, whereas here this is not possible since the roof itself is well removed from the desired antenna locations. Therefore, the antenna drive mechanisms will be mounted in metal boxes with the antennas mounted on top of the boxes and the whole assembly placed upon the new platform extension. The rest of the submarine type equipments have been placed in the classroom with the Model SS on the right of the picture, the SV to the left. The opposite bulkhead contains other sets of the same equipment. Here the student is able to see all of the components of these radars and thereby gain a familiarity with the equipment more readily than with a simulation of the shipboard installation.

The Model SG-6 Radar Equipment, not shown, is installed with all of the components except the antenna grouped together. The antenna has been placed near a window in the classroom. The echoes are not as good as would be expected from this modern radar, of course, but it is believed that this disadvantage is offset by the convenience in studying this equipment now being supplied to the fleet.

Credit for the maintenance of these equipments goes to CRE R. J. Donaldson. With twenty-five search radar equipments and nine fire control radar equipments under his charge, he has sufficient problems for any one man. To add to his burdens, it is expected that an installation of a rather complete layout of teletypewriter and line terminal equipment will be begun in the near future.

Overcoming the Ship Electronic Post-War Problems at the Boston Naval Shipyard . . .

During the peak of World War II, the personnel complement for the Ship Section of the Electronics Office, Boston Naval Shipyard, was 66 officers, 15 Civil Service engineers, 75 contractors' engineers, and 23 clerical employees. The present personnel complement is 4 officers, 39 Civil Service engineers, 5 contractors' engineers, and 12 clerical employees.

In view of the drastic decrease in officer personnel and contractors' engineers during the conversion from wartime operation to peacetime operation, many technical and administrative problems arose. Some of the major problems were: 1—increasing and training the Civil Service engineering personnel to compensate for the loss of officer personnel and contractors' engineers; 2—reorganizing shipyard facilities to accomplish ship electronics work; and 3—formulating new methods of operation necessitated by the policy changes effected by peacetime conversion.

After the war, electronics facilities were consolidated into an electronics laboratory, located adjacent to the Ship Section of the Electronics Office.

Increased Civil Service engineering complement of trained personnel, specialized in current Navy electronic equipment, was required to accomplish the assigned shipyard electronics work load. In the procurement of competent engineers several difficulties were encountered: engineers could be hired only on a temporary appointment basis; there were few applicants qualified to perform the highly technical and specialized electronics work required; and the need grew for engineers who would require a minimum of specialized training, in view of the imminent work load. The Electronics Office was able to acquire Naval Reserve electronics officers and former contractors' engineers to increase its staff as Civil Service engineers in order to provide the required electronics engineering services for ships available at the shipyard.

The Ship Section has successfully completed organized training courses in many types of Naval electronic equipment, including SG-6, SR-3 and SR-6 radars, loran equipment, ASW integrated sonar system, Mk 63 GFCS and associated radars, Mk 22 Mod 0, Mk 12 Mod 1, Mk 25 Mod 2, and various radio communication equipments. In accordance with a Bureau of Ships directive, a very successful familiarization course on television is now nearing completion. Equipment familiarization courses have been suspended for the summer months, due to the heavy work load and the vacation period. New courses are currently being planned for the training program when it is resumed in the fall.

Cessation of hostilities, resulting in a reduction in competent military technical personnel, made it necessary for Electronics Office engineers to perform duties ordinarily accomplished by shipboard personnel. One of the important functions of the Ship Section engineers is the preparation of detailed arrival inspection reports, in order to assist the vessel in preparing work lists for the Type Commander, thereby insuring the proper operation of all electronic equipment prior to the ship's departure from the shipyard.

The Boston Naval Shipyard takes its failure reports seriously. The Ship Section constantly maintains an active drive for failure reports, and a sizeable number is sent to the Bureau of Ships weekly.

To successfully complete shipboard electronics work in proper sequence, and in sufficient time to permit careful testing of the equipment, the Ship Section prepares a work schedule, which indicates the completion dates for work on the electronic installations to be performed by other trades in the yard. This schedule is addressed to the Repair Officer and to the various shops within the shipyard.

A weekly status report is prepared and distributed by the Ship Section, in order that the other departments and trades involved in electronic installations and repairs may be kept current with the status of electronics work on each vessel. In the event of work delays, implicating production, planning, supply or other departments or shops, the cognizant activity is informed.

Every electronic equipment which is serviced by a Ship Section engineer has to be signed off by a ship's representative on a prepared form. This sign-off is required, not only for new installations, but for service calls and emergency repairs as well; in fact, it is required for all equipments requiring engineering services. To date the Ship Section of the Electronics Office has enjoyed a 100% ship acceptance from well over two hundred vessels since this procedure was inaugurated.

Navy Day electronics exhibit.

Teletype and CRF Group . . .

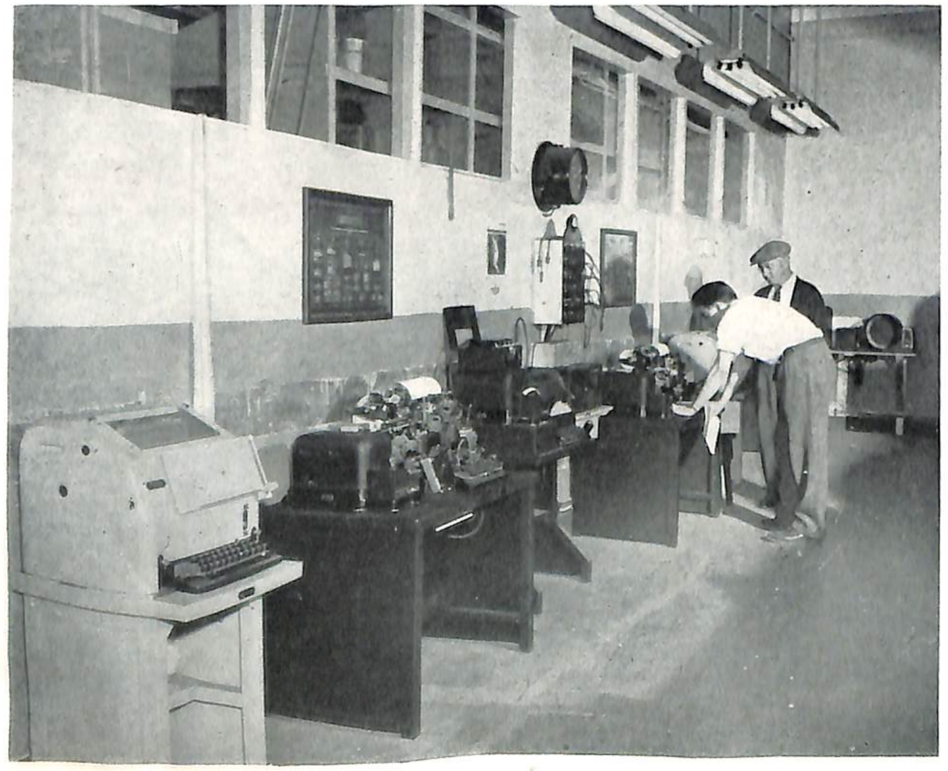
The Teletype Group, Ship & Shore Sections, Electronics Office, consists of 23 Class III mechanics and 1 electronics engineer. This group, as now established, is set up to handle all shipboard and shore teletype maintenance and new installation work. All the individuals connected with teletype work at this shipyard have had previous formal service schooling and practical experience ranging from 2 to 20 years. The major Teletype Repair Facility and Laboratory within the First Naval District is located within the shipyard in the Electronics Laboratory, Building 197. This facility has grown considerably in the past two years, due to the increased amount of teletype installations within the Navy during this period. The increased installations aboard ships and the oncoming shore maintenance work have brought about this expansion.

SHIP PROGRAM

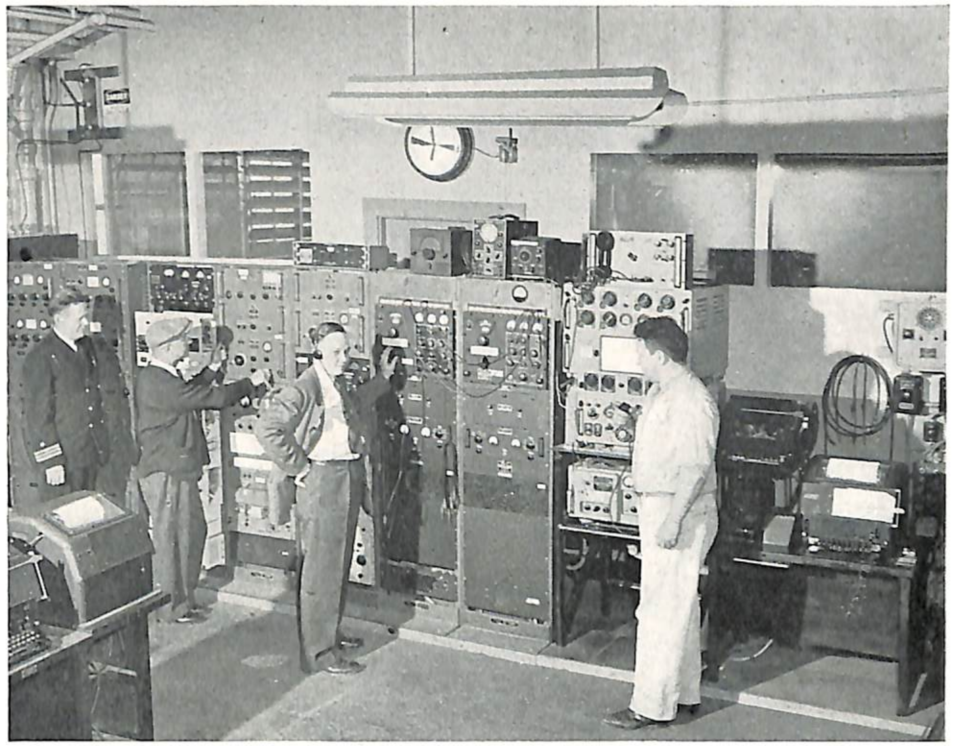
Very good results have been attained in the installation program now underway. The addition of teletypewriter equipment has caused considerable crowding of the majority of radio rooms, due to the physical size of the equipment and the floor space required for the teletypewriter tables. To prevent excessive crowding of these spaces, the associated radio receivers and converters, in most cases, have been mounted in racks. This method has proven very satisfactory in all respects. The ship's personnel have welcomed the teletypewriter equipment, as a whole, and believe that some day it will be the answer to the communication problem. During the present time when operating personnel are at a minimum, handling communication traffic by teletype would alleviate the operator shortage to a large extent, and would also greatly speed up communication traffic.

The h-f and u-h-f local programs have been very satisfactory and, as a whole, the equipment has proven adequate. The present converter, Model FRA Frequency Shift Converter, as used with the modified RBC series receivers, could be improved upon. In most cases this equipment requires that the RBC receiver operate at full gain, and then the signal-to-noise ratio of the receiver becomes excessive. Operation with a receiver of more sensitivity and better signal-to-noise ratio would be desirable. The weakness of this particular piece of equipment is the major fault of any equipment used in the antenna system.

Aside from routine maintenance, the remaining system equipments have been entirely satisfactory. Surprising results have been attained with the u-h-f Model TH-1/TCC-1 telegraph terminal equipment, as modified for use with the TDZ/RDZ equipments. Operation between ships 15 to 20 miles distant from the shipyard has been carried out with 100% success during tests. Due to the nature of u-h-f, transmission results are unpredictable because of the normal variables, such as location of the ship, antenna locations on the ship in respect to the receiving location and the ship's structure within the line of transmission. Due to the physical layout and placement of component parts, it is almost impossible to service and maintain this equipment and keep it in operating condition. With the installation of the new u-h-f terminal equipment (AN/SGC-1) now under development and manufacture, many of the intrafleet communication problems will be answered.



Part of the teletype laboratory.



Radio installation in teletype laboratory.

Lack of qualified teletypewriter repairmen aboard ship presents a major problem to the Ship Teletype Program. Equipments are being misused and inadequately maintained in many instances. This condition will undoubtedly be eliminated when more trained personnel become available.

SHORE PROGRAM

Maintenance of shore teletypewriter equipment has been carried on under New England Telephone and Telegraph Company contract. This contract for the First Naval District was canceled as of 1 July 1948. After that time, the Teletype Group of the Electronics Office has carried on all teletypewriter maintenance within the district. The major Teletypewriter Repair Facility located within the Shipyard, and two minor repair facilities within the district constitute the teletypewriter maintenance facilities within the district. The district has been divided into three sections or areas for routine and emergency servicing, and the major facility handles all major overhauls within the district. All facilities operate on a 7-day week, 8 hours a day, on a staggered-shift basis in order to provide services comparable to the service rendered by the New England Telephone and Telegraph Company. With sufficient rotational spare equipment on hand at the facilities, interruption of service should be held to a minimum.

Spare and replacement parts are on hand in sufficient quantities to meet any emergency. It is estimated that a 6 months' supply is presently on hand at the major Teletypewriter Repair Facility to meet the needs of both ship and shore requirements. Spare parts deliveries have been prompt; with the stock on hand cannibalization or outages due to lack of replacements have never been required.

All of the major activities within the district are now equipped for F.S.K. radio teletypewriter operation, both for h-f and u-h-f circuits. It has been found that the model FRF Frequency Shift Converter, the dual diversity equipment, as used at shore installations, is far superior to the Model FRA equipment as used on shipboard. The sensitivity is much improved over that of the FRA; the associated receiver is not required to operate with maximum gain, and a much better signal-to-noise ratio is obtained.

Captain A. L. Becker visits Boston Naval Shipyard . . . . . .

Recently, Captain A. L. Becker, USN, Assistant Chief of the Bureau of Ships for Electronics, received the official "Electronics" gavel, presented by Captain W. McL. Hague, USN, Commander, Boston Naval Shipyard. A combination of modern and ancient arts, the gavel itself is constructed of the latest high-frequency insulation material, while the accompanying block is the last authentic piece of material from the original planking of the *USF Constitution.*

Commander G. L. Countryman, Captain W. McL. Hague and Captain A. L. Becker.

Captain Becker stated that the gavel and block would be put to good use and that conferences under his chairmanship would continue to be businesslike and to the point, especially now that the authority of his gavel would be backed up by over 150 years of Naval tradition.

Installation and Maintenance of Shore Stations

Due to the acute shortage of station technicians, the Electronics Officer at the Boston Naval Shipyard has assumed a large part of the regular maintenance work at Naval shore stations in his area. This work has covered radio, radar, and teletype facilities. In addition to preventive maintenance, routine service, and emergency work the Electronics Officer is called upon to supply engineering planning and supervision of all new equipment installations in these stations. Engineering surveys, reports and recommendations for long-range planning for Naval stations in the First Naval District are also furnished by the Electronics Office.

Currently, extensive modifications are in progress designed to increase the utility of existing communication facilities and to make maximum provision for "emergency" expansion of such facilities should the need arise.

Of greatest interest are the following items of engineering work now underway:

1—Modification of transmitting antenna systems to prevent interaction.
2—Modification of transmitting and receiving antennas to provide wide-band efficiency.
3—Installation of v-h-f links to permit remote control of transmitters.
4—Installation of teletype station terminal equipment.
5—Surveys to reduce noise level at receiving locations.
6—Engineering surveys and planning for future expansion of communication facilities.

Internal Security Radio Equipment . . . .

The Shore Section of the Electronics Office, Boston Naval Shipyard, installs all internal security equipment in the First Naval District. This section compiles station inventories, originates or processes Bureau correspondence, and undertakes engineering surveys relating to internal security installations. Shop 67 maintains the internal security equipment in the Boston area in accordance with a preventive maintenance schedule established for all fixed and mobile internal security equipment. Under the schedule, each unit receives a comprehensive semi-monthly material and operating check, which is designed to reduce equipment failures, reduce emergency calls, and ensure maximum life of the equipment. A one-half ton pick-up truck, equipped with tools, test equipment and spares, is assigned to Shop 67 for this purpose.

Radio Teletype Adapter

By H. O. Makinson & W. E. Scoville
Development Department
U. S. Navy Electronics Laboratory
San Diego, California

Emergency or "stop-gap" equipment for utilizing standard Navy transmitters and receivers on radio-teletype circuits may be constructed easily by Navy ship- and shore-station personnel. Such equipment employs the "on-off" principle of radio-teletype operation, with the *mark* signal being represented by a transmitted carrier and the *space* signal by the absence of the carrier.

Transmitting. Since Navy specifications call for a minimum transmitter keying rate of 100 words per minute, any Navy transmitter operating normally can accept the 60-word-per-minute output of a standard teleprinter. It is necessary only to connect the sending contacts of the teleprinter into the keying circuit of the transmitter in place of the hand key or tape keyer.

The keying circuit current of the transmitter should be checked before connecting the teleprinter. Although most Navy transmitters key with a current of less than the 60-ma limit of the sending contacts of the teleprinter, some of them require up to 110 ma of current in the keying circuit. Any transmitter requiring more than 60-ma keying current should be operated from the sending contacts of a teleprinter only in an emergency.

Receiving. The reception of "on-off" radio-teletype signals can be accomplished with standard Navy receivers through the use of a simple adapter which may be made small in physical size and which requires only a minimum of parts, most of which are available at every station. The receiver adapter to be described here includes its own power supplies and associated circuits. It should be noted that the unit is designed to operate into a teleprinter line operating on a neutral basis, the d-c resistance of which does not exceed 250 ohms.

All of the components are assembled on a single aluminum chassis. In the model constructed at the U.S. Navy Electronics Laboratory, the chassis size was 7¼ x 5¼ x 3 inches. Placement of parts and the available chassis will determine the final size in every case. In no instance, however, are there any critical construction requirements except for the observation of the polarity markings on the crystal diode and the placement of a 0.01-μf capacitor directly between the plate pin and ground of the cathode follower. The cathode of the diode should be connected to the grid of the first section of the d-c amplifier. Leads to the 0.01-μf capacitor should be kept as short as possible to eliminate any tendency for the output stage to oscillate.

The schematic for the adapter is shown in figure 1. The full-wave, positive d-c power supply, comprising T-101, V-104 (5Y3), L-101, C-106, and R-108, R-109, and R-110, supplies 200 volts at 70 milliamperes. This supply is used as plate and screen voltages for the output cathode follower and operating current for the teleprinter line relay. The half-wave, negative d-c power supply, consisting of one-half of the secondary of T-101, V-103 (6X5), and an RC filter composed of R-107, C-107, and C-108, delivers a negative 140 volts at 10 milliamperes. All voltages are measured with respect to ground and are more than sufficient to provide optimum operation of the unit. R-111 is used as a voltage-dropping resistor and also serves to protect the winding of T-101 should a heater-to-cathode short develop in V-103.

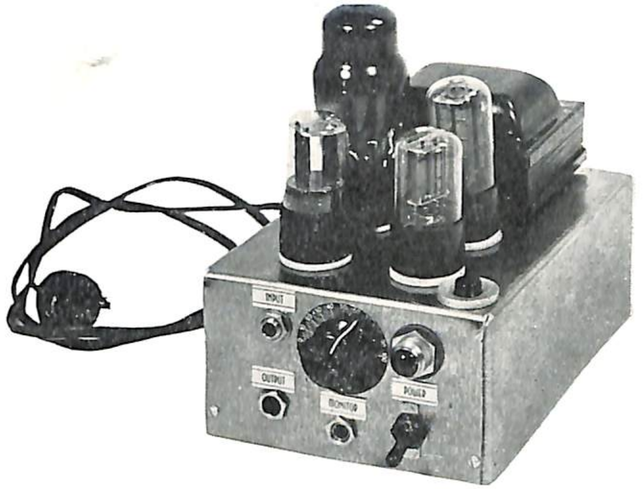


FIGURE 2—*"On-off" radio-teletype adapter operates teleprinters from standard Navy receivers.*

The signal converter-amplifier portion of the adapter consists of a germanium crystal diode used as a clipper, CR-101 (1N34), a two stage d-c amplifier, V-101 (6SL7), and an output cathode follower, V-102 (6Y6). Bleeder resistors, R-102, R-103, and R-104, connected across the negative 140-volt supply, pass 7 milliamperes. The voltage drops across these resistors establish the operating points for both sections of V-101. The cathode of V-101A is held at 138.5 volts below ground for an effective negative grid bias on this section of 1.5 volts. The cathode of V-101B is held at 95 volts below

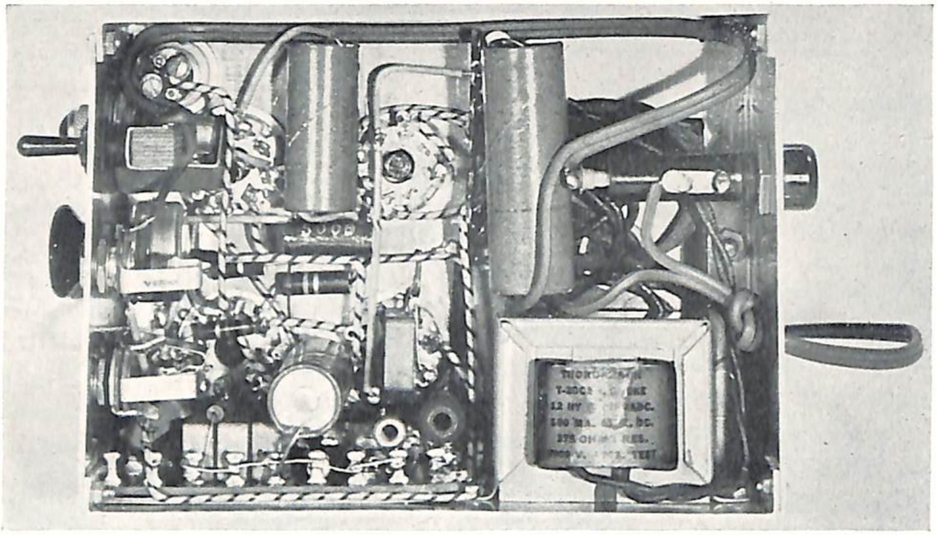


FIGURE 3—*Underside view of radio-teletype adapter showing compact arrangement of parts.*

ground. These cathode potentials remain stable since the total current through both sections of V-101 is much less than the 7 milliamperes drawn by the voltage-divider bleeder.

The negative 1.5-volt operating point for V-101A was chosen so that the plate of this section, connected to the grid of V-101B, would draw sufficient current through R-105 to cause the potential on the grid of V-101B to be equal to or slightly more positive than the cathode potential. Since the cathode of V-101B is held at a negative potential of 95 volts, this zero or slightly positive bias causes V-101B to draw maximum plate current through R-106. Under this condition, the plate of V-101B and the grid of V-102, connected together, assume a negative potential of 75 volts. Since the cathode of V-102 is returned to ground, the negative 75 volts on the grid of V-102 holds the cathode current of this tube at approximately zero.

When a signal, normally consisting of pulses of 1000-cycle audio energy, is fed into the input of the signal converter through capacitor C-101, the germanium diode, CR-101, clips the negative alternations from these 1000-cycle pulses. The remaining positive alternations are then applied to the grid of V-101A to cause an increase in plate current of V-101A and an increased voltage drop across R-105. The grid of V-101B, connected to the plate of V-101A, therefore, assumes a negative potential of 135 volts because of the increased voltage drop across R-105. The grid of V-101B at this point has a negative bias voltage of 40 volts because its cathode voltage is still 95 volts below ground. This bias is far in excess of that necessary to reduce the plate current of V-101B to zero. Thus there is no current through R-106, and the grid of V-102, connected to the plate of V-101B, is at ground potential and V-102 conducts. Capacitors C-102 and C-103 are used as filters to remove some of the 1000-cycle a-f component from the d-c pulses.

Current requirements for a normally-connected teleprinter do not exceed 60 milliamperes. Initial adjustment of line current to this value is made by adjusting the screen voltage of V-102 with potentiometer R-109 while holding closed the spring-loaded switch, S-102. As can be seen from the schematic, S-102 shorts resistor R-106 to ground, grounding the grid of V-102. This is essentially the same condition that is obtained when a mark signal is being received. Since a mark signal is delivered to the unit in the form of 1000-cycle audio pulses, conversion of these pulses from a.f. to d.c. is accomplished.

Any receiver equipped with a beat-frequency oscillator can be used with this adapter. Better results will be obtained, however, with a receiver which also employs an audio filter. Receivers of this type are the RBB and RBC. The audio output of the receiver should be connected to the adapter input jack, J-101. If the output is obtained from the receiver headset jack, the monitor jack on the adapter, J-102, provides a convenient point to monitor receiver tuning. The adapter output jack provides a connection for the receiving teleprinter. The tip contact of the jack is positive, and, as an aid to proper teleprinter operation, a 100-milliampere d-c meter should be connected in series with one of the leads to read teleprinter line current.

To put the system into operation, the power cord of the adapter should be connected to a 115-v a-c outlet and the power switch, S-101, should be placed in the "ON" position. After about a minute has been allowed for the tubes to reach operating temperature, S-102 should be depressed and R-109 adjusted to obtain a teleprinter line current of 60 milliamperes. No further adjustment of the adapter unit is required unless the teleprinter is moved to a new location or the adapter tubes are replaced.

The procedure for receiving radio-teletype signals is the same as that used for the reception of c-w signals. The beat-frequency oscillator is adjusted for a beat note of about 1000 cycles. If the audio filter is used, better results (a higher signal-to-noise discrimination) will be obtained with the b.f.o. adjusted so that the beat note falls within the filter pass band. The gain control of the receiver is used as a threshold control and should be set midway between the two extremes of those settings which give faulty operation of the teleprinter. Such an adjustment is one that will produce an a-f signal of between 0.6 and 1 volt r.m.s at the adapter input. (Too-great receiver gain will result in blocking the adapter and continuous holding of the teleprinter on *mark,* while if the sensitivity of the receiver is too low, the teleprinter will print erratically.) No further receiver adjustments, except those necessary to compensate for frequency drift, will be required.

The adapter can be used in emergencies for the reception of frequency-shift radio-teletype signals. If the receiver used has no audio filter, the b.f.o. should be tuned to zero beat with the frequency-shift *space* signal. The *mark* signal then will appear as a beat tone which will operate the adapter. If the receiver has an audio filter, however, the b.f.o. should be tuned until the *mark* signal beat falls within the pass band of the filter. Gain control is obtained in the same manner as when receiving "on-off" signals.

It must be emphasized that the adapter will perform satisfactorily only on a solid circuit. It is not intended to replace regular f-s-k converters such as the FRA, but only to provide an additional radio-teletype circuit under certain operating conditions.

PARTS LIST

C-101, C-102, C-103, C-104, C-105	Capacitor, 0.01μf. mica, 500 volts. (∓10%.)
C-106	Capacitor, 16μf. electrolytic, 450 volts.
C-107, C-108	Capacitor, 16μf. electrolytic, 250 volts.
CR-101	Germanium crystal diode, type 1N34.
F-101	Fuse, 250 volts, 1 ampere.
I-101	Pilot lamp, 6.3 volts, 0.25 ampere.
J-101, J-102, J-103	Phone jacks, standard.
L-101	Choke, 10-henry, 85-milliampere.
R-101	Resistor, 120,000-ohm, 1-watt. (∓20%.)
R-102	Resistor, 180-ohm, 1-watt.
R-103	Resistor, 5,000-ohm, 1-watt.
R-104	Resistor, 15,000-ohm, 1 watt.
R-105	Resistor, 1 megohm, 1-watt. (∓20%.)
R-106	Resistor 150,000-ohm, 1-watt. (∓20%.)
R-107	Resistor, 5,000-ohm, 5-watt.
R-108	Resistor, 10,000-ohm, 5 watt.
R-109	Resistor, 5,000-ohm potentiometer, 2-watt.
R-110	Resistor, 5,000-ohm, 2-watt.
R-111	Resistor, 10,000-ohm, 10-watt.

All resistor tolerances ∓ 10% unless otherwise marked.

S-101	Toggleswitch, single-pole, single-throw.
S-102	Switch, single-pole, single-throw, spring-loaded, normally "off."
T-101	Power transformer. Primary: 115v. 60 c.p.s., Secondary: 5 volts, 2 amperes; 6.3 volts 2.5 amperes; 700 volts, 85 milliamperes, center-tapped.
V-101	Vacuum tube, type 6SL7.
V-102	Vacuum tube, type 6Y6.
V-103	Vacuum tube, type 6X5.
V-104	Vacuum tube, type 5Y3.
X-101, X-102, X-103, X-104	Tube sockets, octal.

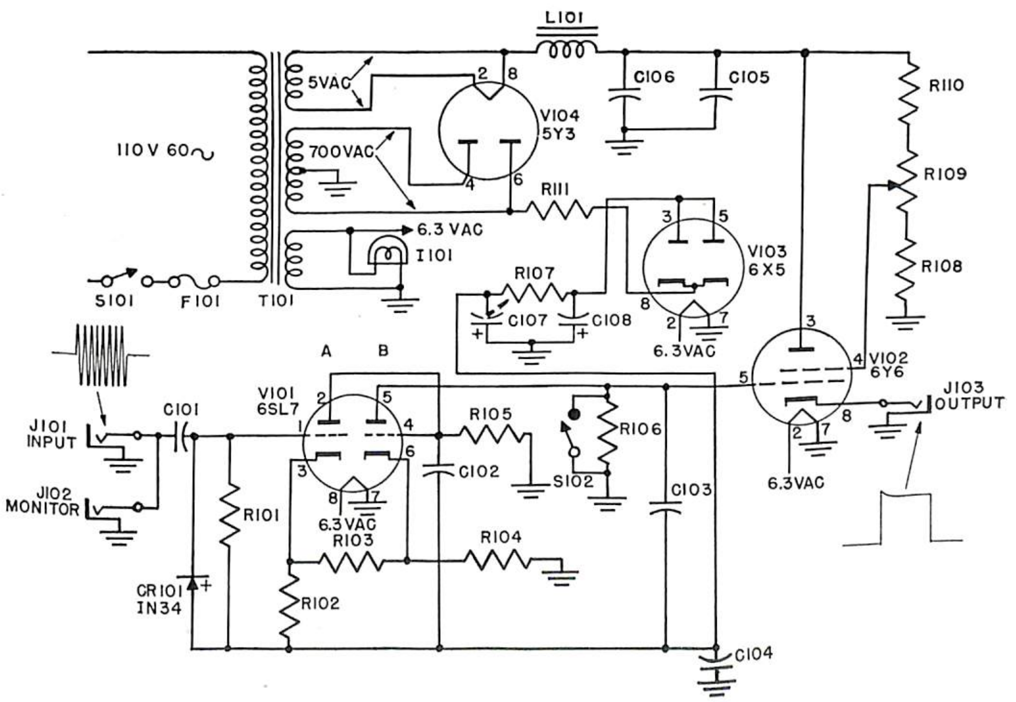


FIGURE 1—*Schematic diagram of the "on-off" radio-teletype adapter.*

Dr. Lee de Forest

Dr. Lee de Forest inspecting the type 2P21 image orthicon.

The Bureau of Ships and the Naval Communication Station at Annapolis recently had the honor to entertain Dr. Lee de Forest, world-famous radio pioneer. At the Bureau, Dr. de Forest was welcomed by Captain A. L. Becker, the Assistant Chief of the Bureau for Electronics. Later, at Annapolis, he was entertained by Captain Paul F. Dugan, the Officer-in-Charge of the high-power radio station.

During his visit at the Bureau, Dr. de Forest was shown numerous examples of the Navy's great advancements in electronics in recent years. He was shown through the display room at the Bureau, and appeared greatly impressed by the exhibits. Among other things, the Model TDZ transmitter installed there excited his curiosity. He expressed a desire to "tear into it" and see how it worked.

Later in the day he was shown the sights at the Annapolis radio station. This was his first visit to a Navy transmitter station in many years, Dr. de Forest said. He seemed to take pleasure in seeing this equipment in operation, and was keenly interested in everything he saw; towers, ground installation, antennas, and scenery as well as equipment. Particularly interesting to him was the Navy's high-power, v-l-f transmitter; he was amazed at the gigantic sizes of tubes and other components.

The last time Dr. de Forest visited Annapolis was in 1902, when he went to the Naval Academy to demonstrate the superiority of his new radio over the one submitted for test by the Germans. This was back in the days when the Navy was first deciding, "Maybe there *is* something to this thing called 'wireless' after all!"

The Secretary of the Navy, desiring to witness the demonstrations, made the trip from Washington in a horse-drawn carriage. When the Academy's saluting battery commenced firing to honor the Secretary's arrival the horses were startled by the sound, bolted, and overturned the carriage. The Secretary was badly hurt. Dr. de Forest transmitted the story of the accident to an assistant in Washington who was operating a radio receiver and who gave the story to the newspapers. This was a newspaper "first," for it was the first time a press release was transmitted by radio.

Dr. de Forest's list of patents is enormous. His "audion," invented in 1907, was the first tube to contain a grid, and was therefore the forerunner of all modern vacuum tubes with the exception of diode rectifiers and magnetrons. He may truly be called the "Father of Modern Electronics" for the audion alone, for without it there would be nothing in the way of radio, sound on film or tape, long-distance telephone, television or radar. Without the modern vacuum tube there would be no atomic bomb.

Other patents included microphones, diathermy apparatus, phonograph pickups, and loudspeakers. Dr. de Forest was the first to conceive of and build a device for recording sound on motion-picture film. All of these things he brought us at stages in the development of modern electronics when such things were previously unheard of.

Much of Dr. de Forest's early nomenclature has survived forty years of advancement in electronics. An example is "A" and "B" to designate the filament and plate batteries, respectively; another, the "grid" itself—he called it that because the early version resembled the grid used in an oven for cooking; a third, the color coding for wires leading to the vacuum tube: green to grid and red to plate. This and much other terminology of his is standard today.

The venerable doctor feels that the electronics art has made such great strides that it is now quite impossible for any one man to learn all there is to know about it. At the turn of the century little was known about those elusive, intangible radio waves and one good physicist could master the new science. Now, nearly fifty years later, with all the ramifications and the volume of intense study required, this is humanly impossible. Even Dr. de Forest has had to specialize; at the present time he is concentrating his energies on color television.

Thank you, Dr. de Forest, for the honor you have afforded the Navy by visiting the Bureau of Ships and the Navy's radio station at Annapolis. We sincerely hope to have this privilege again.

Dr. de Forest and Captain Dugan

Captain Becker and Dr. de Forest

Inspecting v-l-f transmitter

Latest T.A.B. Revisions

An article on Page 19 of February 1948 ELECTRON explained the form and style that future revisions of the Electronic Equipment Type Allowance Book (NavShips 900,115) would have. The following is a list of all T. A. B. revisions issued since 1 November 1947:

Recently many requests have been received in the Bureau for copies of the complete T. A. B. These requests can not be honored because the supply of complete books has been depleted. The publication is continually undergoing revision, however, and a complete file of revisions will eventually comprise a complete, up-to-date T. A. B.

Revision No.	*Ship type*	*Effective date*
7	AGD	11/47
8	AE	11/47
9	PCE	11/47
10	LSM(R)	11/47
11	AGC	12/47
12	Aircraft rescue boats	12/47
13	PC	12/47
14	AR	12/47
15	ARB	12/47
16	LST 1–1153 class	1/48
17	LST 1–1152 class	1/48
18	AE	1/48
19	AGS	1/48
20	PCE weather ships	1/48
21	Bomb target boats 36- and 46-foot	2/48
22	AMcU	2/48
23	YNg	2/48
24	ARH	2/48
25	LCT	4/48
26	LSD	4/48
27	AGSc	4/48
28	LSM	4/48
29	AN	4/48
30	PT809–812	5/48
31	LST–1153 class	5/48
32	PC	5/48
33	Remote Controlled Guided Missile Target Boats	5/48
34	Deletes PE, PGM, PY, PYc, YMT, PF (Frigates), PF(weather vessels), PG (Gunboats except Corvettes) PG (Gunboats, Corvettes class) 62-71, 86, 87, 92-96)	5/48
35	ADG	5/48
36	APD (87-139)	5/48
37	DE	5/48
38	DE Radar Pickets	5/48
39	AS	5/48
40	AVP	5/48
41	AV	5/48
42	APD (37-86)	5/48
43	AD	5/48
44	AG(88-89 Icebreakers)	5/48
45	SSR (481-489 Only)	5/48
46	Deletes ABSD	5/48
47	AGC	5/48
48	AM	5/48
49	AMS	5/48
50	AP	5/48
51	APA	5/48
52	APA Div. Flagships	5/48
53	APA Squadron Flagships	5/48
54	ARL	5/48
55	ARS	5/48
56	ARS (T)	5/48
57	ARV	5/48
58	LCT	5 48
59	CA Flagships (68 class)	5/48
60	PCS 136′	5/48
61	LCI (L)	5/48
62	Torpedo Retrievers	5/48
63	YTT	5/48
64	PT809–812	5/48
65	BB (61 class)	5/48
66	BB (55 class)	5/48
67	YDT	5/48

Measuring F-S-K Spread

By LIEUT. (*j.g.*) H. M. WINTERS
Navy Communication Station
Wahiawa, Oahu, T.H.

When your one and only audio oscillator or 'scope goes up in smoke just when you need to measure f-s-k spread, do you get grey hair? Then read on, Sailor.

An audio oscillator and 'scope are very handy for measuring a frequency-shift signal, but not actually a necessity. If you have a receiver similar to the Model RBC, or one with a b-f-o dial, you're in. Calibrate the tuning range of the b-f-o dial with a frequency meter and determine the number of cycles per dial division. On the Model RBC receiver you will find that the b-f-o dial covers a range of 1400 cycles from zero to ten. This represents 140 cycles per dial division. This figure is constant throughout the tuning range of the receiver.

To measure the spread, set the b-f-o dial at or near zero and tune in the signal with the main tuning dial. Tune the "mark" signal roughly to zero beat and trim up accurately to zero beat with the b.f.o. Note the dial setting. Then adjust the b-f-o dial to zero beat on the "space" signal and note the dial setting. The number of divisions between the two settings multiplied by the cycles per division is the spread. Example: 6 divisions X 140 cycles = 840 cycles spread.

Using the Model RBC receiver you can measure accurately to within 50 cycles. This is satisfactory in most cases.

Performance of RM and Conventional Dry Batteries

In certain types of batteries, either the Ruben-Mallory (RM) or the LeClanche (conventional, sal-ammoniac) dry batteries may be used interchangeably, and are both procured and issued with this in mind. The length of service, however, provided by the RM battery is usually several times that of the conventional sal-ammoniac type. As a help to those requisitioning and procuring such batteries, so that some idea may be gained in advance of future replacement needs, comparative studies have been made of the expected length of life. The results of these studies are expressed as procurement and issue ratios, which are simply the ratios of the length of life of a given RM battery to the length of life of the approximately equivalent conventional type. The ratios are expressed to the nearest whole number.

The ratios have been determined for a number of RM batteries having military applications and with a conventional counterpart. They are listed in the following table:

RM battery type	Length of service ratio
BA–1002	3
BA–1015A	2
BA–1028	4
BA–1033	3
BA–1035	2
BA–1036	2
BA–1037	2
BA–1038	5
BA–1039	4
BA–1040	6
BA–1203	1
BA–1208	3
BA–1210	3
BA–1211	2
BA–1222	1
BA–1246/U	[1] 3
BA–1043	2
BA–1048	1
BA–1049/U	5
BA–1053	5
BA–1059	3
BA–1063	5
BA–1080/U	[2] 2
BA–1228	5
BA–1231	1
BA–1233	2
BA–1234	2

[1] If issued in place of BA–51. Not applicable in all cases due to size.

[2] If issued in place of BA–70. Ratio is 4 if issued in place of BA–80.

The type BA–1247/U RM battery has no conventional or LeClanche counterpart.

Current Leakage of Electrolytic Capacitors

In the maintenance of electronic equipment, the testing of electrolytic capacitors plays an important role. When testing circuits, shorted or open capacitors are usually quite obvious, but determining the rejection point for one not in these categories is a more difficult matter. In the process of repairing an equipment if a defective electrolytic capacitor is replaced with one having a high direct-current leakage the new capacitor either will fail in a very short time or will cause poor overall operation of the equipment concerned.

The direct-current leakage of an electrolytic capacitor, when measured with an analyzer such as the Navy Type –60007 Capacity Analyzer or equivalent, should not exceed the current value calculated from the information listed in the following table:

Rated working voltage (v)	Allowable leakage per microfarad (ma)
15 to 100	0.1
101 to 299	0.2
300 or more	0.5

For example, a 16-mf capacitor rated at 450 volts (working) is to be tested. From the table, the allowable leakage for capacitors rated at 300 volts or more is 0.5 ma per mf. The total allowable leakage is therefore 8 ma (16 x 0.5 ma).

This method holds true whether the capacitor is a dry or wet electrolytic. If the direct-current leakage as measured on the Type –60007 analyzer exceeds the calculated allowable leakage, the capacitor should be discarded. Capacitors in spares should be tested periodically to insure low leakage. This is especially true of wet electrolytics which deteriorate more rapidly due to the chemical action which occurs.

Note that when checking electrolytic capacitors which have been idle for some time, the capacitors should first be re-formed as described in the instruction book for the Type –60007 analyzer. It must be remembered that high voltage is employed in measuring current leakage. It is therefore extremely important that the instructions for operating the analyzing equipment be followed implicitly to prevent damage to the meter or injury to operating personnel.

The Bureau of Ships is in the process of preparing copies of the table included with this article. These copies should be attached to the cabinet of the Type –60007 analyzer. They will be distributed to all vessels and activities possessing the Type –60007 analyzer in the near future.

Adjusting Model SX Search Feed Horns

Pre-production Model SX Radar Equipments were supplied under Contract NXsr-76195, and regular production models under Contract NXsr-96353. Different conditions prevail for the equipments produced under each contract. Under Contract NXsr-96353, with each Model SX, the contractor furnished two short sections of waveguide which were designated as search waveguide extensions. Instructions for using these extensions when focusing the search antenna feed horns for use with different type magnetrons were furnished with each equipment on G. E. Drawing No. K-7897558.

In each production equipment these search waveguide extensions were furnished tailored to fit the particular equipment concerned and its equipment spares. For this reason, when it became necessary to replace these short sections in tender and stock spares and in the two extra sets of equipment spares, a flexible section of waveguide was needed. Accordingly, a flexible 4-foot section, CG-333/U, G. E. Symbol No. E-3021-1 per G. E. Drawing No. K-7120865-1, has been supplied for this purpose. This waveguide extension, together with the Search Guide E-3021, as supplied in tender and stock spares, should be used when the set of equipment spares has been exhausted and it becomes necessary to use tender and stock spares. Figure 1 shows this flexible waveguide extension and search guide installed on an antenna assembly. It should be noted that each search guide supplied in tender and stock spares was modified in order to accommodate the flexible section. This section was not supplied originally, but is now included in the spares.

In the case of pre-production Model SX Radar Equipments procured under contract NXsr-76195, the Bureau of Ships will supply two sets of new feed horns, Search Guides E-3021 and flexible Waveguide Extensions E-3021-1. Upon receipt, the new feed horns and search guides are to be installed in place of the old components. The old components are to be removed from the equipment and the equipment spares as well, and returned to the Inspector of Naval Material, Syracuse, N. Y. These components will then be modified by the contractor and returned for use in tender and stock spares.

After these changes have been made, the r-f plumbing on all Model SX Radar Equipments will be the same. The focusing dimensions are the same using the flexible extension as they were using the short search waveguide extensions, and apply to all Model SX equipments. Due to the extreme frequency sensitivity of the search antenna, it is important that the feed horns be placed very precisely. Figure 2 and the accompanying table give the correct dimensions, when using any of the three different type magnetrons for which the equipment is designed. Dimensions to the feed horns should be measured at the center of the mouths. The *EC* and *ED* dimensions should be made equal to assure that the upper horn is on the centerline of the search dish.

Teddy A. Harper, ET1, of the CIC Team Training Center, San Diego, California, has suggested a detailed procedure for adjusting the feed horns. Refer to figure 2. Uncouple the feed horns from the waveguide at the coupling marked *S*, and remove them from the bracket. The top horn should measure seven inches vertically across its face. At the center of the face (3½ inches) locate point *E*. Next take a square and mark line *EF* perpendicular to the edge of the horn. Now locate a point *B* on the bracket so that *BC* equals *BD* (This means that point *B* is equidistant from the bottom center and the top center of the parabolic reflector). Next locate point *A* which is the exact center of the parabolic reflector. Place the feed horns back in their bracket, clamp a straight edge between points *A* and *B*, and position horns so that line *EF* falls along line *AB* and so that point *E* is exactly 59.92 inches from point *A*. Next pivot horns around point *E* as an axis, and adjust line *AG* to the dimension recommended in the table for the type magnetron in use. Clamp the horns firmly in place and check to make sure that *EC* and *ED* are equal.

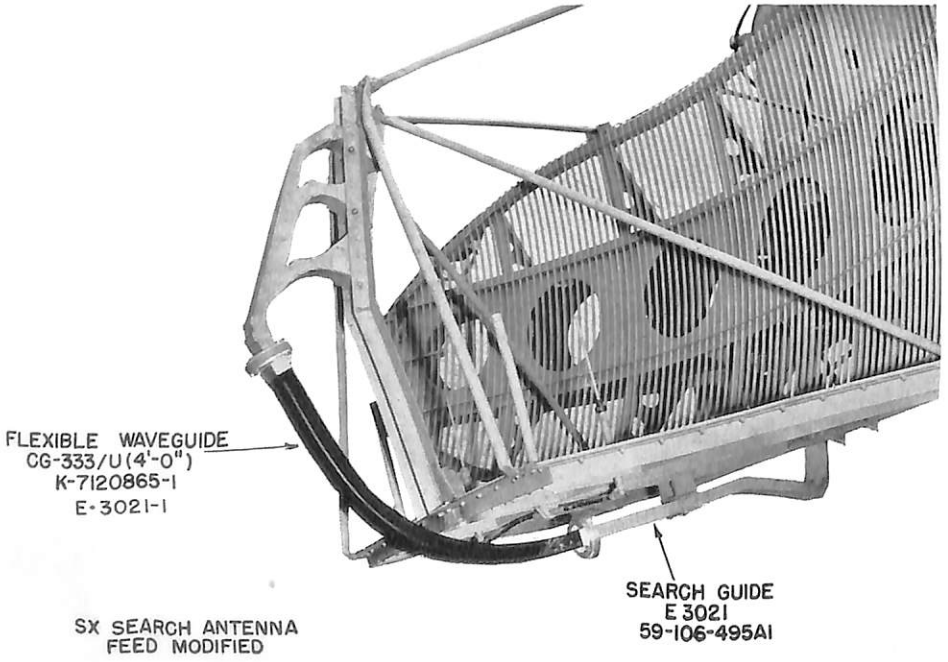
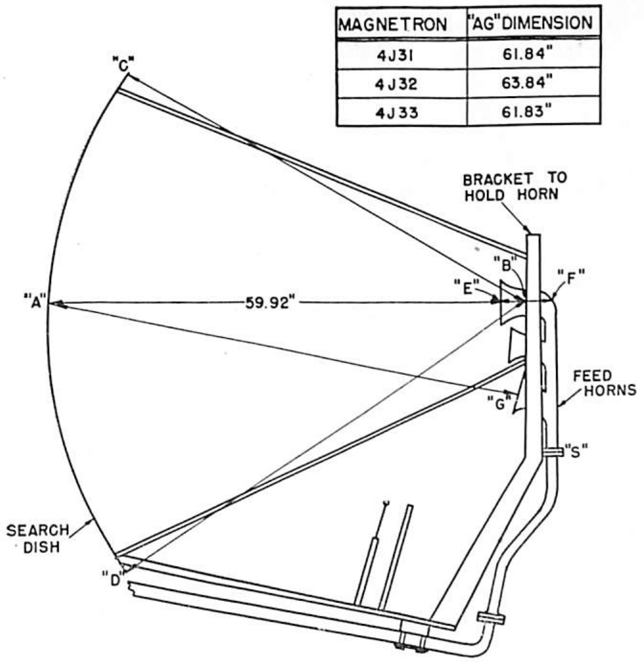


FIGURE 1—*Flexible waveguide extension and modified search guide installed on CAYL-66-ALH Antenna Assembly of the Model SX Radar Equipment.*



MAGNETRON	"AG" DIMENSION
4J31	61.84"
4J32	63.84"
4J33	61.83"

FIGURE 2—*Dimensions and table for proper adjustment of the search feed horns of the Model SX Radar Equipment.*

* * *

ATTENTION SP RADAR TECHNICIANS

The March 1947 ELECTRON carried an article on Page 19 concerning "Model SP Radar Equipment—Field Change No. 59—Addition of Bi-Directional Coupler." Since the response to the original article was far from satisfactory, part of the article is quoted below, with the expectation that the ships concerned will be reminded to comply with the request contained in it:

"Since there are not sufficient modified TR waveguide sections available to permit the distribution of one with each field-change kit it is necessary to obtain additional sections from those ships which now have them in their equipment spares. In view of the fact that the Bureau does not consider these sections as expendable items, ships should not hesitate to relinquish them. Therefore it is requested that all ships having an SP radar bearing Serial No. 101 or higher remove the modified TR waveguide section (G. E. part No. W-7, 351, 952-G2) from their equipment spares and ship it to the Electronics Supply Branch, Naval Supply Depot, Oakland, California. The TR section should be well packed to protect it from damage, and clearly marked 'TR waveguide section to be held for issue with Field Change No. 59—SP.' "

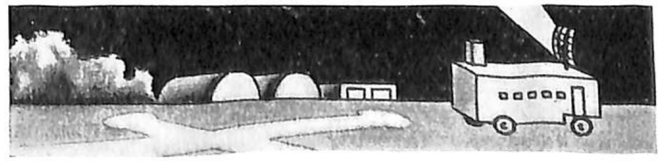
* * *

COUNTERMEASURES BOOKLET OBSOLETE

The Bureau of Ships is removing "Shipboard RCM Installations" NavShips 900,097 from the mailing list. This pamphlet is devoted to type installation plans, shipboard allowance lists and production schedules of radio and radar countermeasures equipment. Since these type installation plans and shipboard type allowances have been revised to meet additional requirements, this publication is now considered obsolete.

Accordingly, it is recommended that requests for modern countermeasures type installation plans be submitted to the Bureau of Ships for action as required. Shipboard type allowances for countermeasures equipment are contained in the Electronic Equipment Type Allowance Book NavShips 900,115.

Type of Approach	Last Month	To Date
Practice Landings	9,787	125,846
Landings Under Instrument Conditions	285	5,862



Magnetic Units . . . .

Basic Physics—Part 12

SYSTEMS OF MEASUREMENTS AND THE ESTABLISHMENT OF INTERNATIONAL STANDARDS

It is possible to express any electric or magnetic quantity in any one of three different systems of units: the electrostatic, the electromagnetic, or the practical. However, the electric field equations take their simplest forms when they are stated in the electrostatic system. Magnetic field equations are most simply expressed in the electromagnetic system of units. Circuit relations are usually given in units of the practical system more adaptable to everyday commercial usage. The point to remember is that the sizes of the units for any physical quantity differ greatly in the three systems; therefore, the manner in which the units of the various systems are related should be thoroughly understood.

At the time electrostatic and electromagnetic units were being developed by scientists and experimenters, interest was centered chiefly in low-voltage, heavy-current phenomena and magnetic field relations were more important practically than those of the electric field. Therefore, between these two systems, the electromagnetic system of units was chosen to be the basic or absolute system. These units were calculated in terms of fundamental physical c.g.s. (centimeter, gram, second) units.

To indicate their absolute nature, the units of the electromagnetic system were prefixed with "ab-." For example: ab-ampere, ab-volt, ab-ohm etc. Units of the electrostatic system were prefixed with "stat-." The more important units of the electrostatic system were derived in part 7.

In addition, there is a series of practical units, the magnitudes of which are conveniently measurable by a common unit more equal to the values of the quantities met with in daily electrical operation. Instruments such as the ammeters and voltmeters commonly used are calibrated in these units. This calibration is always achieved by comparison with standards established for international use. International standards were in turn based on absolute measurements in the electrostatic or electromagnetic systems. This is necessary since the practical units are by definition derived as multiples or fractions of the absolute units.

Since the practical system of units are simply multiples or fractions of units in the absolute system, there has been a recent trend toward the use of M.K.S. units (meter, kilogram and second) for fundamental physical units of measurements. For instance: in M.K.S. units, the unit of force would be equal to 10^5 dynes and the unit of work, 10^7 ergs or 1 joule.

International standards. The International Electrical Congress meeting in Paris in 1881 chose the ohm as the practical unit of resistance and decreed that it would be 10^9 ab-ohms, and chose the volt as the practical unit of electric potential and decreed that it should be equal to 10^8 ab-volts. By the definition of Ohm's Law, the practical unit of current, the ampere, proved to be one tenth ab-ampere.

International standards were created to provide definite physical values and rules for measurement, in terms of which all meters and electrical indicating instruments could be uniformly and universally calibrated.

The International Ohm is the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, the mass of the mercury being 14.4521 grams, and the column 106.300 cm in length and of constant cross section. Resistance standards are usually built of Manganin alloy (copper, manganese and nickel), because it has a very low temperature coefficient throughout the working ranges encountered.

The International Volt is the electric difference of potential which, when steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere. For practical purposes of calibration, it is agreed that the Weston normal (saturated) cadmium cell has a potential difference of 1.0183 international volts at 20° C. This cell is used because it was found to be a precisely reproducible source of voltage, but since the temperature coefficient of this cell is rather high, it may be used only under well-controlled conditions. Because of this disadvantage, the unsaturated cell is used, after having first been calibrated against a saturated cell.

The International Ampere is the unvarying electric current which, when passed through a solution of silver nitrate in water, deposits silver at the rate of 0.00111800 gram per second.

Relationship of the systems. For greater convenience in dealing with electric or magnetic quantities, two interrelated systems of units have been established based on the c.g.s. units of measurement. These are the electrostatic and the electromagnetic systems. The physical relationship between the two systems will be explained in more detail later.

Units in the electrostatic system are based on the unit charge of electricity called the statcoulomb. The more important units of this system have been previously derived in part 7. Units in the electromagnetic system have as their basis the unit magnetic north pole, which will be derived presently.

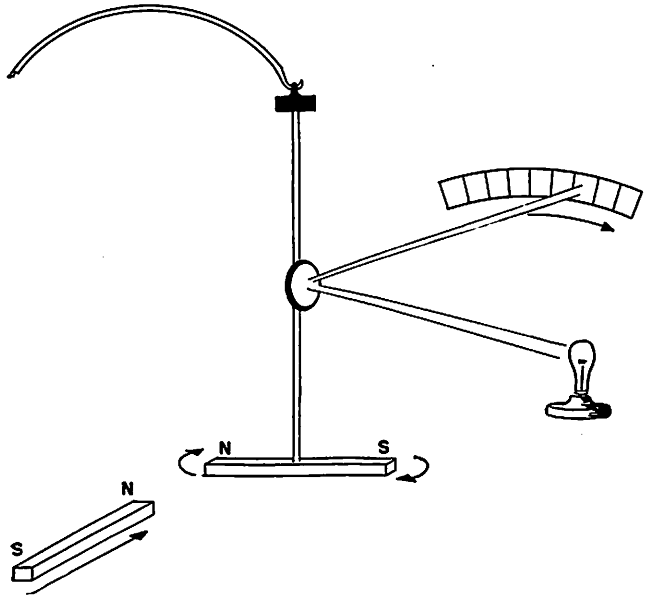


FIGURE 1—*Coulomb's apparatus for measuring the forces between electric charges.*

For practical purposes electrical and magnetic quantities expressed in c.g.s. units prove unwieldy, whereas, when expressed in M.K.S. units, they are more adaptable to practical circuits. The example now to be given indicates graphically why the trend toward the use of M.K.S. units of measurement has increased. Consider voltage and current:

1—When expressed in c.g.s units.

	Practical unit	Electrostatic unit	Electromagnetic unit
Voltage	300 volts	1 statvolt	3×10^{10} abvolt
Current	10 amperes	3×10^{10} statamps.	1 abampere

2—When expressed in M.K.S. units.

	Practical	Electrostatic	Electromagnetic
Voltage	1 volt	1/300 statvolt	10^8 abvolts
Current	1 ampere	3×10^7 statamps.	0.1 abamps.

All quantities in mechanics and electricity can be reduced to fundamental units of length, mass and time. Originally c.g.s. units were used to derive mathematical relationships between them, but they may also be expressed in M.K.S. units. For example, we learned in part 3 that force equals mass times acceleration.

Expressed: $f = ma$

When the mass is one gram and the acceleration 1 cm per second per second, the force is one dyne. In M.K.S. units, however, the unit of force is the newton, which is the force required to impart an acceleration of 1 meter per second per second to a mass of 1 kilogram. One newton is equal to 10^5 dynes.

Force may also be defined as equal to mass times velocity divided by time (when acceleration and velocity are constant).

Expressed: $f = \frac{mv}{t}$ or $f = \frac{md}{t^2}$

This may seem irrelevant at this time, but Newton's Law derived to express force provides a method whereby the two systems of electrical and magnetic measurements can be compared in terms of fundamental units, that are common.

In the study of magnetism it was found that magnetic poles of like polarity repelled each other while poles of unlike polarity were attracted to each other. Note how closely this matches the law applying to like and unlike electric charges in the electromagnetic system.

In fact, Coulomb's Law for electric charges applies equally well for magnetic poles when the separating medium is considered. This law affords a means of comparing the two systems, the e.s.u. and e.m.u. in terms of force which is common to both. Consequently, on this basis, the physical relationship between unit electric charges or unit magnetic poles may be established and expressed in terms of mass, length and time. It follows that if the units of each system can be expressed in common units of mass, length and time, a relationship between the systems is implied.

A study of the force exerted between unit charges and unit poles in the respective systems demonstrates this.

Coulomb's law for electric charges states:

$$f = \frac{Q_1 \times Q_2}{k\,d^2} \text{ dynes per unit charge. (c.g.s. units)}$$

Transposing: $\textit{Unit charge} = \sqrt{f\,k\,d^2}$ e.s.u.

Substituting Newton's third definition of force:

$$\text{Unit charge} = \sqrt{\left(\frac{md}{t^2}\right) k\,d^2}$$

$$= \sqrt{\frac{md^3}{t^2}\,k} \quad e.s.u.$$

This is known as the dimensional formula for an electrical quantity in terms of fundamental physical units, centimeter, gram and second. Thus, the fundamental measurable quantities entering into this basic equation are length or distance, inertia or mass, and time.

Coulomb's Law for magnetic poles can be similarly treated, whence the force in dynes per unit pole (μ is the permeability):

$$f = \frac{m_1 \ x \ m_2}{\mu \, d^2}$$

becomes, by substitution of Newton's definition of force:

$$Unit\ pole = \sqrt{\frac{md^3}{t^2}\,\mu} \quad \text{e.m.u.}$$

Note that the difference lies in the dielectric constant k in the electrostatic system and the permeability μ in the electromagnetic system. These proportionality constants are dependent upon the medium through which the respective electric and magnetic fields are effective.

The relation between the constants k and μ of the two systems is abstract and considered beyond the scope of this course. However, the above comparisons are sufficient to show that there exists a common means through which quantities of electric or magnetic units may be expressed in either system. As stated previously, electric and magnetic equations take the simplest form when stated in their respective systems.

Definitions of unit pole and pole strengths. When a new phenomena of nature is observed, the practice is to investigate the behavior quantitatively by means of controlled experiments and then formulate our findings in a mathematically expressed law. For example, in part 7, Coulomb in deriving the law of electrostatic charges proceeded essentially as follows: He took two charges and actually studied how the force varied for the same two charges as the distance separating them was varied. Then, keeping the distance constant he varied first the state of charge on one body and then the other. The numerical data thus obtained were tabulated and then set down as an equation: $f = \frac{qq'}{d^2} \times \frac{1}{k}$. The quantity $\frac{1}{k}$ is a constant of proportionality depending on the units of measurement and the separating medium.

In order to determine the magnitude or strength of a magnetic field, a unit of measure is required. Since the existence of a magnetic field is made evident by the forces exerted on magnetic poles, or magnetic substances in which magnetic poles have been induced, it should, therefore, be possible to express the magnitude of a pole strength or of a magnetic field strength by the force exerted on some other pole. In order to define this force, a standard unit of measurement must be chosen. This choice can only come from an experimental study of the law of force between magnetic poles.

Coulomb was the first to study the forces experimentally. He initially studied the forces of attraction between poles using the torsion balance. This consisted of a magnet suspended at its center by a flat fiber to which has been affixed a small mirror (see fig. 1). Any twist or torque applied to the fiber causes a deflection of a beam of light directed at the mirror. Thus, the force can be calculated by using appropriate mathematics. The force necessary to produce a given deflection of the balance can be previously determined through calibration.

Long magnets of small cross section were used so as to study the effect of poles as nearly isolated from their accompanying opposite poles as possible. As the pole of another magnet was brought into the vicinity of the suspended magnet, like poles repelled and unlike poles showed attraction. It was found that the force of attraction or repulsion was proportional to the magnetic strength of the pole, and inversely proportional to the square of the distance between the poles.

If the one pole is designated as having a strength m and the other brought d centimeters from it as having a strength m', the force between them can be written: $f = \frac{mm'}{d^2} \times \frac{1}{\mu}$. Here $\frac{1}{\mu}$ is a constant of proportionality and depends on the medium and the units chosen.

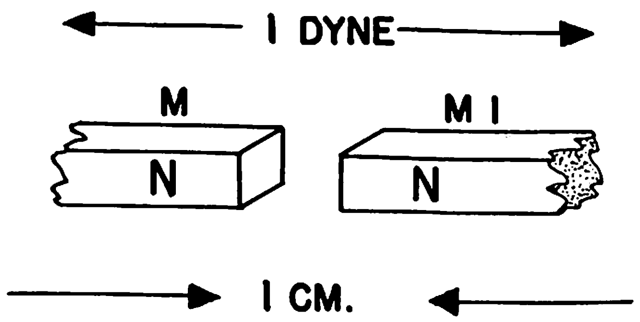


FIGURE 2—*Unit pole.*

The establishment of this law leads at once to a definition of the unit of pole strength. In any system of units, a unit pole can be arbitrarily defined as one which repels an exactly equal pole at unit distance with unit force when μ is unity as shown in figure 2. For if $f = 1$, and d and μ both equal 1, then the product of the pole strengths mm' also equals 1, and $m = 1$, or unit pole. In c.g.s. units of measurement, the unit pole is the magnetic pole which repels an exactly equal pole at the distance of 1 centimeter with the force of 1 dyne.

Concerning the quantity μ: This is a constant involving the nature of the medium between the two poles. It is assumed to have the value of unity for vacuum. For air it is so nearly 1 (1.0000004) that it can be called unity. However, for iron it can be as high as 1000, and in laboratory specimens of alloys as high as 275,000. It is called the magnetic permeability. This will be derived presently.

The practice of conceiving an ideal physical agent based on information obtained experimentally is widely followed in science. For example: In mechanics, we hypothesize the frictionless plane, an immovable body etc.; while in electrostatics, adoption of the theoretical electric charge concentrated at a point helped explain certain facts and guided us in the investigation and explanation of other associated phenomena. As long as the conclusions are correctly applied, values of an ideal physical agent may be assumed.

The unit magnetic pole is an example of just such an hypothesis. It is visualized as being the north pole of a cylindrical bar magnet of very small cross section and of infinite length, whose poles are so concentrated at each end of the bar that all the lines of force emerge from a common point. The distance between the poles is implied as being so great that in studying the magnetic field about the north pole affects due to the south pole may be disregarded. The magnetic field is thus assumed to be uniform and the lines of force composing this field diverge symmetrically in all directions from the point pole source. This is considered true only for a limited space about the magnetic pole under investigation. See figure 3.

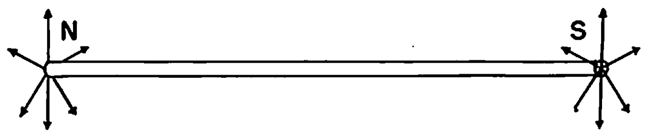


FIGURE 3—*Radial magnetic field lines close to magnetic poles.*

It is necessary to understand thoroughly the concept of the unit north magnetic pole because this concept will be used repeatedly in deriving the units of field intensity and flux density as well as total flux and the magnetomotive force of a magnetic circuit. Furthermore, this concept is used as a basis for explaining certain phenomena in electromagnetism that will be covered in part 13.

Magnetic field composition. The magnetic field of a magnet is that space around it in which its influence can be detected. Theoretically, the field extends through an infinite region, but in practice the term "magnetic field" is limited to the space within which the force is perceptible, depending upon the sensitivity of the measuring apparatus.

A north magnetic pole placed at any point in a magnetic field is acted upon by a force that will tend to move it in a particular direction; similarly, a south magnetic pole placed at the same point in the field will be acted upon by a force tending to move it in exactly the opposite direction. Consequently, if a small compass is placed in the field of an isolated bar magnet that is physically large in comparison to the magnetized compass needle, the north end of the needle will point in the direction in which a free north pole would move, while its south pole points in the direction in which a free south pole would move. This was pictured in part 11, when a compass was used to indicate the direction of the magnetic field about a bar magnet.

The true direction of a line of force in a magnetic field is that direction taken by a free unit pole in moving from the north to the south pole. It is found that the force at each point in the field, in addition to having a direction, has a definite magnitude, and like all force is therefore a vector quantity. This force varies with the distance from the various magnetic elements which cause the field.

Lines of magnetization, force and induction. The exact nature of the various forces associated with a magnet and a magnetic field should be clarified at this point to avoid confusion when referring to lines of magnetization, lines of force and lines of induction.

When magnetic domains are aligned they may be thought of as long needle-like magnets of very small cross section with the poles concentrated at each end.

The inherent magnetizing force of each filamentary magnet is represented by lines called lines of magnetization. These lines exist entirely within the magnet and are directed from the south pole to the north pole.

A bar magnet may be considered as consisting of a large quantity of these long thin magnets. Recent research in the study of the magnetic domains in ferromagnetic substances with the aid of microscopic oil films indicate that the size of the magnetic domains varies with conditions, but they appear to be filamentary in shape with lengths of perhaps 1 mm to some centimeters. The inherent magnetizing force within a magnetic region or a magnet produces a north pole at one end and a south pole at the other end, and lines representing magnetization are arbitrarily taken as directed from south to north within the magnet.

Lines of force emanate from the north pole of a magnet and terminate on the south pole. External to the magnet these lines of force constitute the magnetic field, but since lines of force are directed radially outward from the north pole, some of them will pass through the magnet in traveling to the south pole. Those lines of force directed through the magnet are in opposition to lines of magnetization within the magnet and hence exert a demagnetizing effect. Therefore it follows that the greater the cross section of the magnet, the greater the demagnetizing effect of the lines of force originating at the north pole of the magnet. Experience has shown that as the cross section of a magnet increases in relationship to the length, it becomes increasingly harder to produce permanent magnets of even the best magnetic material.

Lines of induction within the magnet are defined as the vector difference of the lines of magnetization that cause the poles and the lines of force produced by the poles. Since the lines of magnetization do not leave the poles, it follows that in the region outside the magnet the lines of induction are equal to the lines of force. At this point it must be emphasized that although lines of induction and lines of force are equal in air, their use and application is entirely different.

In figure 4 A are shown the various lines associated with a magnet. The "lines of magnetization" exist only within the magnet, and are directed from the S-pole to the N-pole. However, because of the poles formed at the ends, lines of force leave the poles, originating on a N-pole and terminating on a S-pole, and are not closed lines. The cross section of the magnet is so small, however, that practically none of these lines passes back through the magnet itself.

As a bar magnet of substantial cross-section is built up by combining more filamentary magnets, shown in figure 4 B, a considerable proportion of the lines of force leaving the single N-pole now pass back through the magnet, opposing the lines of magnetization. Hence the poles formed at the ends of a magnet are the source of a counter-magnetizing force which tends to demagnetize the magnet.

The vector diagram in figure 4 C will also serve through the magnet from the N-pole to the S-pole and the lines of magnetization directed from the S-pole to the N-pole are called "lines of induction."

The vector diagram in figure 4 C will also serve to account for the lines of force that leave the sides of the magnet. The force H at any point a is due to the combined effect of the N-pole at the end of the magnet, which exerts a component of force H_p, and the internal magnetizing force H_e, which produces the lines of magnetization. Note: the S-pole also exerts force at a, but at points near the N-pole the effect of the S-pole is negligible by comparison. The resultant of H_p and H_e produces the line of induction at the point a, and determines its direction.

In summarizing: Lines of magnetization are inherent within the magnet and directed from south to north; the lines of force originate at the N-pole, pass through the air and the magnet and terminate on the S-pole; and the lines of induction are continuous closed lines, passing outside the magnet from N-pole to the S-pole (numerically equal to lines of force in air) and passing within the magnet from south to north (vector difference of the lines of force and magnetization within the magnet).

Magnetic field intensity. The intensity or strength of a magnetic field at any point in the field is defined as equaling the force in dynes which would be exerted on a unit pole if placed at that point. It is a vector quantity; therefore, it is common practice to give the lines of force comprising the magnetic field a quantitative significance; hence the lines drawn or imagined are usually given a value equal to the force exerted by the field at that point.

Field intensity is evaluated in terms of dynes per unit pole. The unit of field intensity is defined as that magnetic field strength which will act on a unit pole with a force of 1 dyne. It is usually represented as one line of force per square centimeter of area perpendicular to the direction of the field. The unit of field intensity is named the *oersted* and is represented by the symbol H.

$$H = \frac{f}{m} \text{ (dynes per unit pole) oersted.}$$

If a magnetic pole of m units is placed in a field of intensity H, the field being so much larger than that of pole m that no disturbing field effect results, the force acting on this pole is

$$f = Hm \text{ dynes}$$

For example: A magnet of strength 50 unit poles is placed in a field of strength of 6 oersteds at that point. The force exerted is 300 dynes.

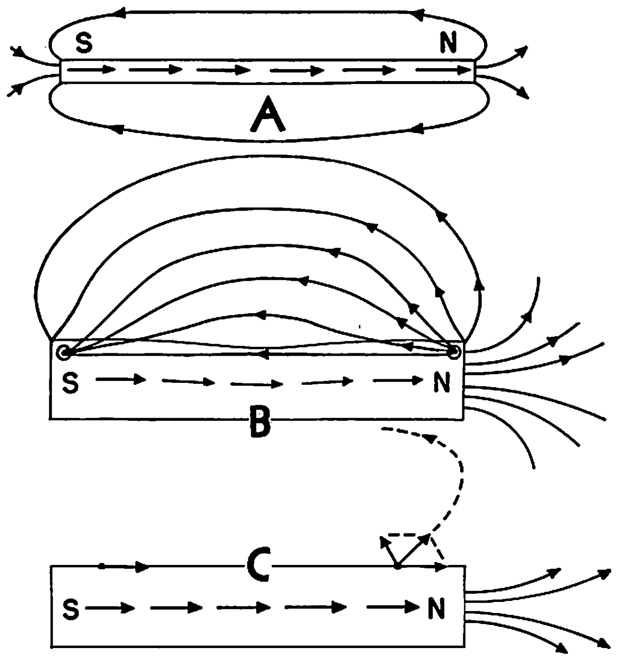


FIGURE 4—(A) *Filamentary magnets formed by alignment of magnetic domains within a magnetic material.* (B) *Lines of force emerge in all directions, some passing back through the magnet.* (C) *Direction determined by vector sum of lines of magnetization and lines of force.*

It must be remembered that field intensity refers only to the force exerted on magnetic poles placed in the field, and is a measure of the strength of a magnetic field.

Magnetic flux. When magnetic lines of force are used with a quantitative significance, the total number of lines passing through a given section in air is termed the magnetic flux, or merely flux. The accepted name for a line of flux is the *maxwell.* Total flux is usually represented by the Greek letter phi (ϕ).

In air, lines of flux, lines of force and lines of induction are all numerically equal, but if the application of the various terms is carefully studied and understood, there need be no confusion in the proper use of the names.

When lines of induction in a magnetic circuit are considered the same as current in an electrical circuit, and when used to induce magnetism or generate an e.m.f., the name flux is correct and hence a line of flux and line of induction are equal, and the same.

However, when force exerted on a magnetic pole is considered, the lines are thought of as lines of force representing magnetic field strength of intensity expressed in units called oersteds.

The total magnetic flux per unit magnetic pole can be established as follows: By definition, unit field intensity is one line of force per square centimeter and exerts a force of one dyne on a unit pole. It can also be stated that an oersted of field intensity is 1 maxwell per square centimeter; similarly, the total flux (ϕ) is equal to the field intensity, H, times the area A, perpendicular to the direction of the flux.

$$\phi = AH \text{ maxwells}$$

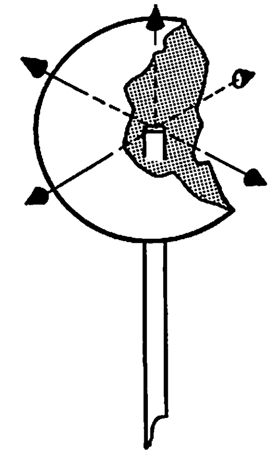


FIGURE 5—*Spherical distribution of lines of force from a unit pole.*

There is a very important and direct consequence of the definition of unit field intensity. Consider an hypothetical isolated N-pole at a point in space. There emerge from it lines of force radially in all directions (see figure 5). For the small space surrounding the unit pole the lines of force are assumed to diverge symmetrically. At all points 1 cm distant or on the surface of a sphere of 1 cm radius with the unit pole at the exact center, the field intensity $H = \frac{f}{m}$ (dynes per unit pole).

Force may also be expressed as the product of magnetic pole strengths divided by the square of the distance separating them: $f = \frac{mm'}{d^2}$

By substitution, we obtain $H = \frac{mm'}{m\,d^2} = \frac{m}{d^2}$ and since the radius of the sphere is 1 cm., thus $H = m$, and there are then m lines of force emerging from the unit pole and perpendicular to the sphere per square cm. The surface area of a sphere is $4\pi r^2$ and when the radius is 1 cm, the area is 4π cm^2 or 12.57 cm^2.

Therefore, it can be said that there are 12.57 or 4π lines of force emerging from a unit pole, or better, $4\pi m$ maxwells, where m represents the strength of the pole in question.

Upon further consideration of figure 5, the field intensity was found to equal $\frac{m}{d^2}$. At a distance of 1 cm, $H = 1$ oersted for any square cm of surface. The number of lines from the pole at the center is $4\pi m$ and constant, and as the distance from the pole becomes greater, the surface area increases as the radius squared; therefore, the field intensity per square centimeter decreases as $\frac{1}{d^2}$.

For example: The field intensity at any point on the surface of a sphere of 1 cm radius, with a unit pole at the center, is 1 oersted or one dyne per unit pole. If the radius is increased to 2 cm, the surface area increases four times. The number of lines per unit pole is constant at 4π, therefore there is effective only one line of force through 4 square cm, and the field intensity is 0.25 oersted.

This may be checked by Coulomb's Law for magnetic poles: $f = \frac{mm'}{d^2}$. Since the force exerted on a unit pole by another unit pole at a distance of one cm is one dyne, the effective force at twice the distance is 0.25 dyne.

Flux density. Flux density is the number of maxwells, or lines of induction, *per unit area* of field cross section perpendicular to the direction of the flux lines. In free space, or air, flux density and field intensity are equal numerically, but within magnetic materials they are quite different. The unit of flux density, one line per square cm, is the *gauss.* See figure 6. In practice, however, when speaking of flux density, the expressions *lines per square inch,* or *kilo-lines per square inch* are used. Flux density is commonly represented by the symbol B.

In deriving the total flux per unit magnetic pole, the value was found to be 4π or 12.57 maxwells per unit pole. Since flux density is the flux per unit area, the flux density per unit pole is 1 maxwell or one line of induction per cm^2. Note again that in air, flux density or lines of induction and field intensity or lines of force are equal.

For example: A pole having a strength of 200 units is at the center of a sphere of a radius 2 cm. In order to find the flux density, proceed as follows:

Total lines leaving pole at the center: $200 \times 4\pi = 2513$ maxwells.

Area of sphere of 2 cm radius: $4\pi 2^2 = 50.24$ cm^2.

Flux density (lines per cm^2) $2513/50.24 = 50$ gausses.

Since $B = H$ (in air), $f = 50$ dynes.

Coulomb's Law for magnetic poles may be used as a means of checking the accuracy of the above calculations.

$$f = \frac{mm'}{d^2} = \frac{200 \times 1}{2 \times 2} = 50 \text{ dynes}$$

Therefore, it is seen that the force exerted on a unit pole at any point on the surface of the sphere is 50 dynes.

Flux density may be determined by the following methods:

1. $B = H$. Flux density equals field intensity in air.
2. $B = \mu H$. Flux density equals permeability times field intensity.
3. $B = \frac{\phi}{A}$. Flux per unit area of field cross section at right angles to direction of the field.

Permeability. The permeability of a medium or material through which magnetic flux is passing is simply the measure of its ability to accommodate flux lines. According to the theory of magnetism, lines of induction cause alignment of the magnetic domains within a magnetic material. The ease with which magnetic regions are aligned vary with different materials, those of the ferromagnetic group having the least internal opposition to magnetic induction.

In ordinary practice, permeability is merely expressed as a ratio of the flux lines existing in a material or medium to the flux lines that would exist in the same volume of air, all other conditions remaining unchanged. By definition:

$$\mu = \frac{B}{H}$$

Permeability is represented by the Greek letter μ (pronounced "mu"). When dealing with magnetism and magnetic circuits, this factor is comparable to the dielectric constant k that must be considered when electrostatic charges are concerned.

In vacuum, the permeability is unity since the flux density and field intensity have been proven numerically equal. In air, the ratio of B to H is 1.0000004. Diamagnetic materials have permeabilities slightly less than unity, while weakly paramagnetic materials have permeabilities only slightly greater than unity, comparable to air. Hence, for all practical purposes, the permeability of air and nonmagnetic materials is taken as unity.

Materials classed as ferromagnetic, composed of iron, nickel, cobalt and their alloys, are strongly paramagnetic. But there are other alloys which are also strongly magnetic although they are composed of various metals which by themselves are weakly magnetic. Permeability depends to a great extent upon the composition, heat treatment and impurities in alloys. Ordinarily the permeability decreases as the proportion of impurities such as sulphur, carbon and phosphorus increases. It is not a constant under varying conditions and as such cannot be determined simply.

Magnetization curves such as that shown in figure 7 are prepared from actual tests on centimeter cubes of magnetic material for purposes of determining permeabilities under various operating conditions. The more rational method is to use c.g.s. units, lines per cm^2 or gausses being the ordinates and field intensity or oersteds the abscissas. Other methods will be explained in the next chapter.

It will be noted that the flux density does not vary in direct proportion to the field intensity, but gradually levels off with but slight increase in flux density as the field intensity is further increased. This indicates approaching saturation in the material, a condition that exists when all possible magnetic domains are in alignment with the induction.

At any value of flux density, the permeability may be found by dividing the ordinate B by the corresponding value of H. A curve determined by this method is called the permeability characteristic curve for the material. This is shown in figure 8 where the permeability of cast steel is plotted as a function of flux density.

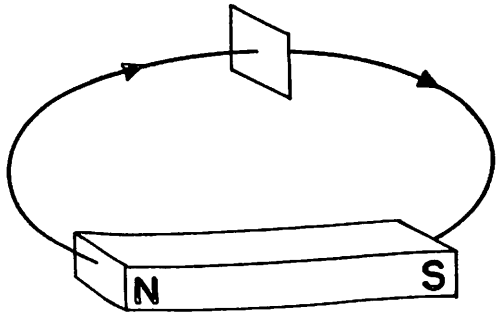


FIGURE 6—*Flux density is measured at right angles to the direction of the field.*

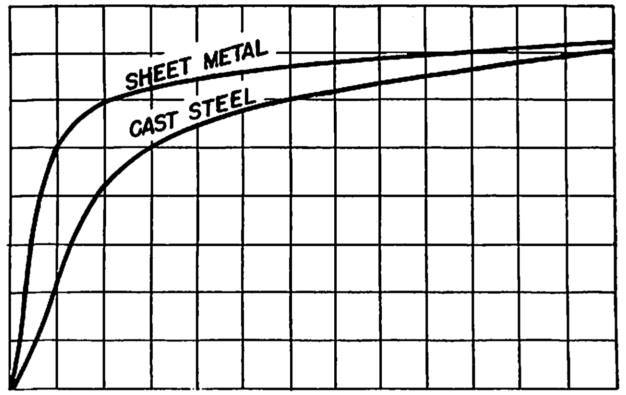


FIGURE 7—*Magnetization curves.*

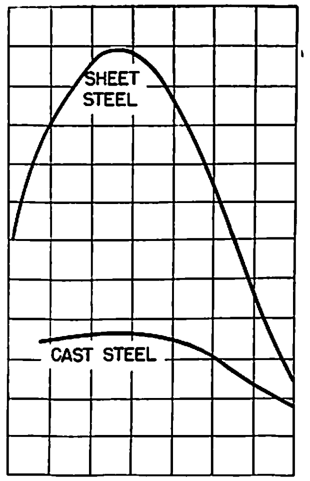


FIGURE 8—*Permeability curves.*

Various grades of steel vary in permeability from below 50 to as high as 2000, while vacuum-treated pure iron may have a permeability as high as 5000. Laboratory specimens of special alloys have been known to have permeabilities of 275,000 under certain critical conditions.

Reluctance. Reluctance is the opposition to the flux lines in a magnetic circuit, and is comparable to resistance in an electrical circuit.

From the theory of magnetism it may be recalled that alignment of magnetic domains within a magnetic material under the influence of a magnetizing force was opposed by some internal friction. This opposition was inherent within the material, being high in non-magnetic materials and small in those of the ferromagnetic group. Hence, as indicated in the preceding section, permeability measures the ability of a magnetic material to accommodate flux lines. If this is true, it is readily apparent that reluctance will vary as the permeability; for instance, a material with a low permeability will have a high reluctance.

The unit of reluctance is defined as that of a centimeter cube of air, since for all practical purposes the permeability of air is unity. As yet no name has been assigned the unit of reluctance.

By definition, the unit of reluctance is that offered by a centimeter cube of air through which the flux lines are assumed constant. In figure 9 A a path of 1 cm^2 cross section is shown 3 cm in length. This path is equivalent to three units placed in series, in the direction of the magnetic field. As the flux must pass through each unit successively, the reluctance is proportional to the length of the flux path.

In figure 9 B the air path is shown with a cross section of 3 square centimeters and a length of 1 cm. If the same flux value is again passed through this area, the reluctance of the path will then be one third unit. Reluctance is inversely proportional to the cross section of the flux path.

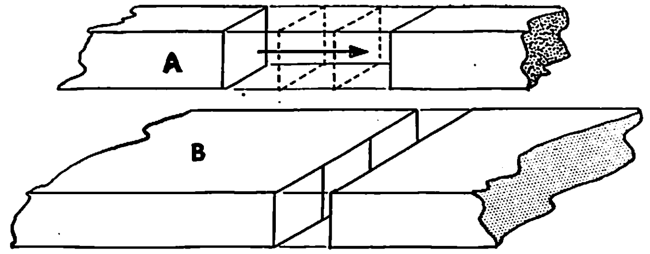


FIGURE 9—(A) *An air path three units of reluctance in value.* (B) *One-third unit.*

However, if the air path were replaced by a magnetic material having a permeability greater than air, or the ability to accommodate a greater number of flux lines, it follows that a smaller cross section would be necessary to pass a representative value of flux. Therefore, when an air path in a magnetic circuit is replaced by a similar volume of iron with a greater permeability, the total reluctance is reduced accordingly.

In reviewing the previous statements and examples, it can be concluded that the reluctance of any portion of a magnetic circuit is proportional to the length, inversely proportional to its cross section, and inversely proportional to the permeability of the materials.

$$\text{Hence: } \textit{Reluctance} = \frac{\textit{Length in centimeters.}}{\textit{permeability times area in cm}^2.}$$

When applying this to a magnetic circuit, it must be remembered that the calculated reluctance is for that portion of the circuit under consideration in which the area is of uniform cross section of a permeability μ. When the cross section or the value of permeability changes, the reluctance of that particular portion must then be calculated. The total reluctance is the sum of the reluctances of each individual part, the same as resistance in a series electrical circuit is treated.

Reluctances in parallel combine just as resistances in a parallel electrical circuit.

In a series magnetic circuit, the total reluctance is:

$$\textit{Reluctance} = \frac{L_1}{\mu_1 A_1} \textit{ plus } \frac{L^2}{\mu_2 A_2} \textit{ etc. . . .}$$

Reluctances in parallel combine the same way as electrical resistances in parallel.

$$\textit{Total parallel reluctance} = \frac{1}{Rel_1} \textit{ plus } \frac{1}{Rel_2} \textit{ etc. . . .}$$

Leakage flux. Electric current has been considered as restricted to a definite path, a wire for example. Surrounding air and insulating supports have a very high resistance compared to the wire and any leakage current is considered negligible. In comparing conductors and non-conductors in electrical circuits, take copper and glass as examples. Copper has a resistance of 1.72 millionths of an ohm per cm^3 while glass has a resistance of 10^{14} ohms for a like volume. From this it can be noted that there is a tremendous ratio of current in a conductor to that in a non-conductor.

However, in magnetic circuits, the reluctance of magnetic and non-magnetic materials is of a smaller ratio, indicating that the flux in air or a non-magnetic material in the vicinity of a magnetic material will be a fair percentage of the total flux. It follows, then, that there are actually no true insulators for magnetic flux; therefore, it is impossible to confine magnetic lines to definite paths in the same way that electric currents are conducted. This is illustrated by the fact that even in the best designed dynamos as much as 15% of the total flux produced "leaks" across paths where it cannot be utilized. This is called *leakage flux* and causes errors of considerable magnitude in magnetic calculations, as shown in figure 10.

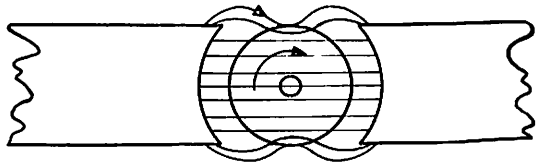


FIGURE 10—*Simplified diagram of the magnetic field of a dynamo, showing leakage loss caused by dispersion of the magnetic lines by air paths.*

Magnetomotive force. The force that tends to maintain flux in a magnetic circuit is called the magnetomotive force and is comparable to the electromotive force in an electrical circuit.

Magnetomotive force is abbreviated m.m.f. and is expressed in terms of work accomplished in carrying a unit pole once throughout the entire magnetic circuit. In c.g.s. units a force exerted through a distance of 1 centimeter is equal to one erg of work. In M.K.S. units the unit of work is 10^7 ergs or 1 joule.

The unit of magnetomotive force is the *gilbert* which is the work accomplished when a unit pole is moved 1 cm. This is equal to 1 dyne per cm, and since a unit of field intensity was defined as a force of 1 dyne per unit pole, magnetomotive force may be expressed in gilberts or oersteds per centimeter.

The magnetization curve shown in figure 9 A is a graph of flux density as the ordinate and field intensity as abscissa and is used to determine permeability at different values of flux. In ordinary commercial practice the abscissa usually represents m.m.f. per cm, which is the magnetic gradient. Although unit field intensity and unit m.m.f. are numerically equal, they are physically different quantities and this should be kept in mind. Field intensity is the force *exerted* per unit pole, and m.m.f. is the work accomplished in *moving* a unit pole by this force.

The magnetic circuit law. The relationship between flux, m.m.f., and reluctance for a magnetic circuit is identical with the relation of current, e.m.f., and resistance of the electric circuit.

$$\phi = \frac{m.m.f.}{R}$$

Stated: The flux is directly proportional to the m.m.f. and inversely proportional to the reluctance of the circuit.

This is often called the Ohm's Law for magnetic circuits, and its application conforms to all the rules of Ohm's Law for electric circuits.

The above formula may be used to solve for flux value of a magnetic circuit of several parts in series having reluctances R_1, R_2, R_3, etc. and m.m.f., F_1, F_2, F_3, etc.

$$\text{Total flux} = \frac{F_.}{R_.} \text{ plus } \frac{F_2}{R_2} \text{ plus } \frac{F_3}{R_3}, \text{ etc. } \ldots.$$

Where each reluctance is equal to $\dfrac{\text{length}}{\text{permeability} \times \text{area}}$

Summary of magnetic units. A unit pole is an hypothetical unit north pole isolated from its companion pole, and of such strength that it will repel a like pole with a force of one dyne when separated 1 centimeter.

A line of force is called a maxwell and is used as a means of indicating the direction of a magnetic field. From each unit pole 12.57 lines of force or maxwells emanate. When used quantitatively, a maxwell per square centimeter is equal to the gauss or the oersted since under these conditions the force is one dyne/cm².

Unit field intensity is the oersted and is the field strength that will exert a force of one dyne per unit pole. This is also equal to one maxwell per square centimeter.

The total lines of force through any area is termed the flux. The area is taken as a cross section of the magnetic field at right angles to its direction.

The gauss is the unit of flux density and is equal to one line of force or one maxwell per square centimeter taken at right angles to the direction of the magnetic field. In air the oersted and the gauss are equal.

Permeability is a measure of the ability of a magnetic material to accommodate flux as compared to air and non-magnetic materials. The permeability of air and all non-magnetic substances is taken as unity. There is no unit of permeability; it is merely expressed as a ratio of flux density to field intensity or magnetomotive force per unit length.

Magnetomotive force (m.m.f.) is the force which tends to maintain flux in a magnetic circuit. The unit of m.m.f. is the gilbert. It is the work accomplished in carrying a unit pole throughout the entire magnetic circuit.

Magnetic potential gradient is the m.m.f. per unit length and is numerically equal to field intensity.

The resistance of a magnetic circuit is called the reluctance, but the unit has not been assigned a name. The unit of reluctance is taken as that offered by one cm³ of air.

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BUSHIPS Electron

A MONTHLY MAGAZINE FOR ELECTRONICS TECHNICIANS

AUGUST 1948 VOLUME 4 NUMBER 2

FRONT COVER. ELECTRON brings to its readers another in the series of stories of the U. S. Naval shipyards. The front cover this month is a view of the Boston Naval Shipyard showing one of the vessels undergoing repair at that activity. Note the staging erected around the mast to expedite installation of a new radar antenna.

BACK COVER. Three views of activity at the Boston Naval Shipyard. At the top, a view of Shop 67 showing some of the machine tools and other equipment. Middle, a warehouse scene. Bottom, Shop 67 at the South Boston Naval Drydocks annex.

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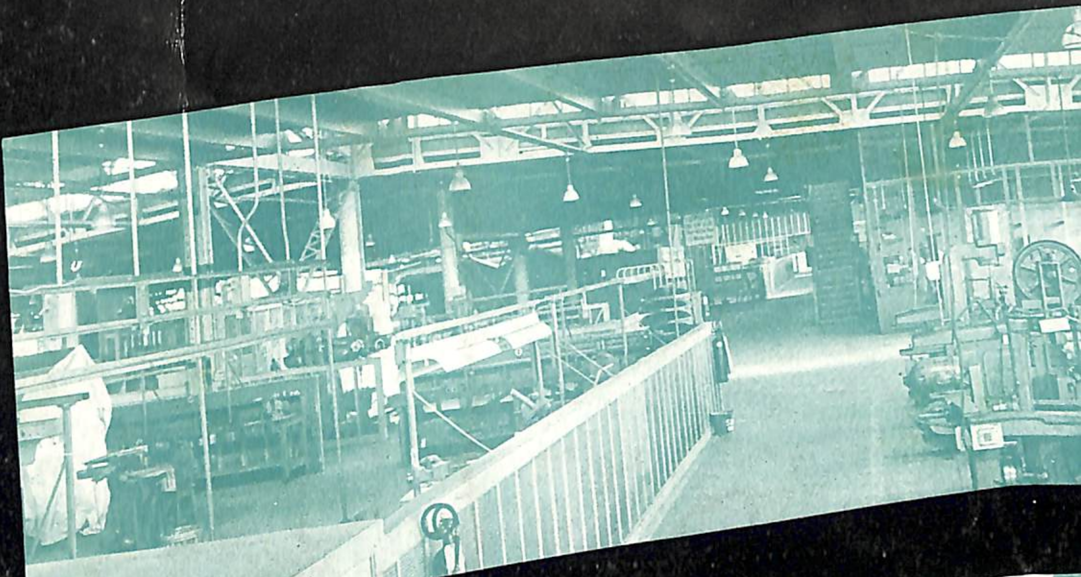

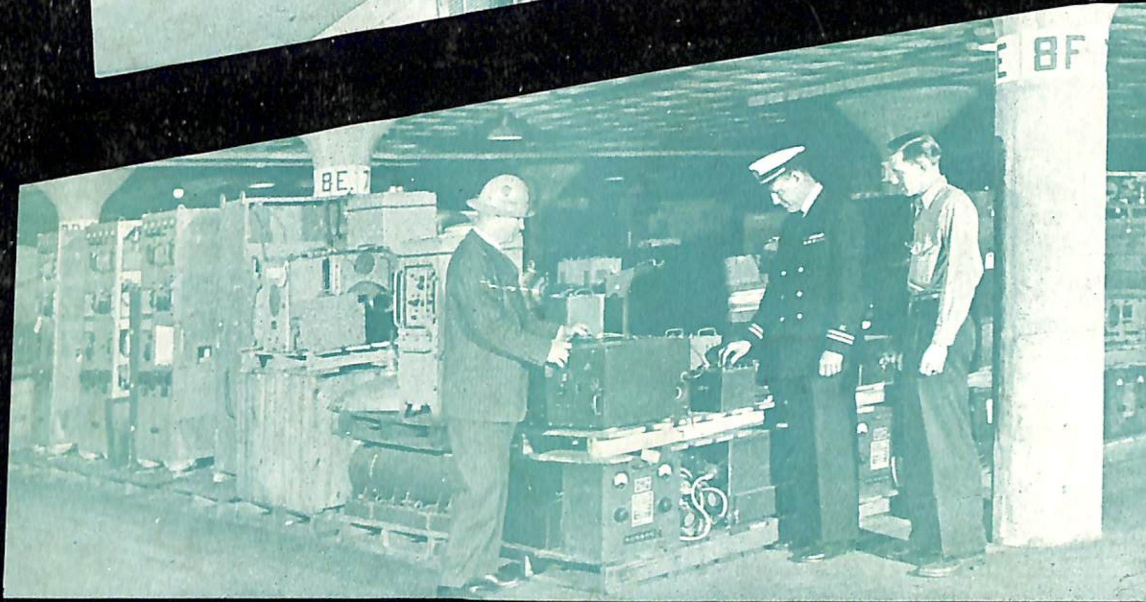

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