NavShips 900,100

DECEMBER 1948

BUSHIPS *Electron*
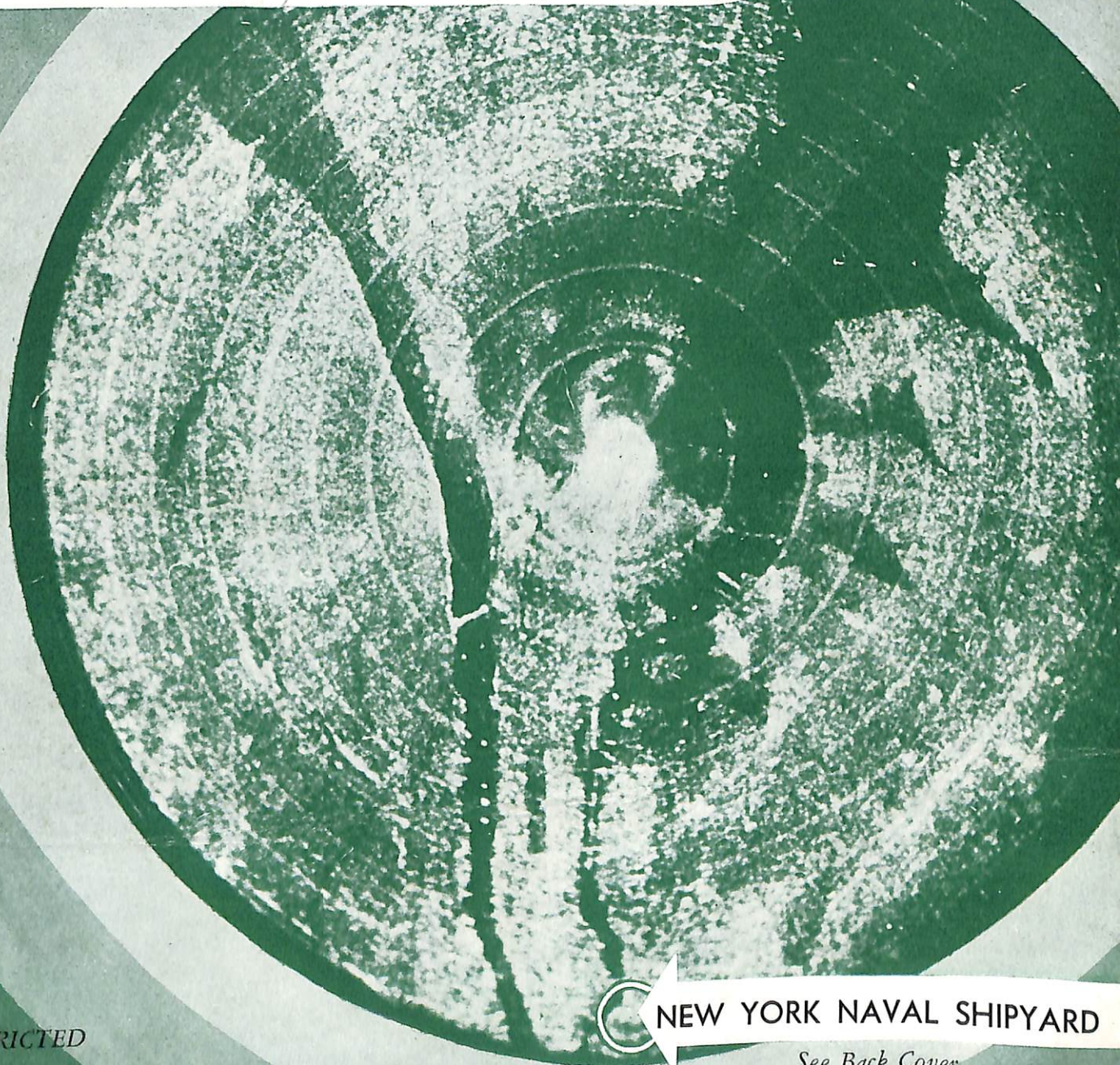
NEW YORK NAVAL SHIPYARD

See Back Cover

View of the Electronics Office at the New York Naval Shipyard, showing (left to right) the Services Section, the Shore Section, and the Ship Section.

ELECTRONICS

AT THE NEW YORK

NAVAL SHIPYARD

The New York Naval Shipyard was established February 23, 1801, through the purchase of about 42 acres of land on which John Jackson had built a shipyard. In 1798 Jackson built for the U. S. Government a small frigate called the *Adams*. This was the first Government vessel built on the site of the present shipyard.

Today the New York Naval Shipyard is a magnificent unit of the National Defense and the Navy, well qualified to accept and complete a large part of the Government's most difficult assignments of ship construction.

This issue of ELECTRON brings to its readers the story of three of the many important organizations within the shipyard. The staff of ELECTRON are indebted to the personnel of the New York shipyard who prepared these articles, and thank the Commander and the Electronics Officer for their co-operation in bringing these stories to ELECTRON.

The front and back covers of this issue show the location of the shipyard in the World's Largest City.

Rear Admiral Frederick E. Haeberle, U.S.N.

Commander, New York Naval Shipyard

FREDERICK E. HAEBERLE
REAR ADMIRAL, U.S. NAVY

Rear Admiral F. E. Haeberle, USN, was born in St. Louis, Missouri, 18 July 1893. He attended the University of Colorado before appointment to the U. S. Naval Academy and was graduated from the Naval Academy with the Class of 1917. Upon graduation he was ordered to the USS WYOMING where he served in the war zone with the British Grand Fleet during World War I. Between World War I and June of 1921 he did post-graduate study at Massachusetts Institute of Technology and obtained his Master's degree in Naval Architecture and Naval Construction. This post-graduate study was interrupted in April of 1919 for eighteen months during which he served as Hull Superintendent at the Philadelphia Navy Yard.

Following a year at Mare Island Navy Yard as New Construction Superintendent and a period of special study at Columbia University, Admiral Haeberle reported to the Bureau of Construction and Repair, Navy Department, where he served until September 1927. During this period he assisted in the design of the earliest heavy cruisers and had charge of design work in the conversion of battle cruisers to aircraft carriers and the modernization of battleships. Between September 1927 and August 1931 Admiral Haeberle had duty at the Puget Sound Navy Yard, first as Hull Planning Officer and later as Hull Production Officer. He then returned to the Design Branch of the Bureau of Construction and Repair in Washington where he was engaged in the design of the aircraft carriers WASP, YORKTOWN and ENTERPRISE. From June 1934 until July 1935 he was head of the Design Division of the Bureau of Construction and Repair.

Between August 1935 and August 1937 Admiral Haeberle served at sea on the staff of the Commander Scouting Force, Pacific Fleet, as Staff Naval Constructor. He was then ordered to the New York Navy Yard where he served as Design Superintendent until October 1942. During this period he had charge of all design and engineering work in connection with the design of the NORTH CAROLINA and MISSOURI classes of battleships. He was next ordered to the Bureau of Ships in Washington, first as head of the Design Branch and later as head of the Construction Branch, serving in Washington until March of 1945. He then returned to the New York Navy Yard for duty first as Manager of the Yard in April 1945 and since 30 November 1945 as Commander, New York Naval Shipyard.

Admiral Haeberle has been awarded the Legion of Merit for his work in the Bureau of Ships and a gold star in lieu of a second Legion of Merit for his wartime work at the New York Naval Shipyard.

THE ELECTRONICS LABORATORY
AT THE NEW YORK NAVAL SHIPYARD
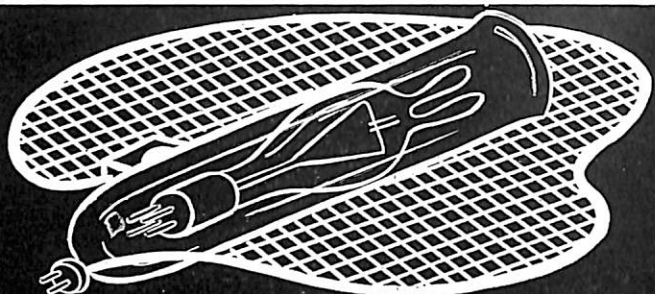
In 1947 the Bureau of Ships recognized that there was a need for the establishment of a program which would provide for the familiarization of electronics personnel with current electronic equipment. Equipment installed in a convenient location would permit electronics personnel to conduct tests and adjustments on it and thus give them that knowledge and background essential for the efficient and accurate performance of their duties aboard ship and throughout the districts.

The program was authorized and the New York Naval Shipyard Electronics Office, under the direction of Cdr. Newell A. Atwood, USN, actively pursued the procurement and installation of the equipments in conformance with the Bureau's program.

For the implementation of this program, a location for the equipment had to be obtained. In considering a location it was decided that it should have the following desirable features: accessibility to personnel; quiet; adequate power; security; clear open space for radar and radio antennas.

A building which notably had all these features was the Electronics Laboratory, which is in a penthouse atop an eleven-story building adjacent to the Electronics Office. The building is a one-story structure 45' x 115' with a large open space at one end for major equipments and several smaller rooms which are used for special projects and for teletype, radio receivers, rcm,
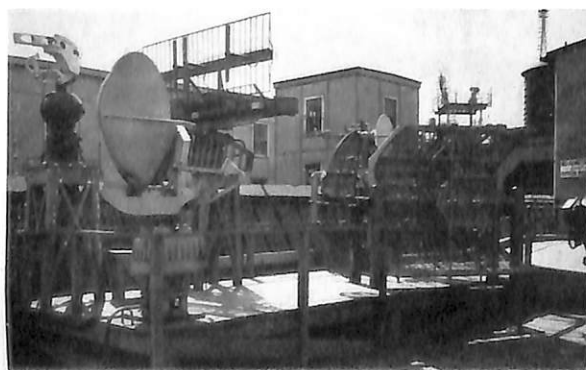
racon, etc. There are also a small machine shop and an instrument room.

In the building is a switchboard on which are available 115-v and 220-v d.c., 115-v 60-cycle a.c., and 115-v and 440-v 3-phase a.c. From this switchboard these voltages are adequately distributed to panels throughout the laboratory spaces. Outside the penthouse, on a 20' x 40' platform, are located the various radar antennas. They are readily accessible for observation and for making adjustments. The space of the platform is limited, but the antennas have been installed so that a minimum interference between antennas is attained. All of the electronic equipment installed is positioned so as to be readily accessible for instruction, test and servicing. As far as practicable, shipboard installations are simulated. The equipments are cabled in accordance with standard Navy practice.

One of the first new equipments to be installed was the SG-6 radar. This equipment occupies a rectangular space with the various units facing the center of the rectangle. The purpose of this arrangement is to permit observation of the various units while adjustments are being made to other units. It also permits small-group instruction without distraction from adjacent operating equipments.

The SR-6 radar was installed in a similar manner to the SG-6, using the same ideas of arrangement, accessibility and observability. To make the SR-6 waveguide run as short as possible, this equipment was placed closest to the antenna platform.

The SO-4, which has a representative 3-cm r-f transmitter-receiver arrangement and has few units, was selected to be installed by new members of the Electronics Office personnel. This afforded them an opportunity to become familiar with Navy cabling, identification and connection practices.

For fire control radar, a Mark 12 and Mark 22 combination was selected as typical of dual-purpose battery radar and a Mark 34 Mod 2, as representative of heavy machine-gun battery radar. It is planned to install a Mark 25 radar when it is no longer in short supply.

RADAR ANTENNAS and PLATFORM used in familiarization.

The transmitters for the Mark 12 and 22 are inside the building and the antennas are mounted on a framework on the antenna platform. An RG-18/U coaxial cable and a waveguide connect these with runs of about 50 feet. These are abnormally long, but for ease of tuning and instruction in transmitter operation the installation has proved satisfactory with no appreciable loss in signal strengths.

The Mark 34 Mod 2 radar installation for the familiarization program was first equipped without antenna, with only the echo box to provide receiver response and display in lieu of bona-fide targets. It was decided that this type of installation was too limited since there was no way to demonstrate the operation of the pointing channels. It was also deemed desirable to be able to acquire and track aircraft targets. Thus the antenna would have to be mounted outdoors. It was felt, also, that a train and elevation indicator would be advantageous at the antenna. The mount should not be too heavy, yet it should be adequate for easy and realistic operation of the radar. To accomplish this purpose, an old Mark 51 director was secured from the Ordnance Section. Since this director was not designed to mount
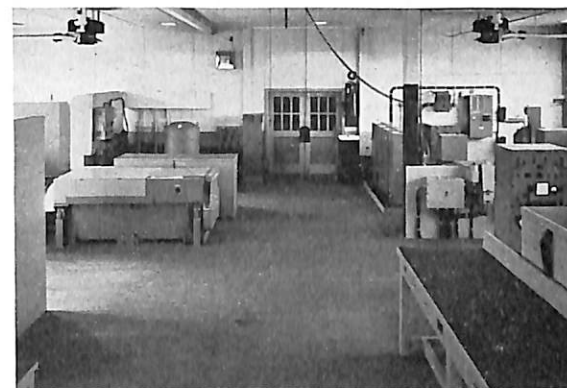
MAIN ROOM in familiarization, west end.

a radar antenna with its associated waveguide or a T&E indicator, certain modifications had to be made to it. The cable twist had to be modified to make room for the waveguide through the center column. A train rotary waveguide joint was mounted in the director base and an elevation rotary waveguide joint was mounted outside the left-hand elevation synchro. The Mark 4 Mod 1 antenna was mounted on the director crossarm.

The next problem was the train and elevation indicator. The local salvage depot was combed, and out of this came a director indicator from a Mark 29 Mod 2 radar. The indicator was then modified to take the pointing information from the Mark 34 Mod 2 radar. A new cable twist was installed with enough conductance for the antenna, the director indicator and the elevation
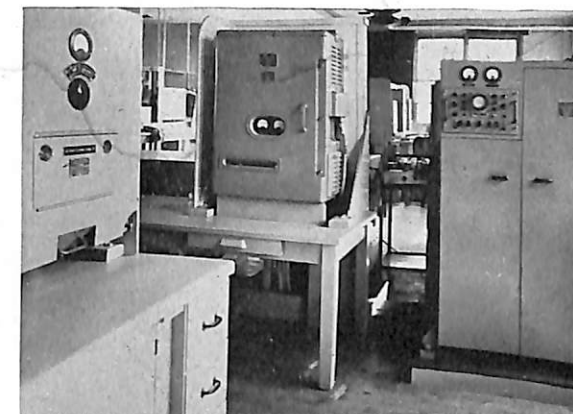
SG-6 SEARCH RADAR, main frame, modulator and rotation control.

synchro. The elevation synchro and the train synchro are used to send train and elevation information to the Target Acquisition Unit Mark 2 Mod 2.

This modified Mark 51 director has been mounted on an octagonal wooden platform about six feet high and six feet in diameter on the antenna platform.

Excellent results have been obtained with this set-up. Land targets at ranges of over sixty thousand yards are normal. Many have been able to familiarize themselves not only with the circuits, adjustments and tuning procedure of the Mark 34 radar, but also with the method and problems encountered in actual tracking of aircraft targets.

As part of the familiarization program it was decided to include an installation of a Mark 8 Mod 2 stable element. In order to simulate stable element operation when a ship is rolling, the stable element was mounted on a platform capable of being rocked approximately 12 degrees above and below the level position. The platform is supported by a horizontal steel shaft mounted on ball bearings. A motor, geared down and connected by a crankshaft, produces the rolling effect. Because of extra difficulties involved, no provision has been made for a pitching motion.

A corner of the ELECTRONICS LABORATORY MACHINE SHOP.

SR-6 SEARCH RADAR.

To demonstrate the action of the stabilizing system, a suitable antenna was obtained to which the outputs of the stable element were connected. This was an old, damaged, six-foot SP antenna which had been dismantled but which was made operative in train, elevation and cross-level. The necessary amplidynes and servo amplifiers were secured. In the absence of an SP console, a device for controlling the rotation and elevation of the antenna is being planned.

Remote indicators representing two vastly different members of the P.P.I. family have been installed. The VF was selected because of its complicated nature, its inherent susceptibility to electrical and mechanical troubles, its accuracy and the fact that it is to be found on all important Naval vessels. The VG-2 remote indicator was installed because it is a projection P.P.I. and therefore presents problems not found in other indicators. No VJ remote was provided since the search radar includes this unit as part of its system.

In one of the smaller rooms is installed the radar countermeasure equipment. This includes the RDO and SPR-2 receivers, RDJ pulse analyzer, RDP panoramic adapter and the DBM radar direction finder. For convenience the associated antennas are mounted on the side walls above the equipments.
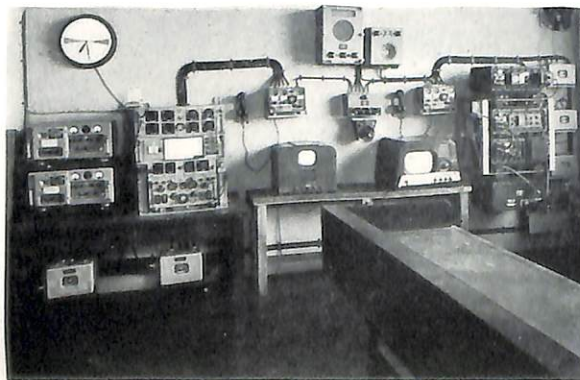
U-H-F TRANSMITTING and RECEIVING
equipment.

Two loran equipments, the DAS and DBE, together with test generators are also located in this room.

The SPN-6 radar beacon equipment was installed as being current racon equipment. It has served well in familiarizing personnel of the group in racon adjustments. It has been used to advantage to train ships' technicians while the ships were being equipped with racon.

Two rooms in the Radio Laboratory provided an ideal place for the installation of radio and teletype equipment. In one is located u-h-f and v-h-f equipments. A TDZ/RDZ combination, together with remote controls, is installed as a typical shipboard installation. An MAR/RDR combination modified for remote operation and shipboard application is also installed. An AN/ARC-1 equipment is installed for v-h-f operations. In addition to familiarizing electronics personnel with u-h-f and v-h-f equipments, this setup has proven most useful in conducting tests with ships to obtain a measure of the operating efficiency of recent or existing shipboard installations.


Section of the ELECTRONICS LABORATORY
INSTRUMENT ROOM.

In the room adjacent to the u-h-f equipment room are installed TCK, TBK and TCZ transmitter equipments. Teletype machines are arranged in the center of this same room so that they are easily accessible for operation, test and adjustment. A type FSA keyer has been installed with connections to the TBK and TCK transmitters which have been modified for teletype operation. A TH-1/TCC-1 terminal equipment is installed for use with the TDZ/RDZ set-up. Usual type FRA converters and RBC receivers have been installed. A type TT-23SG teletype panel is installed for flexibility of interconnection of these various teletype units.

While there is at present no land-line connection to these teletype equipments, a simulated land-line operation is possible.

The sonar installation consists of four typical sonar systems, namely: an integrated sonar system, a QGA echo-ranging system, a QJB echo-ranging system and an echo-sounding system.

The integrated sonar system now installed includes the QDA target depth-determining equipment, OKA resolver, the Mark 23 computer and tangent solver, Mark 1 Mod 3 attack plotter, associated switches, controls and remote indicators. The QDA equipment is installed without its director gear equipment. The mechanical head for the QDA hoist-tilt system is installed and a device to simulate level and cross level inputs has been provided. With this arrangement it is possible to reproduce the conditions encountered aboard ship and therefore it is valuable for training and instructional use. Provisions have been made for the installation of a Model QHB scanning sonar equipment and it will be installed when the equipment, which is now in short supply in the fleet, is available for this activity. When the QHB is installed, the integrated sonar system will be complete.
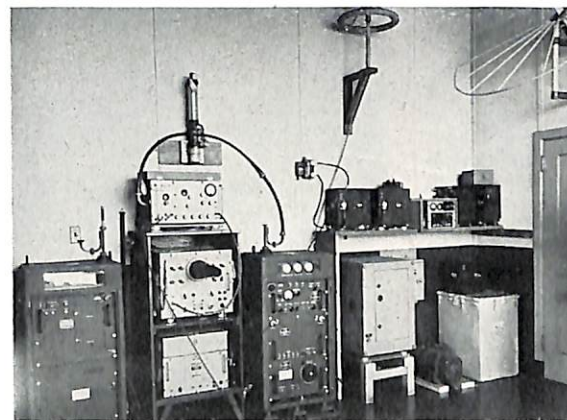
RACON INSTALLATION and IFF.

The QGA and QJB sonar systems are installed so that all units are easily accessible for purposes of demonstration and adjustment. The hoist-train mechanisms of these systems have not been installed because of structural difficulties in the space available. However, the projectors of the QGA and QJB together with the NMC and NMC-2 fathometer projectors are installed in one location on a table rack to demonstrate the mechanical and electrical differences of each system.

Two fathometers, the NMC and NMC-2, are installed. These were selected to cover typical shipboard installations.

The Electronics Laboratory has several project rooms—rooms in which engineering developmental work and tests and special projects may be pursued. These spaces with their bench arrangements, the wide availability of power supplies and the test instruments now have a fine
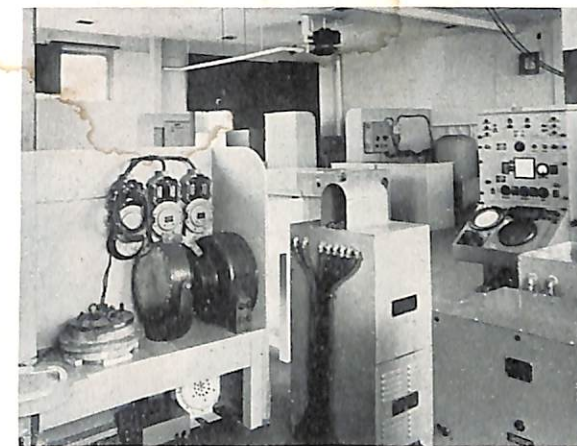
Corner of the SONAR
EQUIPMENT SPACE.

adjunct for tie-in testing with the complete electronics systems of the familiarization program which are in the adjoining space.

Engineers assigned to the Electronics Office are trained in Navy electronic equipment in three ways. First by exposure to equipments existing on ships in the shipyard and by studying with and assisting engineers of higher grades engaged in the operation, test and calibration of these equipments. Secondly by working on equipments installed in familiarization, a new man may be trained to adjust, test and calibrate electronic gear not on a ship in the shipyard or not presently installed on shipboard. Under conditions of quiet, and lack of pressure to meet availabilities, he can concentrate on the problem at hand and thus acquire the familiarity with equipment which is so advantageous while working aboard ship. By courses of lectures on various new electronic equipment prepared and presented by Electronics Office personnel, knowledge of new equipment is disseminated.

The value of this program has already been demonstrated. As the program progresses, additional ways will be found to increase its effectiveness.
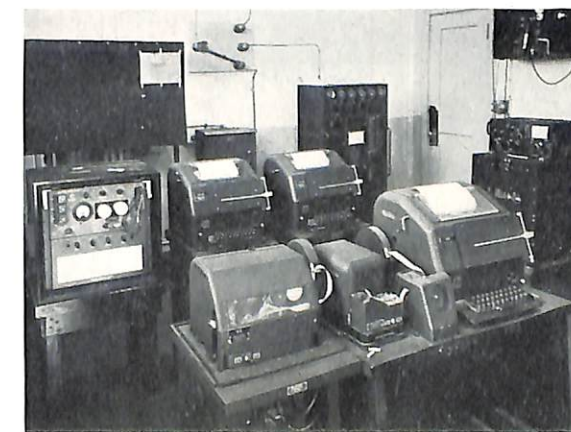
RADIO and LAND LINE TELETYPE equipment.

LT. CDR. E. SOBCZYK, USN
Ass't for Shore Electronics

LT. CDR. R. L. FISCHER, USNR
Ass't for Naval Reserve Electronics

CDR. N. A. ATWOOD, USN
Electronics Officer

Commander Newell A. Atwood, USN, after attending Oberlin (Ohio) College, was graduated from the University of Michigan and the George Washington University Law School. He enlisted in the Naval Communications Reserve in 1933 as a Radioman, Third Class, was commissioned as an Ensign C-V(S) in 1936 and received his present rank in July 1945. In 1946, he was selected for transfer from the Naval Reserve to the Navy for Electronics Engineering Duty. Active in pre-war years as a Naval Reservist in the Ninth Naval District and with the Potomac River Naval Command, Commander Atwood reported for active duty in March 1941. His war-time assignments include Electronics duty with the Naval Research Laboratory, the Bureau of Ships, and the Office of Research and Inventions. He later held the Electronics Desk in the Office of Naval Research and served as Electronics Patent Counsel for the Navy Department until ordered to the Norfolk Naval Shipyard as Assistant for Shore Electronics early in 1947. He reported to the New York Naval Shipyard as Electronics Officer in January 1948.

Commander Atwood was given a Letter of Commendation by the Secretary of the Navy for his wartime work. He is an Associate Member of the Institute of Radio Engineers, a Registered Patent Attorney and an active Radio Amateur, W3KTR. His home is in Bethesda, Maryland.

LT. CDR. H. L. GOFF, USNR
Ass't Shop Super't for Electronics

LT. CDR. E. CARLSTEN, USN
Ass't Repair Super't for Electronics

LT. W. E. JONES, USN
Ass't P and E Super't for Electronics

LT. (JG) J. J. MOORE, SC, USN
Ass't Supply Officer for Electronics

MR. E. J. HOPKINS
Senior Engineer
Electronics Ship Section

MR. J. F. BODENBURG
Senior Engineer
Electronics Shore Section

MR. J. D. LAURENT
Chief Civilian Assistant

Mr. Joseph D. Laurent first became engaged in radio work in 1912 in connection with sets being built for the U. S. Government and in 1913 was employed by the Wireless Improvement Company of New York City. His next and last commercial employment was with Dr. Lee DeForest in 1914 from whence he accepted employment at the Brooklyn Navy Yard in November 1914 in connection with radio drafting and became head of the radio drafting section during World War I.

In 1924 Mr. Laurent was transferred to the Radio Material Office to become the Senior Civilian of that office.

MR. E. M. HOLLEMAN
Senior Engineer
Electronics Services Section

MR. E. A. THIELE
Foreman
Electronics Shop No. 67

ELECTRONICS
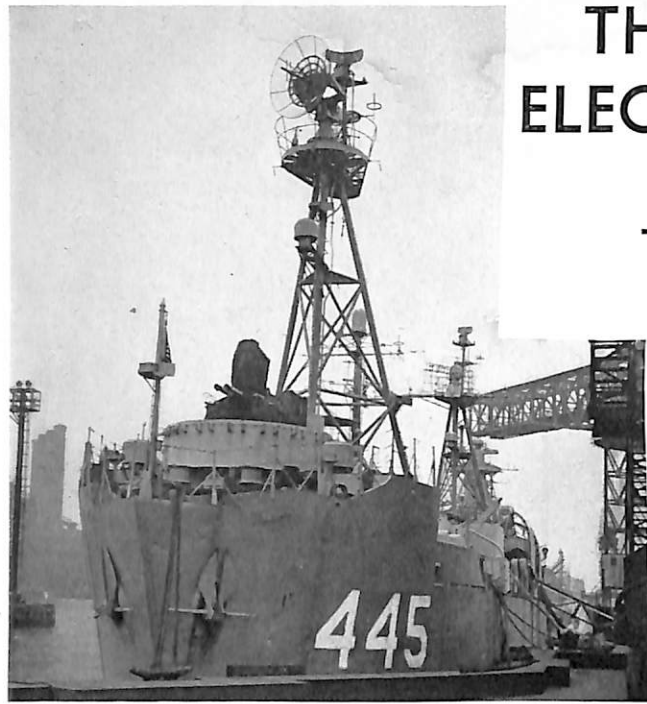## Naval and Civilian Personnel
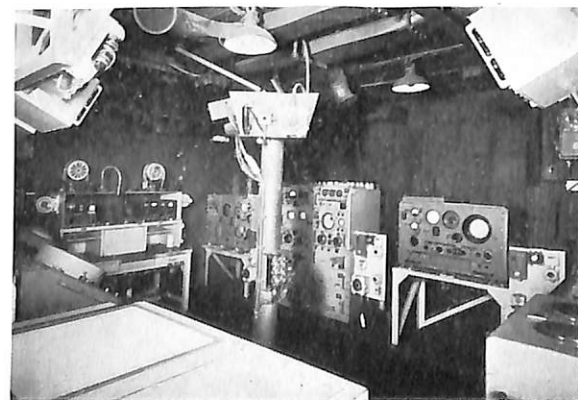## at the
New York Naval Shipyard

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THE NAVAL RESERVE ELECTRONICS PROGRAM
AT THE
THIRD NAVAL DISTRICT

Foremast of the U.S.S. (E) LSM-445

HISTORY

The Naval Reserve Electronics Warfare Program in the Third Naval District actively got under way in the Fall of 1946. At that time, a District Reserve Electronics Officer was assigned to assume responsibility for Electronics Materiel and an Operational Communication Officer was assigned to duties in connection with the communication functions of the program. The overall organization functioned from headquarters at 90 Church Street, New York, N. Y.

As the scope of the program enlarged, an Assistant District Reserve Electronics Officer and an Assistant District Reserve Operational Communication Officer were ordered to duty, during the early months of 1947, to assist in the acceleration of the program. The overall cognizance of the electronics program at the time was under the Electronic Materiel Section of the Bureau of Naval Personnel. A so-called electronic materiel allowance was promulgated as a portion of BuPers Catalogue #15651A and the Chief of Naval Personnel made available to the Third Naval District a certain portion of electronic equipments and materials contained therein, which were available at the time for distribution. The greater part of these equipments were shipped upon request of the Commandant, Director of Training (DREO), directly to authorized activities from BuPers storage stocks at N.S.D. Scotia, N. Y., and N.S.D. Clearfield, Utah.

It soon became apparent that the distribution of electronic equipments under this system resulted in in-numerable cases in the receipt of damaged or incomplete equipments by the activities. For many months, however, it was considered desirable by BuPers that the entire electronics installation program should be undertaken by station force personnel because of the belief that the experience gained by such installation plus the repair of damaged units constituted an integral part of the training program. This policy remained generally in force in the field until the first part of 1948.

During the spring of 1947, a large portion of the third floor of Building #558, at the New York Naval Shipyard, was made available to the District Reserve Electronics Officer for the purpose of installing sufficient radio communication equipment to establish an enlarged master control station for the 3rd Naval District N.D.B. By mid-summer of 1947, this station was completed under the cognizance of the D.R.E.O. using, for the greater part, personnel on active duty to make the installation. The station consisted of a wide variety of various types of transmitters and receivers then listed in the allowance catalogue and which were available at that time. Subsequently, additional space was procured in the same building for the establishment of a District Reserve Electronic Materiel Pool from which miscellaneous component parts made available by the Chief of Naval Personnel and other sources of supply were distributed to activities for installation and training purposes.

Late in the summer of 1947, a two-story building at the Naval Supply Depot, Maspeth, N. Y., was obtained for the storage of such equipments resulting in the

THE U.S.S. (E) LSM-445 after C.I.C.

moving of such storage facilities from Bldg. #558 to Maspeth. By the end of 1947, a tremendous supply of spare parts, components and complete equipments was on hand, available for distribution to Naval Reserve activities as required.

BUSHIPS PERIOD

On an overall policy basis it soon became apparent during 1947 that the methods for the supplying and the installation of electronic equipment at the Naval Reserve activities required a different approach to the basic problem to insure the success desired. This resulted finally in a directive by the Secretary of the Navy indicating that the bureau or office having cognizance of the equipment required for the instruction of the regular Navy or Naval Reserve would assume financial responsibility for the cost of such equipment, including its procurement, installation, modification, repair, and replacement. This policy placed the Bureau of Ships in the position of having cognizance over the electronics program which was subsequently delegated, in the case of the 3rd Naval District, to the Commander, New York Naval Shipyard.

It became apparent, as the program unfolded, that more and more time was required of the D.R.E.O. in the shipyard installation billet, permitting little time for training duties assigned by the Director of Training. A decision thereupon followed which returned the D.R.E.O. to the Training Office and designated the Assistant D.R.E.O. to full-time duty with the shipyard. Later this billet was established as a regular shipyard billet.

An enlarged organization was then formulated consisting of an Assistant Electronics Officer for Naval Reserve, one P-5 civil service electronics engineer, one P-4 civil service electronics engineer and a Philco contract engineering staff of two engineers which subsequently was enlarged to six engineers. Assisting this staff, a group of three Naval officers and one enlisted man was set up and utilized principally for field inspection and electronic materiel problems. This latter group is actually assigned to the Director of Training Office and is on a loan basis to the shipyard to assist in expediting the electronics installation program.

SCOPE OF PROGRAM

The 3rd Naval District, covering the States of New York, Connecticut and the northern portion of New Jersey, has scheduled forty-one Naval Reserve Training

U.S. NAVAL RESERVE TRAINING CENTER, CLIFTON, N. J.
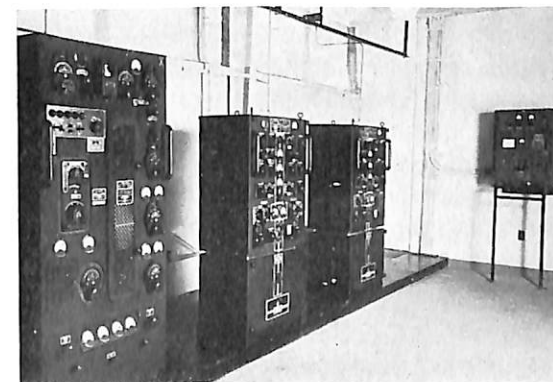
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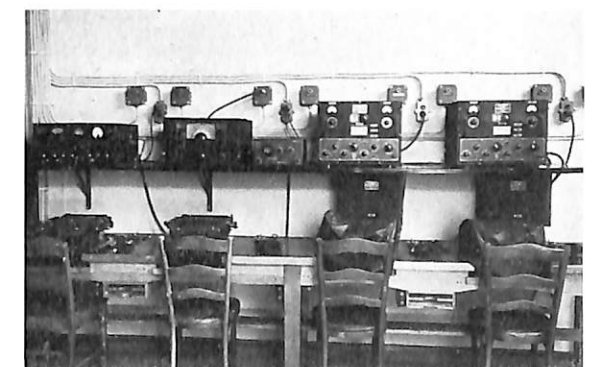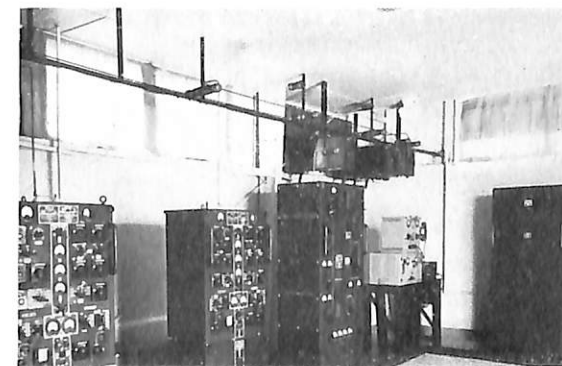
RADIO OPERATIONS

TRANSMITTER ROOM
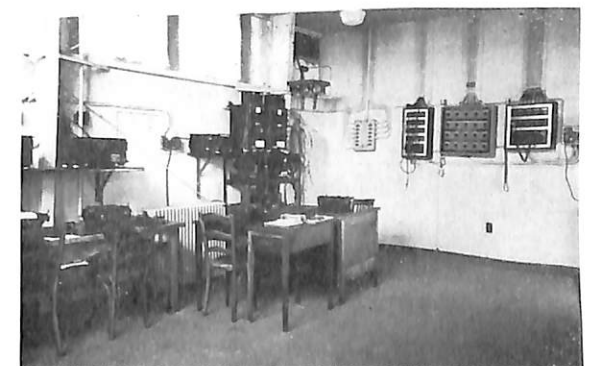
RADIO OPERATIONS

RADIO OPERATIONS, showing transfer panels and cabling (USNR Training Center, Clifton, N. J.)

Centers for completion. In addition, there are fifteen active Volunteer Electronic Warfare Drill Quarters and twelve Volunteer Electronic Warfare Drill Stations.

Radio, radar and some sonar electronic equipment will be provided and installed in these activities in accordance with the established electronic allowance list. The over-all program calls for the training of 2185 RM's, 2153 ET'S, 345 SO's, and 1350 Rd in these organized reserve in this District. In addition to the above program, there are assigned to the Naval Reserve Program the following Naval Reserve vessels: one AGC, one DD, two DE's, one E(LSM), one APL, seven PC's, one LCS(L), one LCC, five AMS's, seven LST's, and three SS's. A number of mobile equipments, such as the SK–1M, SCR–299, SCR–573, SCR–574, SCR–545, MK16, SCR–527A, SCR–634, and MBS are located at various activities throughout the district. A procedure is presently being set up for the modification of allowance at those activities having such equipment so that a procedure to repair and provide maintenance of such equipments can be initiated.

CONCLUSION

The aim of the present schedule is to complete eighteen Training Centers, two Volunteer Electronic Warfare Drill Quarters and ten Volunteer Electronic Warfare Drill Stations by the end of February 1949. It is anticipated that the electronics installation can be completed sixty days after additional Training Centers have been made ready by the District Public Works Officer. Planning and installation work is being accomplished for the Volunteer group when possible, but on a not-to-delay-the-Training-Center-program basis.

A schedule has been promulgated by the Commandant, 3rd Naval District, for participation in regular communication drills by those activities "on the air." The communication facilities installed will be available not only for district communication drills, but for communications in the event of local emergency or, as a supplement to regular Navy communication facilities as required.

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The Material Laboratory, New York Naval Shipyard, is one of the five major laboratories of the Bureau of Ships. It is organized to provide research, evaluation and development services to the Bureau of Ships in the major fields of mechanical and electrical engineering, chemistry, metallurgy, physics and gyrodynamics. The laboratory plays a vital role in the electronics program of the Navy Department. Special facilities and equipment of the laboratory include a sound chamber of advanced design, photometric and spectrophotometric apparatus, Scorsby Gyro test stands, an 80-foot guillotine impact tower, a high-power short-circuit test station, and chemical and metallurgical facilities. The activities of the Material Laboratory which should be of particular interest to the readers of ELECTRON include development and evaluation work in the field of electron tubes, electronic and radio components, waveguides, radio communication aids and safeguards, development of interior communication and fire control equipment, and insulating material development.

The Material Laboratory is one of the most completely equipped electronic testing laboratories in the country. The various types of diversified and complex electronic equipment used in the laboratory are devoted primarily to improving by test and evaluation all parts of electronic equipment even to the smallest elements.

For electron tubes, the program is devoted to the study, examination, critical analysis, and appraisal of new and established electron tube types used in, or being proposed for, applications to Naval service, with the purpose of furnishing expert opinion on their suitability, reliability and durability.

In testing and evaluating components and equipment for the Navy, particular emphasis is placed on those features required for military operation such as ruggedness, long life, and effects of environmental conditions including altitude, humidity, salt atmosphere, shock, blast, vibration, extremes of temperature cycling, dust, and bacterial and fungi conditions. Tubes undergoing such treatment include magnetrons, klystrons, planar lighthouse types, photoelectric, cathode-ray or infrared image converters, receiver, miniature and sub-miniature types, power transmitters, gas regulators, rectifier, thyratron types and Geiger-Mueller types.

COMPONENTS AND CONTROLS SECTION

The work of the Electronic Components and Controls Section embraces the investigation of the multitude of components which constitute the parts of radio, radar, sonar and other types of communication equipment used by the Navy, Army and Air Force.

THE MATERIAL LABORATORY IN ELECTRONICS

MATERIAL LABORATORY, New York Naval Shipyard.

The components involved include transformers, varying in size from microphone input to shore station modulation and radar pulse transformers rated in hundreds of kilowatts, capacitors, crystals, dry disc rectifiers, resistors, potentiometers, relays, switches, tube sockets, keys, and many other items used in electronic circuits.

An extensive program is being launched for miniaturization study. This new field shows promise of unlimited expansion since the need for miniature components has now become universal. Not only the obvious needs such as guided missiles, airborne equipment and portable gear of all types must be considered, but also it may be assumed that all military electronic equipment of the future will incorporate the maximum number of weight- and space-saving miniatures.

The actual work of the section is of such a varied and exacting nature that it requires the services of scientists and engineers possessing thorough knowledge of the electronic, electrical, and mechanical arts together with an understanding of the needs for efficient, safe, durable and continually improved electronic equipment for the Navy's ships.

This section determines the characteristics of the components or equipment with respect to their efficiency, ruggedness and intended uses. The investigations support the Navy and JAN standardization programs, and also serve the purpose of obtaining the utmost information which would be valuable to the electronics divisions of BuShips, BuAer, and BuOrd.

The section employs standard electronic measuring equipment of every description. In addition, a large amount of specialized equipment has been designed and built to investigate all types of components under the very rigorous requirements of JAN specifications. Capacitors, for instance, undergo a 90-day humidity cycling test.

R-F MEASUREMENT SECTION

The Radio-Frequency Measurement Section provides measurement, investigation, and development facilities in the general field of radio and microwave frequencies. Programs involve the measurement and suppression of radio interference, the investigation and evaluation of microwave components and surveys aboard Naval vessels to determine practicability of carrier frequency currents in existing cables for control purposes.

A small direct-current fan motor may run quietly and apparently with no harm to the activities aboard a Naval vessel. To the radio operator trying to establish contact with an aeroplane on the horizon, however, the "hash" generated by the motor in the headphones of the receiver may be loud enough to submerge the signals from the plane. The radio interference from this fan can be effectively suppressed by the application of the proper techniques. Many other types of electrical equipment used aboard Naval vessels are equal offenders as sources of "man-made" interference. Investigation of these sources and development of measurement and suppression techniques for the radio interference is one of the programs sponsored by BuShips and carried out by this section.

Radio noise measurements are made in double-layer copper-shielded rooms, all power and lighting services to which are adequately filtered to eliminate the possibility of unwanted electrical disturbances. Several types of radio noise and field strength meters and a multitude of other electronic measuring instruments are used to conduct the investigations and develop the techniques in mastering the "man-made" radio interference. Surveys in the shipyard are conducted to observe and plot the extent and intensity of the disturbing noise. Radio interference measurements are also made in the field. Equipment which is being investigated for radio noise includes motors and motor-driven devices, rectifiers of all types, welding equipment, induction heaters, battle announcing

low-frequency, ultra-high-frequency or microwave equipment are also evaluated.

Many complex problems of varied nature and difficulty involving measurements and investigations in the frequency spectrum require the services of a highly trained staff of scientists and engineers.

AUDIO COMMUNICATIONS SECTION

The Audio Communications Section is staffed and equipped to conduct investigations, development and technical evaluations on shipboard communications systems. The Section also engages in acoustic and underwater audio-frequency noise measurement and frequency spectrum analysis, with respect to shipboard equipment. The work likewise includes the determination of acoustic absorption and attenuation characteristics.

The wide range and variety of specialized equipments which are investigated, developed, and evaluated include battle announcing systems, inter-communicating systems, electric megaphone equipments, sound recording and reproducing equipments, 16-mm and 35-mm sound motion picture projection equipments and sound-powered telephones. These systems require the detailed evaluation and analysis of the operation and performance characteristics of various individual units.

The major specialized facilities of the section include the following:

1—An anechoic chamber, interior dimensions 27' x 18' x 14', available for all types of free field acoustical objective and subjective measurements, such as noise measurements, acoustical frequency and polar response characteristics, and acoustical distortion. The extremely low ambient noise level and the free-field characteristic of the room provide a convenient and ready facility for complete evaluation of the various types of loudspeakers associated with sound systems.

2—An air-conditioned sound projection room, 20' x 90'. The floor of the room is heavily carpeted and

ANECHOIC SOUND ROOM.

equipment, motion picture projectors, arc lamps, circuit breakers and a multitude of other equipment.

Microwave components such as coaxial connectors, coaxial broad-band attenuators, flexible waveguides, directional couplers, etc., are constantly being improved to have lower power losses or reflection losses, broader frequency band application, higher power handling capacity, or more constant attenuation or coupling factor. The Material Laboratory provides part of the Armed Forces' facilities and skilled personnel needed to cooperate with contractors in the development and proper evaluation of these components. New developments of coaxial cable require the development of measurement techniques and design and construction of measuring equipment for the cable to measure such parameters as characteristic impedance, attenuation, velocity of propagation, and temperature coefficient of attenuation.

The attenuation of an antenna transformer, the insertion loss of an antenna comparison switch, and practically any desired characteristic of a myriad of types of

Apparatus for testing ELECTRON TUBE TYPE 5607 (C.W. tunable magnetron).

the walls and ceiling are acoustically treated for both acoustic absorption and diffusion to provide a controlled but natural quality of projected sound.

3—Free-field outdoor-tower acoustic measuring facilities consisting of two 100' end towers and one 80' center tower, with remotely operated control devices. These are available for supplementing and extending the range of measurements performed in the anechoic sound chamber previously described. These facilities are suitable for response measurements and special distribution characteristics of large loudspeakers and loudspeaker clusters.

4—Simulated gun blast facilities, available for testing and evaluating the performance of loudspeakers under simulated conditions of gun blast. Evaluation is made not only of acoustical deterioration effects, but also of the ruggedness of the equipment to the point of destruction.

DIELECTRICS
AND PLASTICS SECTION

The Dielectrics and Plastics Section is concerned with evaluation of the basic properties of all electrical insulating materials and plastics over the frequency spectrum up to and including the S-band region. Development work underway in this section includes an evaluation of the electrical and mechanical parameters of a representative group of materials as a function of extremes of humidity and temperatures (—50 to 250°C), a new and modified susceptance variation circuit for the measurement of electrical losses at 100 Mc, and a new arc resistance unit which follows the lines of the most recent work of the A.S.T.M. Arc Resistance Sub-committee. Studies of the properties of electrical insulation as related to particular component problems are also in process as, for example, the work on creepage and clearance distances required between metallic parts mounted on electrical insulation which is aimed at downward revision of these requirements to permit lighter and smaller electrical components. Development of electrodes for use in measuring the dielectric losses in thin materials is also in progress. The techniques presently employed on rigid material cannot be employed on thin materials. Thus the development of new techniques and the study of conducting paints, sprayed metal and vacuum deposition as possible electrode materials are required.

The facilities of the section for evaluating the electrical parameters of insulation include dielectric breakdown equipment of various kinds for 60-cycle measurements up to 150 kv, power factor and dielectric constant measuring equipment completely covering the frequency spectrum between 40 cycles and 3000 megacycles, resistance measuring equipment capable of measurements up to 10^{13} ohm and arc resistance and residual

RUGGEDIZATION Equipment for Electron Tubes.

breakdown strength equipment for use at currents up to 40 ma and 15,000 volts.

This section is completely equipped for measurements of mechanical properties of materials, and facilities are readily available for optical and thermal characteristics when required.

The "tropicalization" program being prosecuted by this section has as its objective the improved performance of equipment under severe climatic conditions. Methods of protection include protective fungicidal, moisture-resistant coatings, the redesign of components and the substitution of materials to reduce or to eliminate the effects of moisture and fungus on the characteristics of components. This work is an important phase in the development of improved electronic equipment.

To fulfill the electronics mission of the Material Laboratory there is now being constructed one of the most complete "all weather" test stations in the United States, comprising many large atmosphere and stratosphere chambers. Components and equipments may be tested over ranges of minus 90°F to 185°F in temperature, zero to 80,000 feet simulated altitude and at humidities up to 98 percent. With such equipment the Material Laboratory takes its place as one of the major service laboratories for the Bureau of Ships.

SHIELDED ROOM for Radio Interference Measurements on Naval Electrical Equipment.

NAVSHIPS 4110 . . . . .

By COMDR. EDWARD J. FAHY

Electronics Installation & Maintenance Division,
Bureau of Ships

What a title for an article! But then if you do not know what it stands for it will not bother you and if you do know you will read on. . . .

Navships 4110 is the form which has been euphoniously called "the IBM inventory," the "annual electronics inventory," and more formally, "Ship Electronic Equipment Inventory" or "Installation Record." Now you seagoing people will recognize it, and all you others can get full details in Navships 900,135.

This article is a brief behind-the-scenes look at what happens to the much-used and abused form once it starts on its way to the Bureau of Ships, Code 980.

A little background on the system would be in order at this point and, with the encouragement of soft lights and sweet music, we begin. Postwar stocktaking and subsequent planning presented myriad problems and questions concerning the installations in vessels of the Fleet. One question in particular, we remember, was "What is the quantity and value of communication equipment installed in the entire Fleet?" Good question, that—wish we could have said as much for the answer. Other jackpot questions, such as "How many MBF equipments are installed in destroyers—which destroyers?" convinced the sons of toil in the Ship Installation and Maintenance group that there certainly must be an easier way to earn a living than by digging up the answers to questions of that nature.

In December 1945 the beginning of a machine-tabulated ("IBM") system was laid out by Code 980, in the Bureau of Ships Electronics Division. Many were the huddles and headaches over the form of the system, what information it should contain, ease of operation for the Fleet and Bureau, and required simplicity. By March '46, Lieutenant Lawrence arrived from ServPac to lend his experience to the problem and the system shifted into high gear. That is, it was like throwing in the clutch of an auto that had no engine. That's right son, you get nowhere.

We found that shipboard records were really a wartime casualty. Out of the entire wartime Fleet of about 12,000 vessels there were on hand (even in Opnav's "master" files) only 600 Ships Characteristics Cards and some of the 600 were four years old!

By gathering up the ServLant and ServPac records we obtained a very respectable set of installation records to start the system. So in August 1946 we punched and mailed the first batch of ships electronics inventories and return. In many cases the ship received the form Navships 4110 with the two words "no record" printed across the top. The ships cooperated nicely and filled out the forms according to instructions (more or less) and returned them (more or less).

We received a letter from an irate skipper of an LST after we "jigged" him for never having sent in an inventory, in which he vowed that this was his fourth attempt at sending in inventories—did we burn them? The answer is no, *we* didn't burn them, but the Bureau mail system . . . *quien sabe?*

The system began operating fairly well, for a starter, but the first "monkey wrench" was soon in the works. Despite a prior arrangement with Opnav that the "electronics addendum," as it was known in those quaint days, was not to be included in the Ships Characteristics Card, the Fleet was inadvertently told to include it in the January 1947 cards.

Whereupon we received not only our Navships 4110 sheets for annual inventory, but the original and seven "legible" copies of the "electronics addendum" to the Ships Characteristics Card. Boy, we had 'em laying in the aisles! It took some time to shovel out of that *paper* storm.

Now we must make a most heinous and diabolical confession. As we sifted through the mountains of paper and found a Navships 4110, we seized it like a pearl of worth; and if we then found a companion "original and seven legible copies" of the "electronics addendum," the original-and-seven were given the deep six. (One-minute period of mourning for yeomen who have just gone mad on learning of this.)

Y'see, we really work with the *machine-made* copy of the Navships 4110. If you make corrections on it, we have only to check your corrections. If you retype it, we either have to throw away all existing cards and re-punch a new set, or we have to check every single item, and that is work which we haven't the time for nor the available personnel. Some of you have become conscience-stricken and send along (a) a forwarding letter, (b) the wrinkled Navships 4110 copy complete with coffee cup stains, (c) a nicely *typed* smooth copy of (b). *We'll settle for (b) only, plus coffee stains and all.* Sending in (a) and (c) is a waste of the yeoman's time in typing and the skipper's time in signing.

While we're in a confessing mood we may as well tell all. The system was on its feet. Again in mid-'47, after the foul blow of the characteristics card inventory mixup, the Bureau of Ships changed from IBM tabulating machines to Remington Rand tabulating machines. Such a shift is no simple matter in spite of statements from the salesmen to the contrary. And as usual it caught us at annual inventory time!

The poet Dante in his wildest imaginings could conjure up nothing worse than such a debacle as the conversion-at-inventory time.

For one thing the last IBM machine left the Bureau on 30 November '47. The word "left" is used advisedly in order to depict us left holding the bag. The backlog of inventories on hand could not be processed. Letters poured in from the Fleet demanding their copies of inventories in order to get them ready for the annual 1 January inventory.

Next came the flood of annual inventories. King Canute tried to stop the relentless flood, Joshua tried to stop the sun in its course. Profiting by their failures we tried to stop nothing. And still they came in, inventories, more inventories, and requests for inventories.

Valiantly we tried to stem the flood by getting a service contract which haltingly ground out inventories—with plenty of errors.

By March '48 we could see the end of the heavy load and proceeded to cut over definitely to Remington Rand machines. But—the old Navships 4110 forms would not fit the new machines, so for a brief spell your inventories were returned on plain paper. Things are tough all over, Bub.

Surely after all those strenuous efforts on the part of all hands, we should do something with the information received. We do. The copies of the inventories themselves are in constant use by ship type desks in the Bureau and by the Electronics Installation and Maintenance engineers. The new electronic spare parts (oops, maintenance repair parts) system is based on each ship's installation record. The Ships Characteristic Board uses the inventories as do Type Commanders, Task Force Commanders, the Service Forces and the Naval Shipyards for overhaul planning.

Since the Reserve (inactive) Fleet also operates under this system the same remarks apply to their inventories.

And, happy day, the Bureau does all the work of distributing copies. But you need more copies? Well we are going to try to keep y'all happy by increasing the number of copies per inventory. The new eight-copy forms are with us now. This means copies as follows:

DISTRIBUTION FOR ACTIVE SHIPS

Ship—2 (This will permit ship to always have a copy on hand while the other marked-up copy is enroute to Bureau for processing or for supplying a copy to Task Force Commander on reporting if needed)

ComServFor—2

Type Comdr.—2 (One for overhaul Yard)

Bureau—2 (One sent to OpDevFor where OpDevFor ships are involved)

DISTRIBUTION FOR RESERVE SHIPS

Ship—2 (Forwarded to Group Commander, see Group Commander below)

Group Commander—2 (Regular Group Commander's copy plus overhaul yard's copy)

ComServFor—1

Bureau—3

DISTRIBUTION FOR NAVAL RESERVE TRAINING AND DISTRICT VESSELS

Ship—2

District Comdt—1 (Acts as type commander)

Industrial Manager—1 (Acts as ServFor)

Home Yard—1 (If an assigned Naval Activity, otherwise retain in Bureau)

Bureau—3

FIGURE 1—*Example of an "Electronic Equipment Compilation" sheet. The circled numbers indicate totals as explained by the arrows. Through the use of these sheets an answer is always available to the question "How many XYZ equipments are installed in what types, and which ships of those types?"*

We know the shipyards should get their copies direct from the Bureau, and we aim to supply them eventually. Our next step is to try to get twenty copies per inventory. We'll keep y'all happy yet. And remember, *you do not have to type a thing on the inventory.* Just mark it up with a *red pencil* and send it in. Why a red pencil? At first we allowed any marking agent but when some of the reports came in marked up with charcoal (was *that* what those smudges were!) we drew the line.

But wait, we are not through using those reports yet. By pouring all the tabulating cards into a machine called a "sorter" we can sort them by types of equipment, which are further broken down by classes of ships (see figure 1). Consequently two years, nine months and eleven days later we have the answer to "How many XYZ equipments are installed in what types and which ships of those types?"

Of course we made such compilations in May '47, November '47, and April '48, but now the number of ships "participating" is over 98%. (Haven't tagged all of the little fellows yet. Some of them must get their mail via Vladivostok.)

This compilation really gives out the information. The Electronics Supply Office at Great Lakes uses the compilation for stocking and replenishment purposes which now, for the first time, are based on actual, in-use equipments. Moreover, since a breakdown by geographic location can be made, the materials can be supplied *where needed.*

The actual enormity and status of completion of installation conversion programs now stand fully revealed for the first time. Opnav, the Ships Characteristics Board, the Ship Improvement Guide Planners, constantly refer to the Equipment Compilation. The planning of equipment procurements is now based on facts. Budgets are backed by actual installations (instead of good laundry numbers), and the Mobilization Planning people can work with real figures instead of the mumbo-jumbo, abracadabra that usually characterizes planning where complete, hard facts are lacking.

So if we are now asked where all the SG-1b radars are in the Fleet, the answer can be pulled out of the box almost as simply as pushing a few buttons (provided you reported your SG-1B radars as such and not as SG-1— but you are all honest characters). And if we have to know what equipments are to be found in the destroyers in the Atlantic Fleet—well, it's just as easy.

From the foregoing you now realize that the Nav-Ships 4110 is a mighty useful piece of paper and that as reports go, this is one report that really pays its way. We are doing everything we can at the Bureau end to make life easier and report-less in the Fleet, and to increase the service from current reports. With this spirit and the cooperation of all hands we feel we have a system which, far from being a war casualty, will, by its simplicity, accuracy, and usefulness, be a distinct asset to the prosecution of war.

HIGH FIDELITY SOUND SYSTEMS
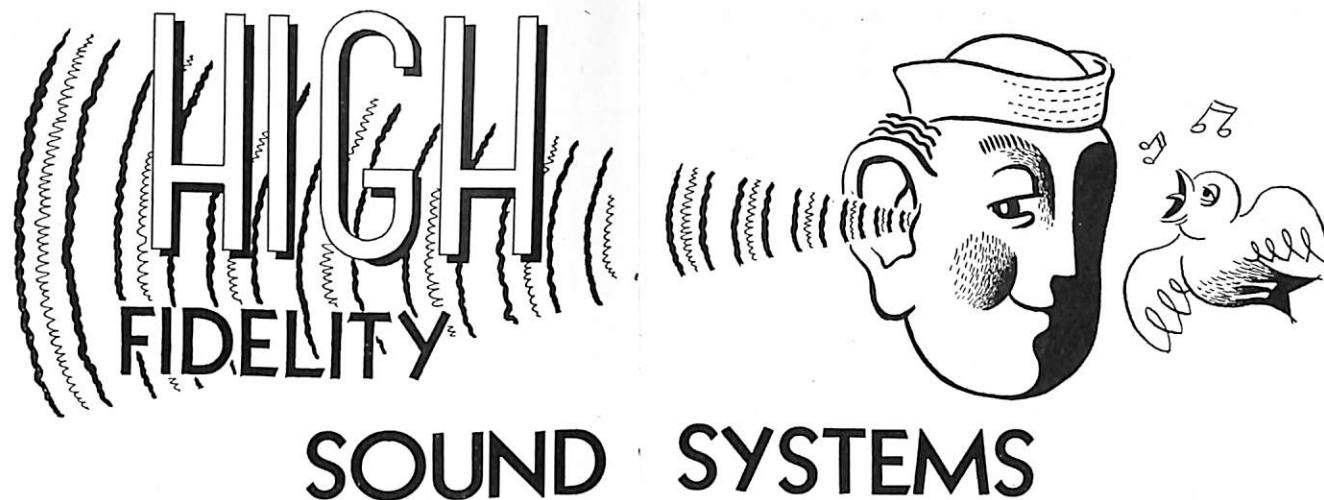
By LIEUT. COMDR. CHARLES W. HARRISON, JR., USN
Electronics Design Division, Bureau of Ships

There are many applications for high fidelity sound systems in the Navy, other than merely as program distribution systems aboard ship and in Naval shipyards. In the hands of an experienced noise analyst, for example, a high quality sound system is of utmost importance in solving the problem of marine machinery noise.

The present paper is concerned chiefly with a discussion of high fidelity sound systems in the light of the writer's experience, comments being confined primarily to the relative merits of several amplifiers, loudspeakers and reproducers.

A high fidelity sound system should reproduce sound indistinguishable from the original; viz., an auditory illusion of reality. This implies that all audible frequencies should be picked up, amplified and reproduced uniformly in their original amplitude ratios and phase relationships at all signal levels. The system should introduce no new audio components in the signal; that is, harmonic and intermodulation distortion should not be detectable. Transient wave forms must be transmitted through the system without distortion. Briefly, a high fidelity sound system may be defined as a system in which distortion of all types is essentially zero, and the frequency pass band includes the full audio-frequency spectrum; viz., from approximately 20 cycles per second to 15 kilocycles per second. (In practice, if the frequency pass band is 50 cycles per second to 15,000 cycles per second, the definition of "high fidelity" is satisfied.) Additionally, a high fidelity sound system meeting the above definition must be pleasing to the listener. When excellent sound systems are being compared the only criterion for selecting the "best" one is the listening test. But before anyone can become a competent judge of the qualities of various high fidelity systems, one must be "conditioned" to high quality reproduction. The average person has listened to restricted-range,

highly-distorted reproduction for so long he regards it as the natural state of affairs.

The writer suggests that one criterion for determining when a sound system holds some promise of being classed as a high fidelity system is its ability to reproduce record scratch. If the equipment fails to set up an almost intolerable scratch when playing the standard commercial shellac recordings presently available, the outfit is probably deficient in one or more respects. An experienced listener can often differentiate between a good and a poor sound system on the basis of scratch produced, without hearing a note of music on either system!

The comments made above relating to the attributes of a high fidelity sound system apply equally to the component parts of the system, which include the loudspeaker, amplifier and pickup. The unknowing introduction of a "weak link" at any point ruins the system. If a truly high quality sound system is desired there must be no compromises at any point. No second-rate parts or components can be utilized.

No doubt many readers have attended electronics conventions where various manufacturers have demonstrated their pickups, amplifiers and speakers side by side with competitors' products in an effort to "prove" their product superior. For illustration, suppose two loudspeakers are being compared. The listener hears first one and then the other. Both are driven by the same amplifying system which has other than perfect response characteristics. By the listening test one might decide that one speaker is definitely superior to the other. Surprisingly enough, the listener would probably pick the inferior speaker! A poor speaker may actually sound better to the ear than a really good speaker, since the good speaker will reproduce all of the distortion present in the electrical input. Even the audio signal available from a high-priced radio receiver may not be sufficiently free of distortion to be usable with a good speaker. Thus one should avoid comparing one loudspeaker with another when driven by a common amplifier, as the superior speaker will show up deficiencies existing at

other points in the sound system. To do justice (if comparing good speakers means anything) one should insist on hearing a manufacturer's *integrated sound system,* using the same recording. But the same fallacy exists here as before, for now the superior system probably sounds inferior, because it is showing up the flaws in the recording! It is surprising how many otherwise competent engineers can be misled in this way. To select the "superior" sound system (if it can be done at all) from several good ones might conceivably be accomplished by weeks of conditioning, ie., by comparing them on a day-in-day-out basis.

LOUDSPEAKERS

For several years the writer employed the acoustical phase inverter type loudspeaker. This speaker consists of a direct radiator speaker mechanism mounted in a closed cabinet except for a port which allows energy radiated from the back of the cone to be used. Although it is possible to build a bass-reflex speaker giving a moderately flat response (by appropriately lining the cabinet, and employing sound-absorbent material of the required thickness across the port opening) the completely-enclosed, suitably-lined speaker cabinet provides superior results. The indispensable cavity resonance of the "untreated" bass-reflex baffle produces a false bass response at a single frequency. Persons conditioned to restricted-range reproduction and preferring loud bass (out of all proportion to the original performance) often overlook the one-note bass effect referred to above. In an effort to improve the writer's experimental sound system, a Western Electric 728B single-diaphragm direct-radiator loudspeaker mechanism was purchased. This speaker has a nominal frequency response rating of 60 to 10,000 cycles per second, at a power-handling capacity of 30 watts continuous. The impedance is 4 ohms, and the coverage angle is 50 degrees. The diaphragm diameter is approximately 12 inches. An enclosure of the recommended cubical content was built for the speaker, consisting of 1¼-inch plywood. All sides were bolted and glued together and the resulting cabinet was lined with Kimsul 2 inches thick. It was felt that this construction would prevent the sides from vibrating and thus radiating undesired acoustical energy.

When constructing a cabinet to enclose a high fidelity speaker mechanism it is of utmost importance that the manufacturer's instructions be followed implicitly. The diaphragm of a high fidelity speaker is designed for a specific acoustical loading. Any deviation from the correct loading results in severe distortion; and, if the speaker is operated at anywhere near its rated power, rupture of the diaphragm is likely. This is in contrast to the usual run of loudspeaker purchased at radio-parts distributors. These speakers can be used with almost any type of baffle with equally inferior results.

When the Western Electric speaker was first com-

pared with the bass reflex speaker the results were disappointing. The electronics engineering staff at the Naval activity to which the writer was assigned selected the bass-reflex speaker as the better of the two. However, later investigation revealed an unsuspected weak link in the sound system (the pickup) and when this was replaced the outstanding superiority of the Western Electric 728B speaker, as compared to the bass-reflex speaker, became apparent. The bass-reflex speaker proved to be well-nigh useless for high-quality reproduction.

In turn, the writer purchased the Western Electric 755A and Western Electric 757A loudspeakers. The W.E. 755A speaker, like the W.E. 728B speaker, incorporates the design principles which give it an emotional characteristic—the feeling of presence. The frequency response of the 8-inch speaker is rated at 70 to 13,000 cycles per second. The impedance is 4 ohms; the power-handling capacity is 8 watts; and the coverage angle is 70 degrees. A cabinet was built for this speaker to Western Electric Company specifications.

The 757A loudspeaker is an outstanding contribution to the sound reproduction field. It has a uniform frequency response from 60 to 15,000 cycles per second; the input impedance is 4 ohms; the coverage angle is 90 degrees (horizontal and vertical) for all frequencies; and the power-handling capacity is 30 watts. The unit utilizes two loudspeakers and a frequency-dividing network. The W.E. 728B speaker is employed to reproduce the low frequencies, and the W.E. 713C receiver with sectorial horn is employed to reproduce the high frequencies. The cross-over frequency is approximately 1,000 cycles per second. A four-step, high-frequency attenuator is provided (in 1-db steps) to compensate for unusual acoustical conditions where the speaker is to be used. A utility cabinet is furnished.
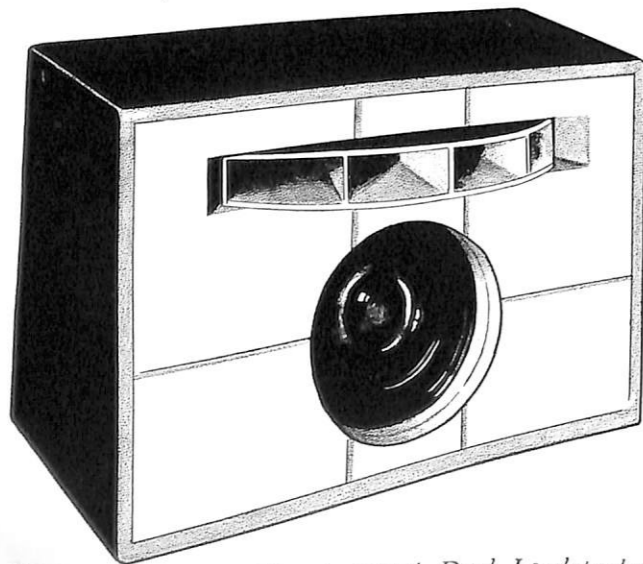
FIGURE 1—*Western Electric 757A Dual Loudspeaker. This speaker is the finest electro-acoustic instrument presently available for general use.*

The writer strongly recommends all Western Electric speakers tested. His recommendation of the Western Electric 757A dual loudspeaker is unqualified. A sketch illustrating the W.E. 757A dual loudspeaker is shown in figure 1.

BASIC AUDIO-FREQUENCY AMPLIFIERS

The belief is wide-spread that a high fidelity amplifier must of necessity employ triodes throughout, and especially in the output stage of the amplifier to achieve proper speaker damping. The writer does not take this view. An amplifier can be built using beam-power output tubes with inverse feed-back properly applied, that will perform equally as well as any amplifier employing triode output tubes with inverse feed-back. One important advantage of the beam-power tube is its power sensitivity. This means that relatively low driving voltage need be developed, with a consequent reduction in distortion in the driving stage. With triodes, such as the 2A3, much larger grid drive is required. These tubes have a very high transconductance, and are therefore very critical with regard to grid bias voltage. Hence in push-pull circuits severe unbalance in plate current must be anticipated unless some form of balancing arrangement is employed. Since the grid circuit resistance of a 2A3 must be kept low, transformer coupling should be used to couple the driver to the output stage. Now, if self bias is used, the cathode resistance should be by-passed to minimize grid-bias variations produced by current surges in the cathode resistor. If this is done, the output stage will often oscillate, sometimes above audibility. Obviously, d-c plate current balance is in no way related to cathode by-passing, but without by-passing of the cathode resistance an a-c signal unbalance is obtained. To stop oscillations it is sometimes necessary to introduce resistance networks, which cause the output stage to become frequency discriminatory. The writer does not wish to belittle the 2A3 type of amplifier, as problems are encountered in the research and development work associated with the production of any good amplifier. But again it is to be pointed out that properly engineered amplifiers using beam-power output tubes (such as the 6L6) may also satisfy the most critical listener.

Having achieved such outstanding success in the use of Western Electric speakers, as developed by the Bell Telephone Laboratories, it was only natural to investigate the amplifier developments of the Laboratories in the interest of obtaining a more "integrated" sound system. The Western Electric Company furnished the writer with schematic wiring diagrams for the "basic" amplifiers, series 124 and 142.

In figure 2 is shown a schematic diagram of the basic 124-series amplifier. The notes on the figure are self-explanatory. Observe that two feed-back paths are employed. One is connected into the cathode circuit of the

input tube (6J7 pentode connected), and the other connects into the screen-grid circuit of the same tube. The only item peculiar to this specific amplifier is the output transformer, Western Electric type 171C. The writer strongly recommends that no substitutions be made. An attempt was made to employ a UTC 6L3 linear standard series transformer in lieu of the W.E. 171C transformer. The transient response of the amplifier was ruined. Unknown to the writer, the gray box marked "W.E. 171C Transformer" probably contains a correcting network of some kind, in addition to a primary and secondary transformer winding! In constructing this amplifier, matched resistors and capacitors should be used. The frequency response is exceptionally good between 50 and 15,000 cycles per second, and harmonic distortion at 12 watts output is less than 1%. The amplifier has a gain of approximately 50 db.

In figure 3 is shown a schematic diagram of the basic 142-series amplifier. This amplifier is the latest amplifier development of the Bell Telephone Laboratories, and is preferred by the writer over the 124-series amplifier.

Notes on the figure are self-explanatory. Inverse feedback is used between the output of the second stage (1/2 6SN7) and the input of the first stage (1/2 6SN7). Again, inverse feed-back is employed between the secondary of the output transformer (type 519A), and the input of the phase inverter. The phase inverter in this circuit is of novel design. (Whether such a circuit will develop sufficient voltage to drive 2A3 type tubes in push-pull in the output stage of an amplifier has not been investigated by the writer.) The only item peculiar to this specific amplifier is the output transformer, bearing the designation W.E. 519A. Again, it is recommended that no attempt be made to substitute any other transformer.

The Western Electric 142-series amplifier is an amplifier of great performance, and is unexcelled by any amplifier the writer has constructed. It has an essentially-flat frequency response from 35 to 16,000 cycles per second, and the distortion is extremely low for both the 12- and the 25-watt output connections.
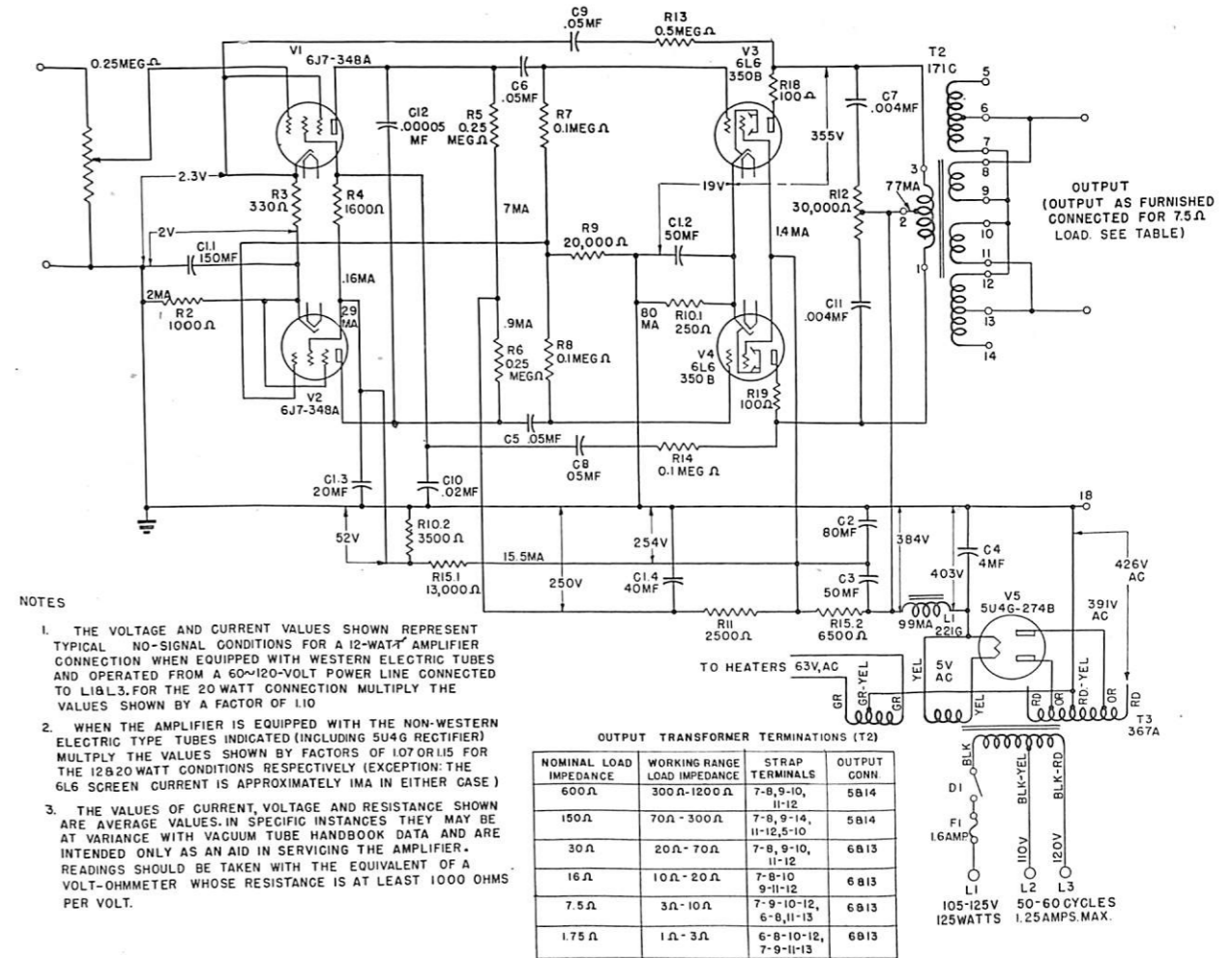

FIGURE 2—*Western Electric basic 124-series amplifier. Preferably R10.1 and R15.2 should be 25-watt resistors. R10.2, R15.1 and R11 are 2-watt units.*

FIGURE 3—*Western Electric basic 142-series amplifier—an amplifier of great performance. If the 12-watt output connection only is to be employed, a 25-watt, 250-ohm resistor may be substituted for R22.1 and R22.2; and a 30,000-ohm, 2-watt resistor for R25 and R30. R23 and R24 should have a power rating of 2 watts.*
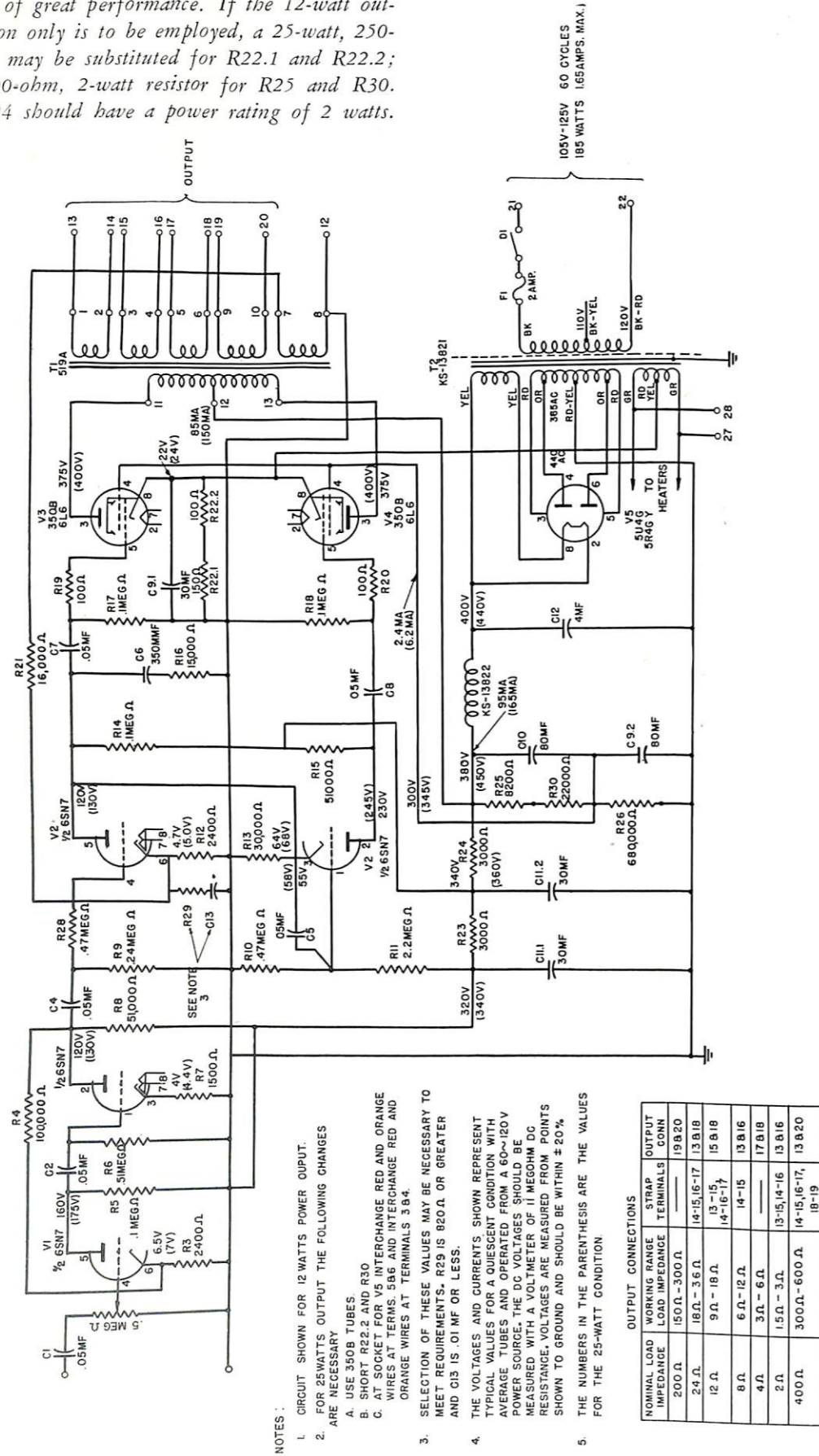
The Western Electric 142 basic amplifier has a gain of approximately 50 db. To adapt this amplifier to the W.E. 109 type reproducer group (pickup, equalizer, etc.) requires a preamplifier, W.E. type 141A. An "integrated" Western Electric Sound System of unsurpassed excellence consists of the 109-type reproducer group, W.E. 142B amplifier (142 basic amplifier plus 141A preamplifier) and W.E. 757A dual speaker. But the writer preferred to experiment with some of the modern inexpensive magnetic cartridges, hence a preamplifier, suitably equalized, had to be constructed.

EQUALIZERS

By definition an equalizer corrects for the recording characteristic at the low- and high-frequency ends of the audio spectrum. Some equalizers correct for the recording characteristic at the low-frequency end only, and neither accentuate nor attenuate the treble response. High-frequency equalizers correct for any high-frequency pre-emphasis employed in the manufacture of recordings, and additionally are effective in reducing surface noise. Some records have transition or turnover frequencies of 500 cycles per second. Others have transition frequencies of 300 or 800 cycles per second. Below the transition frequency a drop in the recording characteristic of 6 db per octave is normal; above the transition frequency the recording characteristic is essentially flat, or rises depending on the amount of high-frequency pre-emphasis employed.

In figure 4 is shown a two-stage equalized preamplifier suitable for use with any of the modern magnetic reproducers, which operate on the variable-reluctance principle. The General Electric, Pickering and Clarkstan cartridges are examples. (These pickups, as usually supplied, are for the reproduction of laterally cut records only.) Unfortunately, no provision is made to compensate for the differing transition frequencies of available records in this equalizer, and no high-frequency equalization is provided. (The author achieves high-frequency equalization as a rule by proper choice of the load resistance connected across the output terminals of the pickup. All cartridge manufacturers supply this information.) Nevertheless, the results obtained from the circuit of figure 4 are highly satisfactory. The circuit is actually a modification of the circuit employed in the G.E. equalized preamplifier, sold by radio-parts distributors. Modification is needed to improve the bass and treble response. The preamplifier, as supplied, is deliberately designed to attenuate low and high frequencies, because the public at large objects to turntable rumble at the low end of the audio-frequency spectrum and record scratch at the high end. Another reason for attenuating the low frequencies is to minimize hum pickup, but hum is no problem if good constructional practice is employed.

The circuit shown in figure 5 is an equalized preamplifier providing for variable bass boost, and a selection of transition frequencies to suit the record being played. This circuit is highly recommended, and is particularly well suited for use with the General Electric variable-reluctance reproducer or other very low level cartridge. Again the proper roll-off in high-frequency response may be accomplished by proper selection of the reproducer loading resistor. The equalizer, as shown, neither accentuates nor attenuates the high frequencies to any pronounced degree.

Figure 6 illustrates a four-stage equalized preamplifier, which theoretically enables one to equalize both the high-frequency and low-frequency ends or the normal recording characteristic, regardless of transition frequency, de-
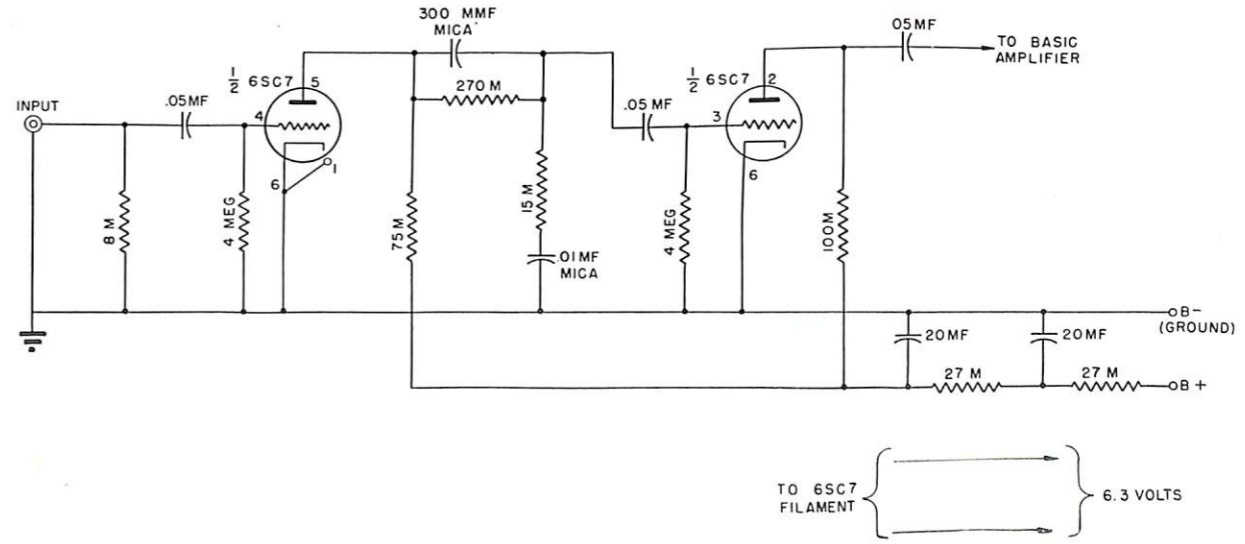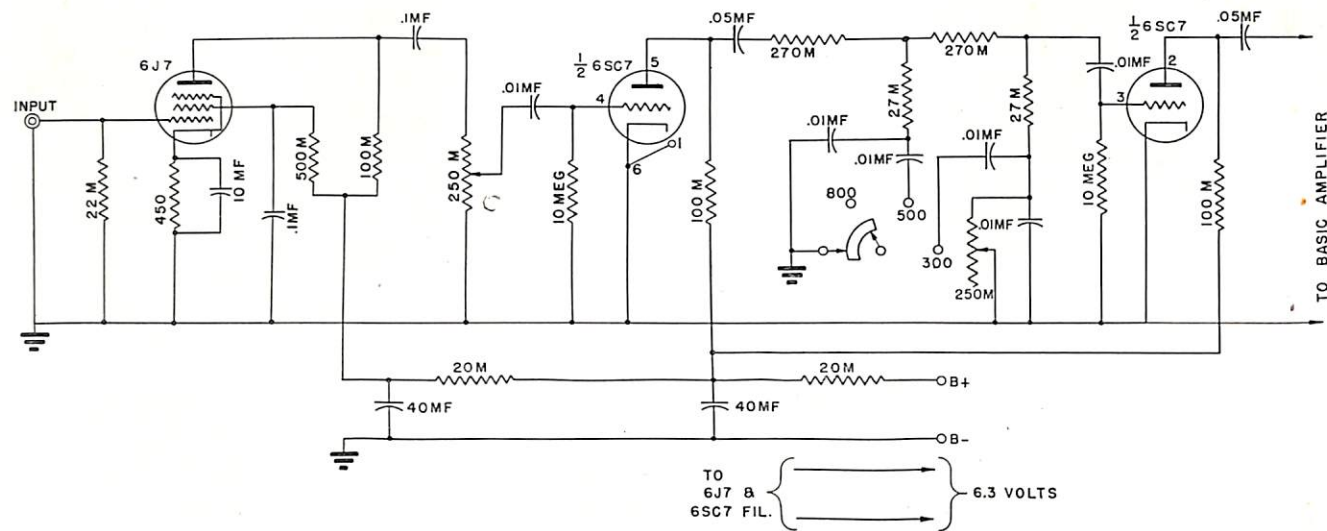
FIGURE 4—*Modified General Electric equalized preamplifier.*

FIGURE 5—*Three-stage equalized preamplifier particularly well suited for use with the General Electric Variable-Reluctance Reproducer, or other very-low-level cartridge.*

gree of pre-emphasis employed, etc. Accordingly, one should be able to attenuate the high frequencies, and thus largely drop out the high-frequency distortion existing in most recordings. The first two stages, employing a feed-back loop, provide distortionless amplification of the reproducer output. High- and low-frequency equalization is accomplished in the second two stages. Here an adjustable feed-back loop provides bass boost. (Less feed-back at the low frequencies is equivalent to increasing the amplitude of the low frequencies.) Resistance is connected in series with the line and capacity in shunt, in steps, to control the treble cut. This equalized preamplifier is a development of Brook Electronics, Inc.

If desired, the first two stages in the Brook preamplifier shown in figure 6, or the first two stages of the Western Electric 142-series amplifier shown in figure 3 may be used in lieu of the first stage of amplification (6J7) employed in the preamplifier shown in figure 5, if the reader has an aversion to pentodes. All parts used in the construction of these equalizers should be able to withstand 400 to 500 volts d.c.

REPRODUCERS

In this section a brief discussion of the characteristics of the Pickering, Clarkstan and General Electric cartridges will be given. These cartridges as usually supplied are for the reproduction of laterally cut recordings only.

The G.E. and Pickering reproducers have fixed styli, and may be obtained with either diamond or sapphire tips. The G.E. cartridge is normally equipped with a sapphire point 0.003 inch in radius. The Pickering cartridge is equipped with a sapphire tip 0.0027 inch in radius, or with a diamond tip 0.0025 inch in radius. Sapphire styli may be purchased for the Clarkstan car-

tridge from about 0.001 inch to 0.003 inch radii (in discreet steps). This reproducer has the great advantage of a removable stylus. All of these pickups are presently available with 0.001 inch radius styli for use with the new Columbia (LP) records.

The writer feels that a stylus radius of approximately 0.0022 inch should be selected, if a combination of commercial recordings and transcriptions are to be played. A needle 0.003 inch in radius tends to ride on top of the grooves of most transcriptions, giving rise to severe distortion. But a needle this size is satisfactory for most commercial recordings, other than possibly the English Decca (ffrr) series.

Needle talk, i.e., acoustical energy radiated directly by the pickup mechanism, the tone arm or from an area of the rotating record in the immediate vicinity of the stylus, is about equal for the Pickering and Clarkstan reproducers. It is much less severe in the case of the General Electric pickup.

The Pickering and Clarkstan cartridges have a great advantage over the G.E. cartridge in that their approximately equal outputs are roughly ten times the output obtainable from the G.E. reproducer. The Pickering and G.E. cartridges may be used in automatic record changers. The Clarkstan cartridge may not be so employed. Diamond styli cartridges are recommended for automatic changers, in that the tone arms by necessity are heavy (otherwise the changer mechanism will not trip). Sapphire styli show almost immediate signs of wear when used in such applications, and should be examined frequently.

The output of the G.E. cartridge falls off very rapidly above 10,000 cycles per second. The Clarkstan and Pickering cartridges have no audible upper-frequency limit. The harmonic distortion for both the Pickering

and Clarkstan cartridges is practically non-existent, and the Pickering reproducer will track a recording with very low pressure applied, provided a good, well-balanced tone arm is used. Nominal pressure is about 7 grams (1 ounce equals 28.35 grams).

Although the manufacturers of the Pickering and Clarkstan reproducers state that their products will not respond to unwanted vertical modulation in a record, actual tests show that all three of the reproducers discussed here respond to vertical modulation. In fact there is a region in the pass band of each cartridge where the vertical response is only about 10 db below the lateral response. This means that any vertically "polarized" scratch (noise) will come through to the speaker, attenuated about 10 db. This test was actually carried out first by selecting a good vertically-cut transcription (a transcription containing essentially no lateral modulation), and second by playing it with a properly-weighted transcription tone arm.

In selecting a reproducer, and later examining the state of stylus wear, a good magnifying glass, providing a magnification of some 25 diameters, is indispensable. Before the writer adopted the "glass" technique, several G.E. cartridges were bought with short styli. Any lint gathering around a short needle will lift the pickup off the record surface!

TEST RECORDINGS
FOR HIGH FIDELITY SOUND SYSTEMS

Procurement of test recordings or records for entertainment purposes where high fidelity sound systems are involved is a difficult, although by no means hopeless, problem. In general the commercially available standard recordings are well-nigh useless, for although some of them are reasonably free of scratch, they are exceptionally dull and lifeless, and afford little or no listening enjoyment. A full-range, "live" recording is essential, which is neither "over-cut" nor contains an excessive amount of high-frequency distortion. Few transcriptions (16-inch diameter) may be regarded as truly high fidelity recordings, because the groove speed which decreases as the center of the transcription is approached is too slow (33-1/3 rpm). Knowing the groove speed and the diameter of the cutting stylus, it is not difficult to compute the upper frequency limit of the transcription. In general this is below 10,000 cycles per second. Recording a 16-inch transcription at 78 rpm would greatly increase the high-frequency range, but a sapphire play-back stylus probably would burn up immediately.

The English Decca (ffrr) recordings have a frequency range of approximately 30 to 14,000 cycles per second, and apparently very little compression is employed in the recording technique. As a result some of these records are over cut; however, the use of a volume expander is obviated in their reproduction. By a judicious choice

of stylus radius the rough spots in these recordings may be smoothed out somewhat.

The London full-range recordings show promise of being suitable for high fidelity sound equipment.

The RCA red seal vinylite (deluxe edition) records easily cover the frequency range of 30 to 12,000 cycles per second. Sears Roebuck has released a few red plastic recordings having high frequencies present of around 8,000 to 9,000 cycles per second.

The London Gramophone Co. records—HMV—are reasonably good, but must be selected with care. Some HMV recordings contain a very intense scratch band at 8,000 to 10,000 cycles per second. This characteristic never shows up on a record demonstrator; only when played on high fidelity sound equipment. The HMV TTS (true transient series) recordings should be very good, when available.

World Transcriptions, although not classed as strictly high fidelity recordings, are in general very good. On the other hand, the transcriptions distributed by the Armed Forces Radio Service, as tried by the writer, are not particularly good.

In procuring high fidelity recordings one should make arrangements (if possible) to take out about five albums of a given selection, and from the five albums make up one good one. Only in this way is it possible to assemble a good library at the present time. Care should be exercised in testing a recording at the distributors. The tone arm of the test instrument may be entirely too heavy and the pickup stylus may be worn blunt. For example, the single playing of a HMV TTS recording with a heavy, worn pickup will destroy the recording for high fidelity applications.

The following recordings for tests of high fidelity sound systems are recommended:

Offenbach *Gaite Parisienne*, Victor Red Seal Deluxe Edition DV9.

Cesar Frank *Chorale No. 3 in A Minor*, HMV Recording (Pipe Organ).

Gounod *Fauste Ballet Music*, Decca (ffrr) album EDA-11.

Bizet *Carmen Suites, Nos. 1 and 2*, Decca (ffrr) album EDA-41.

Thomas *Raymond Overture*, Decca (ffrr) single record K1299.

Gilbert and Sullivan *A Wandering Minstrel*, 1, London Album LA3.

TESTS OF HIGH FIDELITY
SOUND SYSTEMS

To determine whether a sound system meets the requirements for high fidelity reproduction, a sweep frequency generator and an oscilloscope are particularly useful. The Clarkstan Corporation manufactures two sweep frequency transcriptions (with marker pulses at known frequencies) covering the range 70 to 15,000

cycles per second.[1] These records, when employed with a slow sweep-speed oscilloscope, enable one to analyze a complete sound system, less the loudspeaker, for amplitude distortion, harmonic distortion and transient response. These tools were employed by the writer in determining the operating characteristics of the equipment described in this paper, with the exception of the Brook equalized preamplifier. The apparatus described shows excellent characteristics in all respects.[2]

AUXILIARY EQUIPMENT

Certain auxiliary equipment is required when constructing a high fidelity sound system. The turntable motor should be a constant speed type to minimize speed variation, or "wow." The noise level, especially motor rumble, should be at least 35 to 40 db below record playing level. The writer has found that the Rek-O-Kut Model T-12 table is satisfactory. A play-back arm must be selected which is properly engineered for lateral pickup applications. The specifications for lateral and vertical play-back arms are different, if optimum results are desired. The arm should include finely-controlled adjustment of stylus pressure, virtually frictionless lateral and vertical bearings, three-point adjustable mounting for accurate self-leveling, extremely low basic resonance, etc. The Gray Research and Development Company's play-back arm Model 103S meets these requirements, and permits the mounting of any of the modern magnetic reproducers.

A good f-m tuner is a very valuable adjunct to the equipment described in this paper, for such a tuner when used to receive line programs (originated locally) immediately converts it into a radio receiver of unsurpassed excellence.

ACKNOWLEDGMENT

Mr. William C. Bechler, Jr., Senior Civilian Electronics Engineer, Philadelphia NavShipYd, cooperated wholeheartedly in the experimental program reported here by contributing substantially toward the purchase of components for the construction of the several sound systems.
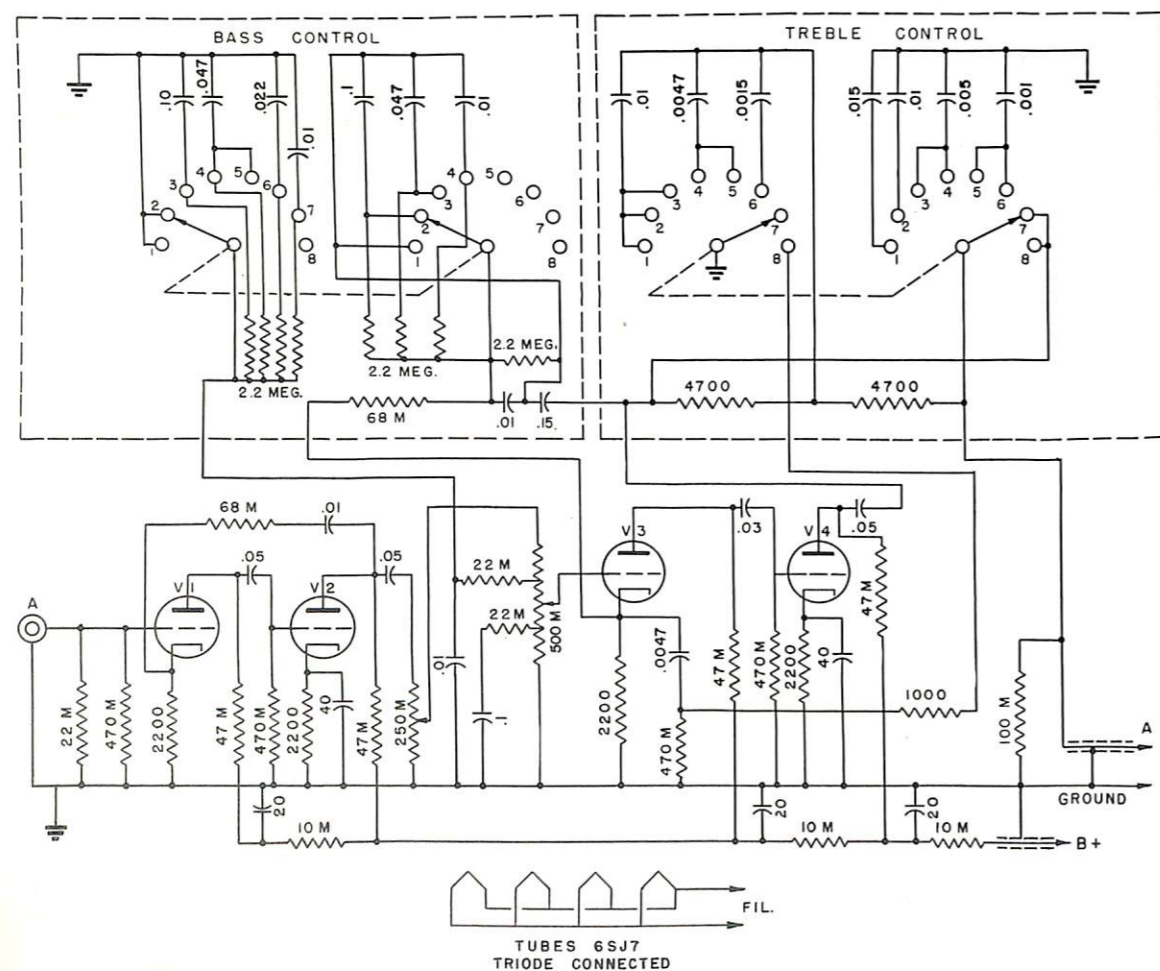
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[1] The Clarkstan sweep frequency transcriptions are not particularly "flat." Use should be made of the regions near the rim only.

[2] The writer formerly made use of a Thordarson tone control inserted between the preamplifier and the basic amplifier. To the ear this control does an excellent job. But when one "sweeps" the system, the Thordarson tone control will cause a flat amplifier characteristic to look like a snake which has eaten eggs, and hasn't bothered to wrap itself around a tree to break them!

FIGURE 6—*Four-stage equalized preamplifier.*

AN IMPROVEMENT
IN THE SOLUTION OF
THE PROBLEM OF
SYMMETRICAL ANTENNA ARRAYS

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

Several years ago the writer published a paper entitled "Symmetrical Antenna Arrays."[1] In this paper a method was presented for calculating the impedance properties of antenna arrays consisting of n identical radiators oriented at the vertices of regular polygons. All antennas were required to carry currents of equal magnitude, but not necessarily of the same phase. However, the choice of phase angle was such that the required electrical symmetry of the array was maintained.

In view of the importance of the theory of symmetrical antenna arrays for determining the driving point impedance of the primary radiator in a corner-reflector antenna and for calculating the radiation properties of polyphase and of two-phase multiple wire transmission lines, it is deemed desirable to indicate how the latest improvements in antenna theory may be incorporated into the solution of the problem.

Consider an array consisting of n identical antennas symmetrically disposed on the circumference of a circle. (In figure 1 is shown an array consisting of five identical antennas.) Each antenna is of half-length h and radius a. The origin for co-ordinates ($z = 0$) is the meridian plane of the array. Let it be assumed that the antennas are driven by identical generators maintaining the flow of equal currents but differing in phase by an appropriate angle. By direct analogy with antenna theory previously formulated,[2] the distribution of current along antenna (1), for example, is given by the following integral equation:

$$\int_{-h}^{+h} I(z') \left\{ \sum_{k=1}^{n} p^{m(k-1)} \frac{e^{-j\beta R_{1k}}}{R_{1k}} \right\} dz' = -\frac{j\,4\pi}{R_c} \left(C_1 \cos \beta z + \frac{1}{2} V_o^e \sin \beta/z/ \right) \quad (1)$$

Here $I(z')$ is the current flowing in element dz' of any antenna forming the array

m is zero or any positive integer introduced for the purpose of allowing a choice of phase angles between currents, consistent with the maintenance of electrical symmetry in the array.

p must satisfy the auxiliary equation.

$$\sum_{q=0}^{n-1} p^q = 0 \quad (2)$$

$$\beta = \frac{2\pi}{\lambda}, \; (\lambda \text{ is the wavelength}) \quad (3)$$

R_c is the intrinsic resistance of free space

$$R_c = 376.7 \simeq 120\pi \text{ ohms} \quad (4)$$

C_1 is an arbitrary constant to be evaluated from the boundary condition.

$$I(h) = 0, \quad (z = \pm h)$$

V_o^e is the voltage applied across the input terminals of any radiator.

$$R_{1k} = \sqrt{(z - z')^2 + b_{1k}^2} \quad (5)$$

In (5), b_{1k} is the distance (taken in the meridian plane) between the center of antenna (1) and the center of antenna k.

When $k = 1$

$$b_{11} = a \quad (6)$$

An immediate improvement in the solution of the problem of symmetrical antenna arrays consists in regarding the expression

$$\sum_{k=1}^{n} p^{m(k-1)} \frac{e^{-j\beta R_{1k}}}{R_{1k}} \quad (7)$$

as the kernel of the integral equation. Formerly[2] it was considered satisfactory to treat the effect of coupling of $n - 1$ radiators upon the reference antenna as simple correction terms; the kernel of the integral equation being

$$\frac{e^{-j\beta R_{11}}}{R_{11}} \quad (8)$$

Equation (8) is obviously derived from (7) by substituting $k = 1$ throughout. It is of importance to observe that (7) is a function of the number of antennas involved in the array.

In late 1944 the writer suggested the above approach to the solution of coupled antenna problems to King[3]. In 1946 Tai[4] suggested the same procedure and it was

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[1] Charles W. Harrison, Jr., "Symmetrical Antenna Arrays," Proc. I.R.E., Vol. 33, pp. 892-896; December, 1945.

[2] Ronold King and Charles W. Harrison, Jr., "Mutual and Self-Impedance for Coupled Antennas," Jour. Appl. Phys., Vol. 15, pp. 481-495; June, 1944.

[3] Private letter to Prof. R. W. P. King, Harvard University.

[4] C. T. Tai, "Coupled Antennas," Proc. I.R.E., Vol. 36, pp. 487-500; April, 1948.

used by him to extend the theory of an isolated symmetrical center-driven antenna, as presented by King and Middleton,[5] to include two element antenna arrays.

Further improvement in the solution of the problem consists in choosing a superior distribution function in expanding the integral equation, as was done in an earlier paper.[5] For example, by adding the same quantity to both sides of the equation, (1) may be written

$$I(z) \sum_{k=1}^{k=n} p^{m(k-1)} \int_{-h}^{+h} \frac{\sin \beta(h-/z'/)}{\sin \beta(h-/z/)} \frac{e^{-j\beta R}{}_{1k}}{R_{1k}} dz' =$$
$$-\frac{j\,4\pi}{R_c} \left\{ C_1 \cos \beta z + \frac{1}{2} V_o{}^e \sin \beta/z/ \right\}$$
$$-\sum_{k=1}^{k=n} p^{m(k-1)} \int_{-h}^{+h} \left\{ I(z') \right.$$
$$\left. -I(z) \frac{\sin \beta(h-/z'/)}{\sin \beta(h-/z/)} \right\} \frac{e^{-j\beta R}{}_{1k}}{R_{1k}} dz' \qquad (9)$$

One selects the magnitude of the complex quantity

$$\psi(z) = \left| \sum_{k=1}^{k=n} p^{m(k-1)} \int_{-h}^{+h} \frac{\sin \beta(h-/z'/)}{\sin \beta(h-/z/)} \frac{e^{j\beta R}{}_{1k}}{R_{1k}} dz' \right| \qquad (10)$$

as the expansion parameter.

From (10) it is clear that $\psi(z)$ is a function of the number of antennas forming the array. This is in contrast to the former solution of the problem of symmetrical antenna arrays, where the expansion parameter was a function of the overall length and radius of the reference antenna alone.

One selects $\psi(o)$ as the expansion parameter when $\beta h \overset{<}{=} \frac{\pi}{2}$, and $\psi(h - \frac{\lambda}{4})$ as the expansion parameter when $\beta h \overset{>}{=} \frac{\pi}{2}$.

In solving (9) the iterative procedure previously developed[2] is employed. The expression

$$\sum_{k=1}^{k=n} p^{m(k-1)} \int_{-h}^{+h} \left\{ I(z') \right.$$
$$\left. -I(z) \frac{\sin \beta(h-/z'/)}{\sin \beta(h-/z/)} \right\} \frac{e^{j\beta R}{}_{1k}}{R_{1k}} dz' \qquad (11)$$

may be regarded as the "correction" term in carrying out this process. That any one of the integrals involved in (11) is rather small may be demonstrated (though possibly not in a precise mathematical way) as follows:

It is well known that the distribution of current along an antenna is essentially sinusoidal. That is

$$I(z) \simeq I_{max} \sin \beta(h-/z/) \qquad (12)$$

Here I_{max} is the maximum current existing along the antenna. (The first I_{max} occurs $\frac{\lambda}{4}$ from the free end.)

[5] Ronold King and David Middleton, "The Cylindrical Antenna: Current and Impedance," Quart. Appl. Math., Vol. 3, pp. 302-335 (1946). Corrections to this paper appeared in Quart. Appl. Math., Vol. 4, pp. 199-200 (1946) and in Quart. Appl. Math., Vol. 6, pp. 192 (1948).

In the primed coordinate system

$$I(z') \simeq I_{max} \sin \beta(h-/z'/) \qquad (13)$$

From (12) and (13) one obtains

$$I(z') \simeq I(z) \frac{\sin \beta(h-/z'/)}{\sin \beta(h-/z/)} \qquad (14)$$

Therefore the integrand of (11)

$$I(z') - I(z) \frac{\sin (h-/z'/)}{\sin (h-/z/)} \qquad (15)$$

tends to zero.

The solution of the problem of symmetrical antenna arrays, as outlined here, is far superior to that presented in the earlier paper[1]; for from an investigation of appropriately phased close-spaced arrays one obtains the characteristic impedance of two- and four-wire transmission lines satisfactorily when $n = 2$ and $n = 4$, respectively. Further, an interesting but severe shortcoming of the previous theory is avoided; that of obtaining a net negative input resistance for an array when $\beta h = \pi$ for certain values of n!

It is a well-known fact that a wide variety of impedance values may be obtained for the same antenna by changing parameters in the vicinity of the input terminals. No exact statement concerning driving conditions is made in the mathematics; the gap between input terminals is represented simply as a discontinuity in scalar potential. But in spite of this shortcoming of the integral equation method for solving the antenna problem, as presented here, it is the only advanced theory presently available for solving problems involving coupled antennas.
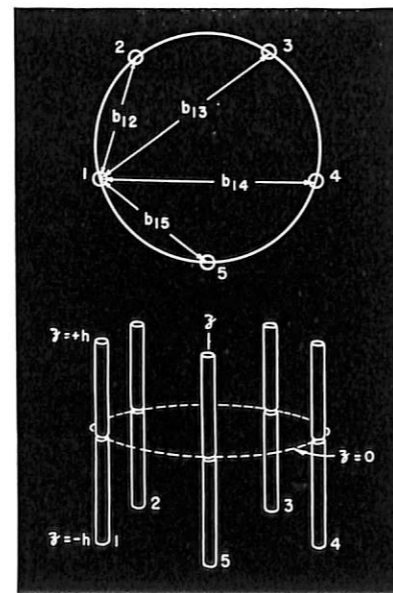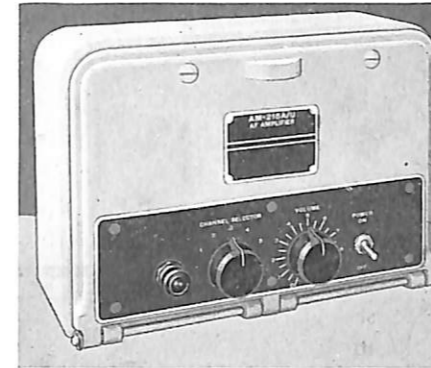

FIGURE 1—Five-element circular array. All antennas have identical dimensions. For the present theory to apply, they must be driven such that electrical symmetry is obtained.

TYPE AM–215A/U
AMPLIFIERS

A quantity of 7500 Type AM-215A/U Audio-Frequency Amplifiers has been procured and is being delivered under Contract NObsr-39405. These amplifiers differ only very slightly and insignificantly from the Type AM-215/U A-F Amplifiers already distributed (and described on page 15, ELECTRON, Sept., 1947), and differ not at all in performance.

Both of these amplifiers are multiple-input a-f amplifiers designed for general communication work in conjunction with Naval electronic receiving equipment and associated loudspeaker units, especially the Navy Type -49546 loudspeaker.

The AM-215/U is a five-tube, three-stage audio-frequency amplifier with push-pull output, incorporating inverse feedback. The power supply and amplifier are included in one compact unit. The chief distinction between the AM-215A/U and the AM-215/U is that in the former a 12AU7 voltage amplifier and phase inverter tube is utilized in lieu of the 6J6 in the latter.

The three controls for the unit are mounted on the front panel along with a shutter-type pilot light. They are respectively an on-off power switch, a volume control, and a channel-selector switch. The last switch has five positions and is used to select one of the five input channels as the source of sound for the amplifier.

Five 600-ohm input circuits are provided for connecting to audio sources, such as radio receivers, microphones, or phono preamplifiers. One input circuit at a time is connected to the input transformer, by the input selector switch as desired. The other input circuits are each terminated in a 620-ohm resistor.

A maximum of two watts continuous power may be fed into each input, and a minimum of approximately six milliwatts is required to produce full output. The power gain is 32.2 db. The frequency range is 250 to 4000 cps ± 3 db.

The maximum output of the amplifier is 10 watts with less than 10% total harmonic distortion at normal voltage rating. Two output impedances are provided, 600 ohms and 15 ohms, for feeding a conventional 600-ohm line or a standard speaker voice-coil.

The power supply is built on the same chassis with the amplifier. It operates from a 110/115/120-volt a-c power source, 50 or 60 cps and supplies all filament and plate power required by the amplifier.

The complete equipment is housed in a die-cast aluminum case which is made up of two pieces riveted together. The front panel of the amplifier serves as the cover for the case. The chassis is mounted to the rear side of the front panel, extending back from the panel at an angle of 90 degrees. The panel and chassis are also die-cast aluminum. A neoprene gasket is placed around the grooved edge of the panel so that, when the case is closed, the unit is sealed and made "drip-proof." The two Dzus fasteners at the top of the panel are used to secure the panel. The panel is hinged at the bottom so that it and the chassis will swing out of the case for adjusting and servicing. The tubes are accessible when the panel is opened at an angle of approximately 60 degrees. When the panel is opened to an angle of 180 degrees, the chassis will be outside the case, be upside down, and completely accessible for servicing.

The exterior of the case and panel is finished with a smooth Navy-gray enamel. The chassis and interior of the case are painted gray.

The unit may be mounted from the rear, top, or bottom surface of the case.

The unit weighs 23½ pounds, and the overall dimensions are 7″ deep, 12″ wide, and 8⅜″ high.

GCA BOX SCORE

Type of Approach	Last Month	To Date
Practice Landings	8,723	160,423
Landings Under Instrument Conditions	291	6,867

Electron ORBIT

CATHODE-RAY TUBE CAME FIRST

Sirs:

Congratulations on the visit of Dr. Lee de Forest to the Bureau of Ships and the Naval Communication station at Annapolis.

In your excellent article reporting his visit (ELECTRON, August, 1948) you called attention to Dr. de Forest's great contributions to the science and art of electronics. Thus by statement and by the visit itself (with four fine photographs for the record) you have honored a much neglected man. Probably there are relatively few of the younger men who have heard enough of the story of Dr. de Forest's achievements to appreciate his greatness, since the textbooks seldom mention his name.

I find only one small omission of fact in your article. At the top of page 27, you say the audion was "the forerunner of all modern vacuum tubes with the exception of diode rectifiers and magnetrons." Have you overlooked the cathode-ray tube, which was in use about 1895? My question is not intended to detract from your praise of Dr. de Forest, but in view of the recent widespread use of the cathode-ray tube for radar and television I should welcome an article in ELECTRON recounting the history of the grand-daddy of them all.

ARTHUR S. MARTHEUS

Training Director,
Office of Supervising Inspector of
Naval Material,
Pittsburgh, Penna.

This letter poses the interesting question, "What were the antecedents and development of the cathode-ray tube?" ELECTRON has decided to throw this one open to the field. Anyone with the knowledge (or time for research to dig out the knowledge) is urged to send us an article on this subject. The best article received will be published in ELECTRON with full credit to the author. LET'S GO, you would-be authors!—Ed.

AN AID IN TUNING 723B
AND 2K25 KLYSTRONS

Sirs:

The tuning of a Klystron to a specific frequency, as

is necessary when tuning the receiver of a microwave radar, is annoying at best when all proper equipment is handy, and extremely difficult or nearly impossible at worst when nothing but a wavemeter such as the Frequency Meter TS–33/AP is provided.

This laboratory has found replacement of Klystrons and their retuning to be greatly facilitated by means of an oscilloscope and a TS–33/AP. The frequency meter is coupled to the waveguide in the usual manner, and, with the meter selector switch on CRYSTAL-VIDEO, the scope is connected to the video output jack of the wavemeter. A resistor of about 50,000 ohms is placed in series with the repeller plate lead, and a coupling capacitor of about 0.01 mf. is connected to the repeller side of the resistor. One side of the sweep voltage of the scope is then coupled through the capacitor to the repeller, and the Klystron is thus frequency-modulated by the sawtooth wave through a range varying from 20 to nearly 100 Mc, depending on the Y-axis gain setting. The sweep voltage may be obtained from the exposed rear terminals in the case of scopes such as the Dumont 208, or by bringing out a lead from the horizontal deflecting plates in the case of other scopes. In the latter case it is recommended that the coupling capacitor be placed inside the scope case. In either situation, the working voltage of the capacitor must be sufficient to handle the voltages involved.

The Klystron output will appear as a bulge above the time base, and the wavemeter setting will appear as an inverted pip, since it draws energy from the Klystron. It will be necessary to dip the wavemeter in the customary manner to get a rough correlation between the scope presentation and the meter, but the dip will not be as sharp as usual. By alternately shifting the wavemeter and Klystron frequencies, it is a relatively simple matter to get the Klystron to the correct operating neighborhood, and then by reducing the Y-axis gain, the sweep may be reduced until the Klystron is unmodulated, putting out pure C.W.

The magnetron must, of course, be shut off or disconnected during the foregoing operations to prevent false indications. Leaving the 50,000-ohm resistor in the circuit has not in any way affected equipment

operation. It is expected that S-band Klystrons may be adjusted in a similar manner.

WALTER L. PRAGNELL

Mass. Inst. of Tech.,
Instrumentation Laboratory,
Cambridge, Mass.

THE SINGING PALM

Sirs:

Am enclosing a few negatives of pictures taken of a new type of radio receiver which I have never heard of before. One day last week one of the laundry girls at the station noticed a palm tree smoking, and Dean and I went over to investigate. We found that an insulator supporting the transmission line to the WVTG antenna had broken, and that the wire had dropped down against the tree. As we approached the tree, we heard music, which was our local broadcast, coming from it. The transmission wire had burned about half-way through the trunk; our palm tree was acting like a pretty good receiver, and fairly clear signals were being obtained. Before we had to cut it down, I had a couple of snaps

taken, thinking ELECTRON might be interested. Incidentally, the heart-of-palm salad obtained from the tree was mighty tasty.

LT. COMDR. GRANT HORSLEY
O-in-C,
Naval Radio Station,
Barrigada, Guam

Well, Science explains everything. We think we have an explanation for this, but before we print it we would like comments from the Fleet and from Navy shore activities. If you think you know how the modulation component was detected and converted to sound, let us hear from you.

Address correspondence to
Editor, "Buships Electron"
Code 993b, Bureau of Ships
Navy Department
Washington 25, D. C.

MODEL JT
WIRING
AND ADJUSTMENT

The Bureau of Ships has received reports of three Model JT Sound Receiving Equipments in which the "Press for Difference Listening" Switch S–301 was connected incorrectly, so that the opposite effect from that indicated by the labeling of the switch occurred. In one case, after the wiring to the switch was corrected, maximum ranges of 20,000 yards were obtained compared to previous maximum ranges of 4000 yards. Reports have also been received of three Model JT equipments in which RLI Meter M–501 read backwards because of reversed connections.

When symptoms such as these are found in other Model JT equipments, the proper procedure is to check the wiring of the equipments to see whether it agrees with that shown in the instruction book for the Model JT equipment, NavShips 900,424A. If the wiring is incorrect, it should, of course, be corrected. If it is correct, however, then in all probability one of the hydrophone halves was reversed by the installing activity when the hydrophone was connected to the JT slip rings or master control unit. When this is the case, the submarine should be submerged and the hydrophone halves should be properly phased in accordance with the following procedure:

1—Train the JT on the generated signal emitted by the submarine sonar test target (submerged).

2—Place the AVC-MAN switch in the MAN position.

3—Depress S–201 watching volume indicator M–301 at the same time.

4—M–301 should show a null reading on target when S–201 is depressed.

5—If Step 4 shows a maximum, interchange one of the hydrophone halves at P–504 and repeat Steps 1 through 4.

6—When Steps 1 through 4 give the proper results, depress S–301.

7—Note the drop in listening signal strength when S–301 is depressed to give difference listening.

8—When Steps 1 through 7 give correct results, observe training sense of handwheel. Clockwise rotation should result in increased bearings. If not, interchange S1 and S3 of the 5CT synchro at terminals No. 3 and 5 of E–505, to correct the training sense of the handwheel.

9—Switch to AVC.

10—Train JT across target (SSTT) and observe the RLI meter sense with respect to the training sense.

SILVER SOLDERING MODELS
SR-6 AND AN/SPS-6 WAVEGUIDES

The Bureau of Ships has received many requests from installation and field activities for a procedure for silver soldering flanges to the stainless steel waveguide used with the Models SR-6 and AN/SPS-6 series radar equipments. The following is the procedure used by the contractor:

1—Make a steel block ½″ x 1″ x 6⅜″ and another ½″ x 1″ x 3⅛″.

2—Clean thoroughly the inside edges of the flanges and the outside edges of the stainless steel guide where the two pieces are to be soldered.

3—Flux the stainless steel guide and the flange mating surfaces with Handy and Hamon silver solder flux which has been thinned with water to the consistency of table cream, and is free from lumps. Place the flange on the end of the guide in its proper position, making sure it is square with the axis of the guide.

4—Clamp the flange to the guide with two C-clamps using the ½″ x 1″ x 6⅜″ block to hold the guide to the flange. The ½-inch dimension of the block should be in contact with the guide and flush with it and the flange.

5—Heat the flange on the side away from the guide, making sure that no heat reaches the guide behind the flange. Also do not use more heat than is necessary to melt the silver solder.

6—When the flange is up to temperature, apply silver solder that melts at 1140°F or lower to the outside of the flange (under flame) until the silver solder flows into the cracks between the guide and flange.

7—Allow the guide and flange to cool in air. Do not cool by special means as this will cause the guide to buckle.

8—Remove the C-clamps and the block, and repeat the above procedure on the opposite side of the guide. Then solder the two narrow sides of the guide, using the ½″ x 1″ x 3⅛″ block.

The performance of the entire radar set depends upon silver soldering the flanges and guide properly. Therefore, extreme care should be taken both in silver soldering and handling to make sure that a minimum of buckling occurs. A waveguide installation may be considered good if the waveguide dimensions have not been changed over 1/16th of an inch from the original dimensions after soldering and installing.

In the near future, the Bureau of Ships will forward 16-millimeter movie training films on this subject to all U. S. Naval shipyards and training schools. These films will cover the procedure for silver soldering stainless steel waveguide, as applied by the contractor of Models SR-6 and AN/SPS-6 series radar equipments. Information as to the availability of these films will be published when available.

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MAINTENANCE REPAIR PARTS
FOR RADIO SET AN/ARC-1

Eight Radio Sets AN/ARC-1 less remote control units and cables, are being shipped from the San Francisco Naval Shipyard under Shipment Order No. 201143 to each of the following activities:

San Francisco Naval Shipyard (Code 125)
Puget Sound Naval Shipyard
Boston Naval Shipyard
Norfolk Naval Shipyard
Charleston Naval Shipyard
Mare Island Naval Shipyard
New York Naval Shipyard
Long Beach Naval Shipyard

Philadelphia Naval Shipyard
Industrial Manager 8th Naval District
Building 263 U.S. Naval Station
New Orleans (Algiers) Louisiana

The above equipments are not to be repaired, but are to be cannibalized for parts and components for use in repairing Radio Sets AN/ARC-1 now installed.

If equipments aboard vessels which are at sea become inoperative and cannot be repaired due to lack of repair parts, the nearest Electronics Officer should be contacted for replacement components. The necessary parts will be made available from the equipments which have been cannibalized.

DISTRIBUTION OF TYPE -10695
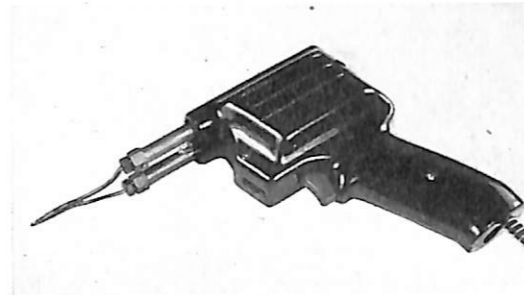# SOLDERING GUNS

FIGURE 1—*Navy Type –10695 Soldering Gun.*

A quantity of 1760 Navy Type –10695 Soldering Guns (shown in figure 1) and 1760 packages of six long-life tips each have been procured by the Bureau of Ships. They have been distributed in equal amounts to E.S.B., N.S.D., Bayonne, N. J. and S.S.D., N.S.C., Oakland, California, and are now ready for issue. This type soldering gun incorporates a prefocused spotlight to illuminate the work, and a flexible tip to facilitate soldering in difficult spots. This feature is shown in figure 2. Another feature is the dual-heat switch. A normal heat of 100 watts is available for light soldering operations when the switch is triggered to the first position, while the second position allows 135 watts of heat for soldering to larger metallic bodies such as chassis

and large lugs. A heating time of five seconds saves time and power.

The dimensions of the gun are: reach (housing to tip end), 4 inches; horizontal length, 8¼ inches; vertical length, 6¼ inches; and thickness, 2¼ inches. These soldering guns will be issued and drawn in accordance with the allowances shown in the Electronic Equipment Type Allowance Book, NavShips 900,115.
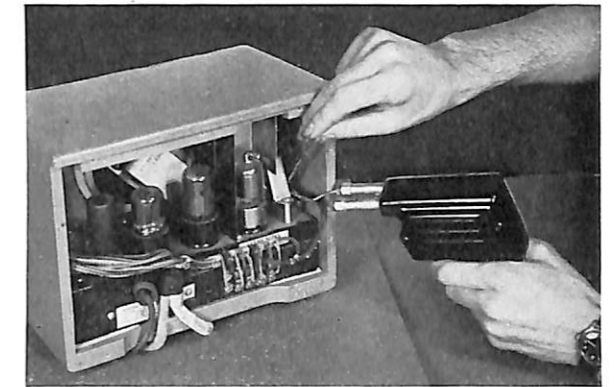

FIGURE 2—*Type –10695 gun in action. Note that the flexible tip permits the technician to solder in close quarters without removing chassis from case.*

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MAINTENANCE
OF STAND-OFF ANTENNA INSULATORS

Chapter 67 of the Bureau of Ships Manual calls for periodic inspection and cleaning of antenna insulators. Failure to comply with such a schedule will result in inefficient operation, as has been evident from several reports received from the Fleet. Visual inspection and megger tests should be made to see that all antennas and insulators are in the best condition.

All stand-off insulators, end seals of transmission lines, and waveguide windows should be cleaned at least once a month, and more often if conditions warrant such a practice. Aboard submarines this maintenance should be carried out as soon after surfacing as possible after every dive lasting an hour or more. If the submarine does not submerge for extended periods, this procedure should be practiced at least once a week.

The smaller the insulator, end seal, or waveguide

window, the more important is this maintenance procedure. Several rinsings should be used to remove accumulated dirt and salt water deposits. The cleaning must be accomplished thoroughly with nothing left to chance.

After each cleaning, a coating of Dow-Corning Compound No. 4 should be applied to the entire surface of the insulator. This compound, a jelly-like silicone material, forms a film from which water droplets run off easily, thus affording less opportunity for salt to deposit or dirt particles to adhere to the insulator. The compound should be applied with a clean cloth. Care must be taken to insure that the entire surface is covered with a thin film. Dow-Corning Compound No. 4 is available from all Electronics Supply Offices, and a supply should be carried aboard each vessel for antenna insulator maintenance.

MODELS SS AND SV-1 RESISTOR CHANGES

As a safety precaution lessening the possibility of dangerous high-voltage shock, it is strongly recommended that resistors R–4 (1H) and R–5 (1H) in the P.P.I. power supply of Models SS and SV–1 Radar Equipment consoles, be changed. Because of their location in the equipment, these ½-watt resistors have been proven very fragile. They frequently become broken when unit 1H of either the Model SS or SV–1 console is placed in the rack.

These two resistors are connected in series and make up the bleeder path for the 5000-volt cathode-ray tube power supply in the P.P.I. section of the console. If either of these resistors breaks or burns out, the bleeder path is broken so that capacitors C–1A and C–1B which are charged to 5000 volts, and capacitor C–2 which is charged to 2000 volts, have no discharge path to ground. After the equipment is turned off, the capacitors remain charged for several hours. Then personnel servicing the equip-

ment may come in contact with the capacitors or associated leads, and receive a severe or possibly fatal shock.

It is recommended that these ½-watt resistors be removed from their present position back of the power supply chassis and placed in stock or discarded. Two 2-watt resistors, R–4 (1H) 0.1 megohm and R–5 (1H) 1000 ohms, should be requisitioned from stock and connected in series so that R–4 (1H) is between test terminals TP–2 and TP–3 behind the panel. Figure 1 is a schematic of the unit. The dotted lines indicate the portion that is to be changed; the solid lines indicate the new wiring.

Referring to figure 7–94 of the SV–1 instruction book Ships 341 and figure 7–72 of the SS instruction book Ships 335, the following shall be deleted:

R–4 (1H) . . . ½-watt
R–5 (1H) . . . ½-watt
Lead "a-b" from terminal TP–2.

FIGURE 1—*Schematic of P.P.I. power supply of Models SS and SV–1 showing changes to be made to circuit wiring.*
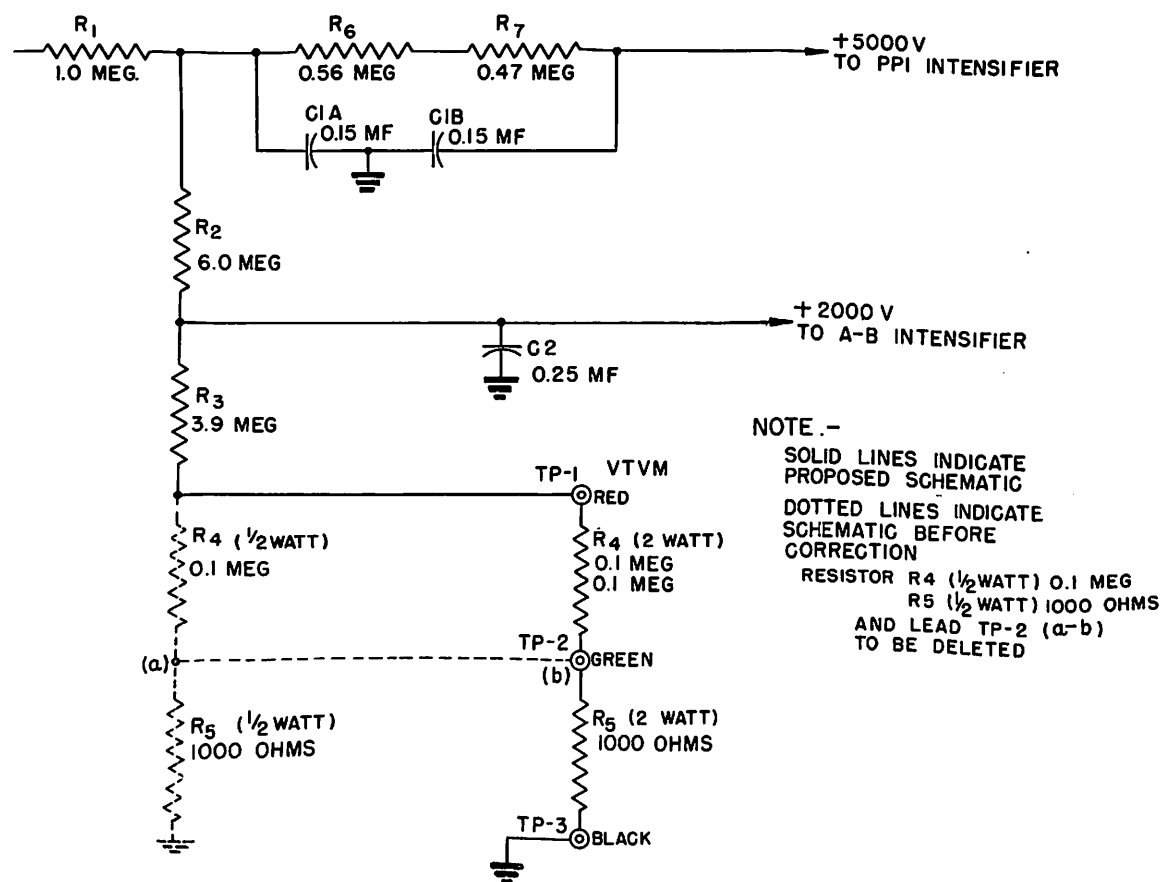
AUTOTUNE HINTS

By COMMANDER E. H. CONKLIN, U.S.N.
Electronics Officer, ComCruBatLant

Almost every ship and shore radio station now has a piece of radio equipment that uses some form of the *autotune* in order to obtain remote, pre-set tuning. Ships have Models TDZ, RDZ and AN/ARC-1 that are crystal controlled. Models TCZ, TDO and TDH use autotunes to reset a high-frequency master oscillator as well as to adjust other circuits when changing frequency. Increased familiarity with this unit, therefore, is a necessity.

Observations indicate that some common errors are being made, both in tuning and maintaining the autotune units and their associated equipment. This paper does not intend to replace the instruction book, but to direct attention to the more common troubles, some of which are not emphasized in the instruction books. Some of the comments do not apply to Model MAR/RDR, the autotune of which operates in the reverse direction compared with Collins types.

TUNING PROBLEMS

Multiturn autotune units, especially on the TDZ which has nine of them, are inclined to make the fingers raw after tuning up all of the channels. To facilitate turning the dials rapidly, the Bureau is procuring a quantity of dial cranks which will probably be available in early 1949.

Tuning may be done initially with complete disregard for the autotune mechanism when the dials are unlocked. After a channel has been tuned, the dial settings should be logged. Some of the controls may require accurate reset; so the dial readings should be logged down to 1/10th of a division.

After the proper settings have been obtained, each autotune should be locked on one channel. This should be done by rotating a control to the left (counterclockwise) at least 1/3 of the way, and then by approaching the logged setting clockwise. Note that 1/3 of the way to the left on the multiturn unit refers to the small counter dial, not to the large dial; it amounts to some 700 dial divisions or seven complete turns on the large dial. This counterclockwise rotation is necessary to make sure that the pawl is in place before the autotune is locked. It is necessary to approach the final setting slowly, of course, to avoid overshooting and making it necessary to back off counterclockwise a long way before again approaching the final setting clockwise. A recently designed autotune permits an approach from either side, but it is not used in the models mentioned above.

When locking the autotune with the locking bar that is located in the center of the dial, be certain that the cams inside are locked. It is possible, by loosening the

bar more than one-quarter turn, to have the locking bar tighten up too soon and bind against the two small stop nubs on the metal plate below the bar, instead of tightening up the cams. When this happens, each dialing operation will wipe off the pre-set adjustments. When it is necessary to correct this condition, move the stop nubs clockwise with a fingernail before tightening the bar. Hold the dial with one hand while turning the bar; if it is not possible to hold the dial without turning it clockwise, allow the dial to back away counterclockwise about one division, and lock the bar.

After one or more channels have been set up and every locking bar checked to see that it is tight, dial some other channel and then return to the one that has just been adjusted. The settings should be the same as those logged, and the meter readings should be normal. Do this on low power (TUNE-OPERATE switch in TUNE position). It will be desirable, too, to check every one of the channels to ascertain that all are still on the logged settings.

In the case of the Models TCZ, TDO and TDH in which a very accurate setting of the master oscillator autotune is necessary, it is sometimes found that the adjustment of one channel changes the adjustment of another slightly. While there is probably a cure for the trouble, such as by cleaning out dust between the stop rings, the operator's problem is to complete the adjustment satisfactorily. This may be done by bringing the dial up to about five divisions less than the final setting, locking the bar, and doing the same thing on the other channels. Then each channel may be brought up to perhaps one dial division short of the final reading and locked. After this, the accurate positioning can be done without disturbing other channels.

In order to avoid unlocking the bar on the autotune units on the TCZ, TDO and TDH when checking tuning, it is convenient to dial the MANUAL tuning position, leaving all of the autotunes locked. The master oscillator checkpoints can be verified, or tuning checked, without disturbing the pre-set adjustments unless necessary.

CORRECTIVE MAINTENANCE

One Navy yard has found autotune cams whose rough edges prevent the pawl from falling into place. It was necessary to clean off the burrs in order to obtain normal operation.

On several occasions, one or more channels would not tune up properly, but would come up on any random channel instead. This was found to be the result of failure of "hunting" current through a bad contact in a connector. Many cases of erratic operation of dialing

or of the test key are caused by aging of the selenium rectifiers in Model TDZ, as discussed in the instruction book.

One transmitter occasionally failed to produce normal output. A comparison of the dial with the logged settings disclosed the fact that one of the autotunes was several hundred dial divisions short of the proper setting. It could be turned clockwise by hand until it came up against the stop, at which time the transmitter operated normally. After a channel was dialed and all controls were brought to zero, this one dial would stop while the others were turning. As a result the autotune motor would complete its cycle before this one control had reached its pre-set adjustment. Inasmuch as the dial did not turn abnormally hard, it is presumed that its clutch was slipping. This can happen when a lubricant overflows onto the clutch mechanism.

Occasionally the reversing switch operates improperly, such as by bringing all dials to zero and then failing to reverse the motor to drive the dials to their correct positions.

Improper adjustment of relay K-101, in the Type –23497 remote channel selector equipment, may cause pulses to be missed. This tunes the equipment to a lower channel number than that dialed.

In one Type –23497 remote channel selector unit, a short from the K-101 relay contact to ground shorted the selenium rectifier and prevented the receiver from being dialed to any channel above the third.

The shielded cable to J-101, in the upper left portion of the Type –23497 remote channel selector unit, has been found to short relay K-101 and to prevent the operation of the channel selector. This is aggravated by the fact that it is difficult to bring in the three incoming cables in such a manner that neither they nor the shielded cable press against any of the relay contacts and upset normal selecting operations. While care in placing the cable knockouts and internal runs may avoid this trouble, installation of a metal rod railing on the shelf supporting the relays should prevent the difficulty.

REPORTING TROUBLES

It is suggested that all autotune symptoms and their cures be reported to the Bureau in some detail, especially during the coming few months, so that a complete summary of these problems can be published for the benefit of all hands.

ACKNOWLEDGMENT

The information contained herein includes material supplied by Pearl Harbor Naval Shipyard, the Naval Air Facility Naha, and the *U.S.S. Albany* (CA–123).

NEW FREQUENCY-SHIFT KEYER

Delivery of the new Keyer KY-32/GRT frequency-shift equipment has been completed, and it is now available at the various installation activities. The KY-32/GRT is an accessory to the Model TCK-4 Radio Transmitting Equipment, originally designed only for radiotelephone or "on-off" keying in radiotelegraph service. By the installation of the new f-s keyer, the TCK-4 may be converted to a frequency-shift-keyed radioteletype transmitter without interfering with its normal function of radiotelephone or radiotelegraph transmission.

As is well known, frequency-shift keying is that type of keying which causes a transmitter to radiate at one frequency for a "mark" interval, and then shift to a different frequency for a "space" interval. Previous equipments adapting the TCK to such f-s radioteletype service—for example, the Model FSA Frequency-Shift Keyer Equipment—have required extensive modification of the TCK.

In one modification suggested by the Naval Research Laboratory, the master oscillator of the TCK is converted into a frequency-doubling amplifier. This stage is excited by an external keyer such as the FSA. A system of this type—in addition to the keyer—requires an electronic coupling unit, switching equipment, a connector, and other accessories. Several other systems have also been used. Some utilize the TCK oscillator and the 200-kc side-step feature of the FSA. Other systems employ the inductive-loop method of coupling between the keyer and the transmitter.

In the majority of cases, the operation of the TCK on frequency-shift keying utilizing these systems has been satisfactory. Such modifications, however, have tied up the TCK transmitters for f-s-k service only, preventing the use of such modified TCK's on the c-w or radiotelephone service for which they were originally designed. Use of the KY-32/GRT keyer eliminates many of the modifications outlined above, and does not impose any restrictions on the use of the transmitter.

The KY-32/GRT is constructed as a small panel-and-chassis assembly which may be mounted in a cut-out at the side in space already available in the transmitter cabinet. On this chassis are mounted components for three circuits:

1—An audio-oscillator circuit for producing the f-s keying, which is usually plus-and-minus 425 cps from the center frequency.

2—A circuit for providing 200-cps phase modulation

for application where its use would improve transmission.

3—A circuit, using the same oscillator as in (2), for generating a 425-cps test tone for adjusting the transmitter and keyer.

The keying circuit consists of a triode-connected pentode arranged as a reactance tube; it is in series with a 150-$\mu\mu$f condenser connected to the tank circuit of the TCK-4 transmitter. As the d-c keying signal fed to the grid of the pentode varies, the reactance (capacitance and resistance) of the tube also varies. Effectively, a variation in capacitance appears across the tank circuit of the master oscillator of the TCK-4 and the transmitter frequency shifts accordingly. A change of 3 $\mu\mu$f at the plate of the tube produces a total shift of 850 cps from "mark" to "space." With the KY-32/GRT off, the load on the TCK-4 master-oscillator due to this connection does not appreciably change the frequency of the TCK-4 in normal service. Three types of input keying-signals may be used with the keyer:

1—Neutral keying, which requires a positive voltage input (+30 to +120 volts) for a "mark" interval, and removes the voltage entirely for a "space" interval.

2—Polar keying, which requires a positive voltage (+30 to +120) for a "mark," and a negative voltage (—15 to —120) for a "space."

3—Keying using external make-and-break contacts deriving its voltage from within the keyer.

The total frequency-shift is normally 850 cps (up 425 cps from the center frequency for a "mark," and down 425 cps for a "space"). It may be varied, however, from about 100 cps to perhaps 1700 cps, by varying a "frequency-shift" dial on the keyer panel and referring to calibration curves provided in the instruction book.

Using the KY-32/GRT is easy, and so is its installation. Turning a switch and allowing the keyer to warm up is all that is required to shift the TCK-4 from standard voice or radiotelegraph to radioteletype.

Installation of the unit may be accomplished in many instances by ship's personnel. Complete instructions for performing the installation and making the necessary connections to the TCK-4 are contained in the instruction book (NavShips 91,109) accompanying the keyer.

The KY-32/GRT Frequency-Shift Keying Equipment derives its power (about 35 watts) from the TCK–4. It adds less than 15 lbs. to the overall weight of the transmitter. It is manufactured and procured under Contract NObsr-39150.

At present, the KY-32/GRT may be used only with the TCK-4, and not with other models of the TCK, or other equipments. An effort is being made, however, to overcome this limitation.

Before installation of the new keyers, all previous modifications to the TCK-4 transmitters, required by the use of various coupling units made up by shipyards, should be removed, and the transmitters restored to their original condition. After installation of the KY-32/GRT, all surplus coupling units, and all previous keyers used with the TCK-4's, such as the FSA and the O-5/FR, should be returned to the nearest Electronics Office for BuShips distribution.

BEARING PULLER
FOR MODEL TCK
MOTOR-GENERATOR

It has been reported to the Bureau of Ships that difficulty has been experienced with the bearing puller supplied with the motor-generators of certain Model TCK series Radio Transmitting Equipments. One such report stated that a reasonable amount of pressure on the puller failed to force the bearings from the shaft. The unit in this case had to be taken to the shop for removal of the bearings.

All activities and vessels having Model TCK series transmitters with motor-generators aboard are requested to report all deficiencies of the bearing puller and any difficulties experienced to the Bureau of Ships, Code 982.

TCS ADAPTOR UNITS

An adaptor unit is required whenever the Model TCS Series Radio Transmitting-Receiving Equipments are to be interconnected into the standard Navy six-wire radio remote-control system. On all future shipboard installations of Model TCS equipments where an adaptor unit is necessary, the installing activity will be required to manufacture this unit. Instructions are detailed in the Electronics Installation Bulletin, No. 229 (not issued to ships other than tenders) and will also appear in the January, 1948 supplement of the Communications Equipment Maintenance Bulletin.

CLASSIFICATION
OF PO, AND YQ
INSTRUCTION BOOKS

The "Instruction Book for Components of Airborne Early Warning System Comprising Navy Models PO and YQ," NavShips 900,602, and the operator's handbook, NavShips 900,602.2, have been reclassified from RESTRICTED to CONFIDENTIAL. The classification of the equipment remains RESTRICTED.

CONDUCTORS and RESISTORS

BASIC PHYSICS
PART 15

The distinction between conductors and resistors. It has been previously shown that, in some substances, electrons are able to pass readily from atom to atom and such substances were called conductors. On the other hand, in other substances, electrons can only be removed with difficulty, and these substances were termed insulators. However, all substances offer some resistance to current flow and hence are not perfect conductors; moreover, all insulating materials are conducting to some extent, so that there are no perfect insulators. For the most part, however, there is a marked distinction between conductors and insulators. The metals and carbon are good conductors. Most organic and vitreous substances are insulators—rubber, oils and insulating materials derived from vegetables, for example. Glass, quartz, and ceramics are vitreous insulators at normal temperatures, but at extremely-high temperatures become conductors (in an electrolytic sense only).

The marked differences between conductors and insulators may be illustrated by a few comparisons of known substances used for conductors and insulators. Pure copper at 20° C. has a specific resistivity of 1.724 millionths of an ohm between opposite faces of a centimeter cube. Pure water, free of minerals, is in the intermediate class with a specific resistivity of 0.5 millionths ohms per cubic centimeter, while hard rubber has a resistivity of approximately 10^{16} ohms per cubic centimeter. The contrast between current flow in a conductor and that in an insulator is emphasized when a comparison of the resistivity of copper is made with the resistivity of hard rubber. The ratio is approximately 6×10^{21}, which means that many millions of units of current will flow through a copper conductor for each unit of current that will flow through a sample of hard rubber of similar size.

Types of electric currents. There are several kinds of electric currents which must be reviewed and studied in detail before developing concepts of what conductors and insulators are. The various effects manifested by the passage of electric current through conducting and non-conducting media will be briefly reviewed and new ideas introduced during the development of our concepts.

Three kinds of electric currents are recognized and considered within the scope of this course:

1—Conduction currents, in which the electric charge is carried by "free" electrons moving between the atoms and molecules of a conductor which is usually of a metallic nature. The flow of current always produces heat because of thermal agitation, as noted by Joule, and causes a magnetic field to surround the conductor, an observation attributed to Ampere.

2—Convection currents, in which the electric charge is carried by moving particles other than electrons, such as the movement of positive and negative ions in gases and liquids. This is known as electrolysis when the ion movement takes place in liquids. Electrolysis is always accompanied by the development of heat according to Joule's Law as well as a chemical change in either the electrodes or the electrolyte.

3—Polarization currents, which are not an actual movement of electrons or electric charge *through* a substance, but a displacement of the electric charges within the molecules themselves, although the actual total charge within the molecules continues to average out to zero. Such a displacement takes place in materials in which there are very few "free" electrons; such materials are normally termed dielectrics.

Another type of electric current, the so-called "displacement current," is due to changes in the electric induction, but is of very complicated nature and will be developed under the subject of electromagnetic wave propagation.

Factors affecting conduction currents. The term electrical conductor is used in connection with metallic substances because of the crystalline structure of the atoms and molecules, which permits a relatively large number of "free" electrons to be used for the conduction of electric charges.

The electrical resistance of any conductor is directly proportional to the length of the conductor and inversely proportional to its cross-sectional area. Further, it was found that two conductors of the same physical dimensions will have different resistance if made of different substances; this effect is due to the atomic or molecular structure and the available "free" electrons. It is described by a quantity known as the *specific electrical resistivity,* which is defined as the resistance offered by a cubic sample of the substance having unit dimensions. Consequently, a conductor of length L, cross-sectional area A, and specific resistivity ρ (Greek letter "rho"), has a resistance R expressed in ohms, which may be found by the equation:

$$R = \rho \frac{L}{A}$$

Copper has been found to have a specific resistivity of 1.724 millionths of an ohm, which actually means that a specimen of copper 1 centimeter long and 1 square centimeter in cross section will offer 1.724×10^{-6} ohm resistance between opposite faces of the cube.

The resistance of a metallic conductor changes with temperature. In all metallic conductors this change is positive or increases with temperature above a reference temperature, and decreases as the temperature is lowered below a reference temperature. This factor is called the *temperature coefficient of resistance,* and is approximately the same for all pure metals.

If R is called the resistance of a sample at some reference temperature, usually 20° C., the resistance at a second temperature is expressed by

$$R_t = R(1 + at)$$

where a is a constant called the *temperature coefficient of resistance,* and t is the change in temperature. When the new temperature is higher than the reference temperature, the resultant resistance will be greater, but when the final temperature is less than the reference temperature, the resultant resistance will be less than the original value.

Certain alloys have been developed in which the temperature coefficient of resistance is very small; these materials are useful for the resistance elements and standards in laboratory and measuring instruments, in which the resistance must remain as constant as possible. For non-metallic substances, such as carbon, liquids and insulating materials, the temperature coefficient is negative over certain temperature ranges.

When referring to resistance of wires of circular cross-section, one uses a convenient unit of area called the *circular mil* (abbreviated the C. M.) to express the cross-sectional area of wires. One circular-mil is the area of a wire of circular cross-section with a diameter of one mil (one mil = one-thousandth of an inch).

This avoids the use of the factor $\frac{\pi}{4}$ in calculating the area of a circle.

The resistivity of conducting materials may then be measured in terms of ohms per circular-mil per foot. Thus, copper has a resistivity of 10.4 ohms/C.M./ft, meaning that a specimen of copper 1 foot long and 1 C.M. in cross section will have a resistance of 10.4 ohms.

The following table lists the specific resistivity in ohms per centimeter cube, and ohms per circular-mil per foot, as well as the temperature coefficient of resistance for the common types of conducting materials.

TABLE I—*Resistance properties of common materials*

Material	Microhm/cm³	Ohms per Circular mil/ft.	Temperature Coefficient
Aluminum	3.21	19.3	.0038
Carbon	4000 to 7000	24,000 to 42,000	—.00025
Constantan	49.0	295	—.00004 to .00001
Copper	1.724	10.4	.0039
Iron	12 to 14	72 to 84	.0062
Lead	20.8	125	.0043
Manganin	43.0	258	.000002 to .00005
Nichrome	110	660	.00017
Platinum	11.0	66	.0038
Silver	1.65	9.9	.004
Tungsten	5.6	33.0	.0045
Zinc	6.1	36.7	.0037

The utilization of conductors. The use of metallic conductors covers a wide field and varies according to the application. In efficient power transmission from place to place, low resistance is necessary to minimize losses commensurate with other factors such as the cost, maintenance, and strength of the conductor. Although silver has lower resistivity, copper is used because it has the advantage of ductility, high tensile strength, is easily soldered, and is not readily corroded by the atmosphere. Copper has nearly as low a resistivity as silver but is much cheaper. In spans of transmission line where the distance is great, copper-clad steel is often used to provide greater strength with low resistivity. In other instances, aluminum may be used to provide a conductor of greater radius for the same weight of wire, in order to reduce corona and ionization of the surrounding air when extremely high voltages are present.

When the primary purpose of the electrical conductor is to produce heat or light, as in heaters, electric lamps, and arc lights, conductors are used whose resistance varies from moderate-to-high (depending upon the operating temperature). Nichrome is used in open-air heaters, and tungsten is used in lamps, since these applications call for operation at red or white hot temperatures. Carbon is used for arc lights and in electric furnaces when the temperature is above the melting point of most metals.

Protective fuses for electrical circuits are made of metals having moderate resistance and which have a low melting point, such as lead and lead alloys, so that the circuit may be opened in the event of current overloads. The fuse element is constructed of thin strips of appropriate dimensions encased in an insulating holder of glass or fiber. The insulating case is necessary to confine the arc which is produced when the fuse element melts under overload conditions.

There are many phenomena associated with conductors and the movement of electrons within them. These are dependent upon the way that energy is supplied, which may be as a potential difference, or as heat, light or mechanical utilization of the pressure caused by sound. The various effects will be briefly explained in order to give a better idea of the relationship between electrons and energy.

The various effects of heat on conductors. In part 14 of *Basic Physics,* it was shown that an e.m.f. was generated at a junction of two dissimilar metals when heat was applied. A thermal current produced in this manner was dependent upon the difference in temperature between the two junctions. This behavior of conductors under the application of heat is called the *Seebeck Effect,* and is due only to the external application of heat to the junction.

When a current is caused by an external e.m.f. to flow in a circuit consisting of junctions between two dissimilar wires, the junctions will react in just the opposite manner to the Seebeck effect. Current flow through the junctions will cause an inversion of the Seebeck effect which is called the *Peltier Effect,* after the discoverer.

The effect of external heat on a conductor carrying an electric current was closely studied by the English scientist, Thomson, later Lord Kelvin, who discovered that an e.m.f. exists between different parts of the *same* metallic conductor if the parts are at different temperatures. An experimental set-up such as shown in figure 1 was used to demonstrate this effect. A copper bar of uniform cross section was heated in the center by a steam jacket and each end was left at room temperature. A point midway between the center and each end was found where the temperatures were the same, and thermometers were attached. When an external e.m.f.

caused current to flow through the conductor from one end to the other, as shown, it was found that, in the region where the current was directed from a cooler to a hotter part of the bar (thermometer A), that region was actually cooler than before the current flow. The current, in passing through the region at thermometer B, or from a hotter to a cooler portion of the bar, caused that portion of the bar to become warmer than before current flow. This effect is distinct from the normal heating effect due to thermal agitation by the current flow in accordance with Joule's Law of electrical heating. The effect demonstrated above is now known as the *Thomson Effect.*
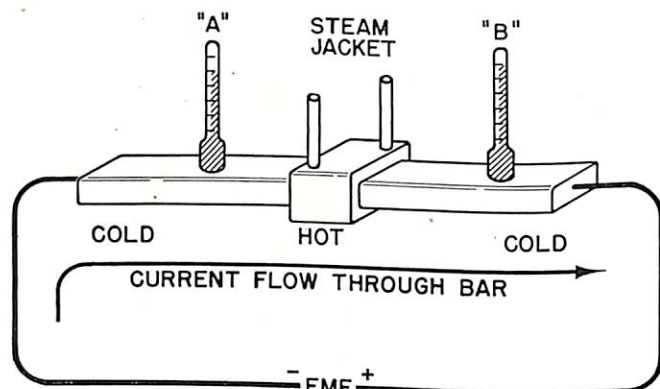

FIGURE 1—*The Thomson Effect demonstrated by passing an electric current through an unequally-heated copper bar.*

When metallic conductors are heated to incandescence by the passage of an electric current, the electrons are given sufficient energy to enable them to overcome the potential barrier at the surface of the metal, and the electrons leave the metal at low velocities. Upon leaving, however, energy is lost and they are then attracted back to the metal. In the vicinity of the heated wire, however, there will exist a cloud composed of electrons that are either leaving the wire or are falling back. This characteristic of electron behavior is called the *Edison Effect.* In order to utilize the electrons that compose this cloud, the heated wire is enclosed in an evacuated glass envelope with an anode of opposite polarity to attract the negative electrons.

The photoelectric effect. During the latter part of the last century, attention was also called to the effect of various radiations such as ultraviolet rays, infrared rays, and ordinary light upon various metals. It was noted that electrons were emitted under certain conditions which formed a space charge similar to the Edison Effect. The intensity of the light was found of no importance in causing electron emission, but that the energy supplied and hence the quantity of electrons depended upon the frequency or color of the radiations. This characteristic of certain elements is known as the *photoelectric effect.* An increase in the frequency or color of

the light (infrared is at the low end), through yellow to ultra-violet above the visible range, causes an increase in the velocity of electron emission. A decrease in the frequency decreases the velocity. At a limiting frequency (which is to say, color) which is a characteristic of the metal, the photoelectric effect disappears.

The metals that exhibit a photoelectric effect such as caesium, lithium, sodium and potassium, have a limiting threshold in the infra-red region, so that electron emission takes place throughout the visible spectrum of light. Copper, aluminum, and zinc have a limiting threshold in the ultra-violet region, which is above the visible spectrum of light.
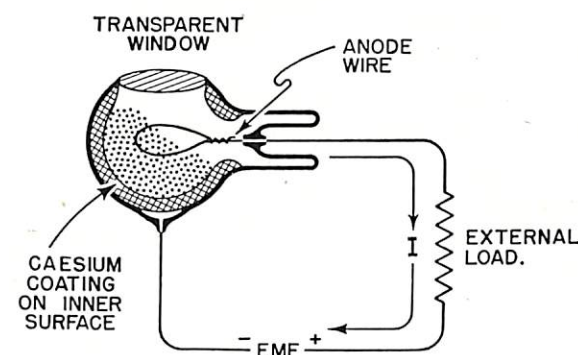

FIGURE 2—*Simple photoelectric cell.*

The photoelectric property of these elements is utilized in the photoelectric cell (shown in figure 2) which consists of a light-sensitive surface on the inner wall of an evacuated or gas-filled glass tube. Caesium is the most active of the elements under illumination by visible light. This metal is deposited as a thin layer and serves as the cathode or source of electrons. In order to utilize the electron emission, an anode of fine wire is also placed in the tube. A positive potential is applied to the anode, which attracts the electrons from the vicinity of the cathode. These electrons constitute a current flow through the external circuit where they are suitably amplified. A light-transparent window is provided in either the end of the tube or at the side to permit entry of light.

Another photoelectric property of metals depends upon the intensity of illumination and not the color. This is the so-called *photoelectric effect.* It is utilized practically in the *photoelectric cell,* in which the amplitude of current caused to flow will depend on the brightness of the light source. A thermocouple such as selenium and iron will produce a thermal e.m.f. due to contact alone, but when subjected to light, it was found that the potential developed at the junction of the metals varied in almost direct proportion to the intensity of the light source, and the device could be employed as a photoelectric cell. Exposure meters used in photography

utilize this principle, and are usually calibrated in terms of intensity of illumination—foot candles, etc.

An interesting and useful aspect of the application of resistances is the ordinary microphone such as used in telephone mouthpieces. It consists of a capsule-like holder partially filled with loosely-packed, minute granules of carbon. A flexible diaphragm is fitted into one end and electrical connections are made to the diaphragm and case with an external circuit.

Carbon has a high value of resistance, and under these conditions the effective resistance will depend on the closeness of contact of the surfaces between the granules of carbon. The resistance then can be varied by pressure applied to the flexible diaphragm, and corresponding variations in the current flowing through the device will result. Sound energy is converted to electrical energy through the mechanical medium of the flexible diaphragm which is caused to vibrate in unison with sound. The changes in current flow in the electrical circuit associated with this energy-converting unit are suitably amplified to actuate receivers at the other end of the line. These units are called *carbon buttons.*

Factors affecting convection currents. The movement of an electric charge (current flow) by an agency other than an electron is called convection current. These agencies are called ions and may be either atoms or groups of atoms which are positive ions when deficient in one or more electrons, and negative ions when there is an excess of one or more electrons. In metallic conductors, convection currents may occur when the metal
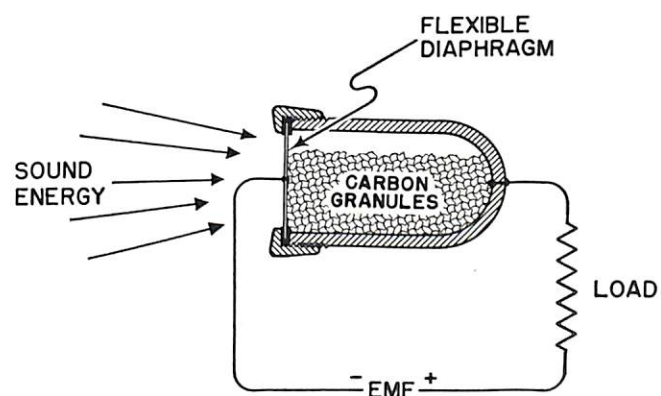

FIGURE 3—*Single carbon "button" as used in microphones.*

is normally fluid, such as mercury, or when a metal is in the molten state. Convection current, however, is usually attributed to the chemical change that takes place in the electrolyte when a current flows through a solution. Conduction of current through gases by ionization of atoms or molecules is merely called ionization, since ordinarily no chemical changes occur.

Ordinary liquids are classified as intermediate conductors (pure water, with a specific resistivity of one-half megohm per cubic-centimeter is an example). Here let us point out again that solutions of metallic salts and acids are of the electrically-conducting kind, while liquids of an organic nature such as oils act as insulators. This difference is due to the chemical nature of the solutions. The salts and acids are easily dissociated into ions which are carriers of electric current, whereas the inorganic liquids are not dissociated to any extent under normal conditions.

The flow of current in a liquid is always accompanied by chemical changes in the conductor. Such conductors are termed electrolytes, and conduction accompanied by chemical decomposition of the electrodes or the electrolyte is called electrolytic conduction. When the chemical decomposition is caused by a current supplied by an external source, or caused by the current caused to flow as a result of simple voltaic action, it is called electrolysis.

Within the electrolyte, the convection current equals the sum of the charges transferred through any cross-section of the solution by the two streams of ions, one moving toward the anode and the other toward the cathode. The conductivity of the electrolyte depends in part upon the number of ions per unit volume of the solution. The particular kinds of ions are in turn determined by the particular kinds of elements used in the salt or acid solution. When molecules dissociate, it is found that the ions formed carry charges proportional to the valence of the atom or group which forms the ion. For example, when common salt dissociates in water, we have:

$$NaCl = Na^+ + Cl^-$$
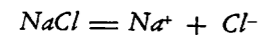
with each atom having a single charge. An example of dissociation with atoms having a valence greater than one is copper sulphate:

$$CuSO_4 = Cu^{++} + SO_4^{--}$$

which dissociates into a copper atom with a double positive charge and a sulfate ion with a double negative charge.

A peculiar characteristic of an electrolyte is that under certain conditions it may be caused to exhibit great opposition to current flow in one direction and very little opposition or resistance to current in the opposite direction. However, when chemically active in this manner, the electrolyte is termed a dielectric instead of an insulator or a conductor because of this two-fold nature. This effect is a function of the potential difference that exists across the surface between the liquid and the metal with which it is in contact. A film of this nature is formed chemically by the application of voltage of correct polarity when aluminum is used as the electrode with an electrolyte of ammonium phosphate. The actual surface of the contact between the metal and the electrolyte

offers a low resistance to current flowing from the electrolyte to the metal but, below a certain critical voltage, the surface offers a very high resistance to current flowing from metal to the electrolyte. The film in contact then acts as a good dielectric, separating the postively charged metal anode and the negatively charged electrolyte.

Detrimental electrolytic effects. The earth is a good conductor of electricity, not because of the inherent resistivity, but because the cross-section is extremely large. The resistance of any ground-return circuit is practically all at the point where the current enters or leaves the ground. The earth as a return circuit is extensively used in power circuits, such as electric railways, but is also supplemented by bonding the rails at each junction and frequently connecting the rails to buried copper cables. The supplementary ground return is used to offset several detrimental effects in utilizing the ground as a return circuit.

No harm is done in an earth-ground-return circuit unless the currents find their way into and follow water pipes or buried metal telephone and electric cables. At a point where the current enters such a pipe or cable, the metal acts as the cathode of an electrolytic cell and therefore is not affected chemically, but at the points where the current leaves the pipe to return to ground, the metal acts like an anode and is decomposed by electrolysis. The electrolyte for such chemical action is due to the presence of salts, or alkaline or acid content in moist earth.

Electrolysis of water pipes can be discovered and repaired, but electrolysis of the reinforcing rods in concrete structures is likely to remain undiscovered until the structure collapses. Junctions of iron and brass or copper pipes are especially susceptible to chemical decomposition because the metals form the electrodes of a voltaic cell and the dissolved salts and minerals in the water act as the electrolyte. This combination causes chemical decomposition of the iron pipe with subsequent damage to the joint.

In electrical circuits, particularly aboard ship, the moist salt air acts as an electrolyte between contacts and junctions of dissimilar metals. Faulty contact, noisy connections, and effective increases in the resistance of contact result. Corrosion of various parts of antenna installations may be accelerated by the electrolytic action provided by contact with salt water.

The conduction of electricity through gases. If the molecules in air could be kept intact, air would be a perfect non-conductor of electricity, but due to the sun's rays, cosmic rays from distant stars, and local electrical disturbances on the earth, the molecules are ionized—split into positive and negative ions. Electricity is transferred whenever ions move toward charged bodies of the
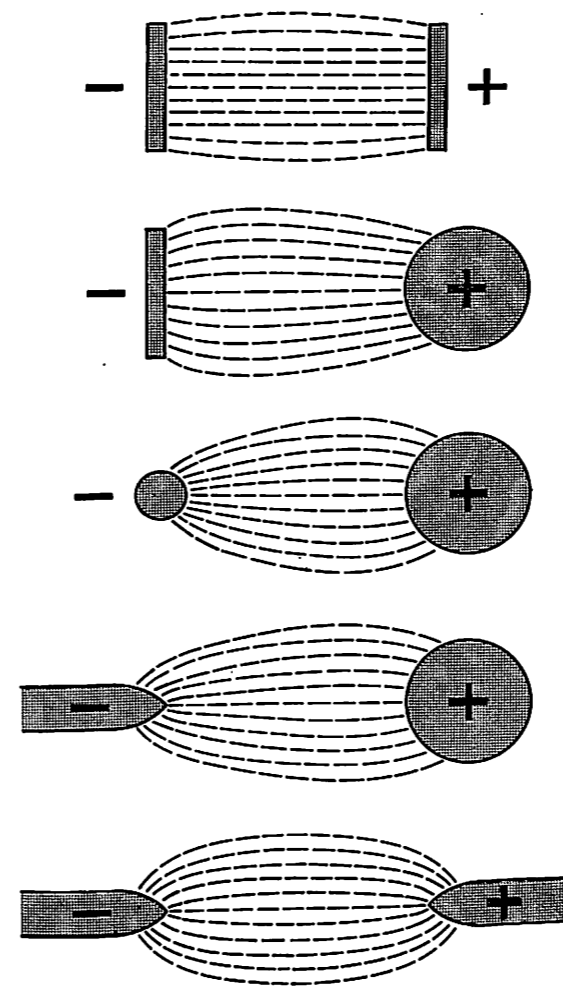

FIGURE 4—*Comparative electrostatic fields existing between charged bodies of different contours.*

opposite sign. This constitutes an electric current, whose magnitude is determined by the potential gradient along the path of ion flow and by the rate at which ions are set free within any given volume of air.

When a potential difference exists between two bodies, any stray charges in the gas space will be accelerated toward the body of opposite sign; electrons and negatively charged ions of gas go to the positively charged body and positive ions are attracted by the body of negative polarity. The energy acquired by the accelerated charges will be dissipated in collisions with gas molecules, and if the charge has sufficient energy, it will ionize or split up a gas molecule upon colliding. The ions into which a neutral molecule has been split are charged, of course, and each will be attracted toward the electrode with the potential of opposite sign.

Thus, a process of ionization started by a single stray electron will continue as long as a potential difference is maintained. It is particularly to be noted that the mechanism of ionization in a gaseous medium is quite different from that in the case of electrolytic conduction. In a gas, ionization is caused by collision between elec-

trons and ions, or between ions and molecules, while in a liquid medium, ionization is the direct result of a chemical action called dissociation.

Conduction through gas at reduced pressure. The passage of an electric current through gas at pressures below that of the atmosphere is initiated and sustained by the movement of electrons and negative gas ions toward the electrode that is positive. Positive ions move to the negative electrode. Under conditions of reduced pressure, such as partially-evacuated enclosed tubes, however, ionization will cause a characteristic glow depending upon the type of gas used. Neon- and argon-filled tubes used for display purposes and fluorescent tubes used for lighting purposes all utilize this principle.

Since an electron leaves an electrode with practically zero velocity, it will be immediately attracted by the positive electrode, and will gain velocity as it travels toward the anode. When the gas pressure is reduced, there are fewer molecules of gas present, and the electron will attain a greater velocity before striking a molecule to produce ionization—which effectively reduces the potential required to produce ionization. All along the length of the tube, electrons strike gas molecules and thereby produce the visible glow.

Ionization paths in air. The phenomena of gaseous ionization vary with the potential difference applied across the gas-filled space. Therefore, it is necessary that the electrostatic field be considered. As already shown under the subject of electrostatics, the concentration of the flux lines will depend to a great extent upon the surfaces presented by the charged bodies. Figure 4 compares the concentrations of the flux lines in the electrostatic fields between various combinations of surfaces. Note that the concentration of the lines of flux per unit area close to the surface of a charged body become greater as the surface becomes more curved (that is to say, approaches a pointed shape).

Ionization may occur in ordinary air near conductors not enclosed in an evacuated space. The first indication of such ionization of the surrounding air is usually the appearance of thin bluish or purplish streamers issuing from the area of greatest field concentration. This is accompanied by a hiss or faint crackling noise as well as the familiar odor of ozone (produced by certain chemical changes in the air along the ionization path). Such a discharge, caused by ionization, and evidenced by the streamers, is sometimes called a brush discharge or *corona* when it occurs in the air over a relatively large area of a charged surface or wire. When the magnitude of the electrostatic field reaches a critical value, a spark will jump the intervening space.

Under certain atmospheric conditions, clouds accumulate electric charges through the contact of electrically-dissimilar layers of air or the fall of negatively-charged

raindrops. A difference of potential will then exist between such clouds and the earth's surface (which is generally neutral or negatively charged). When the potential difference is great enough, the entire air path between the cloud and earth will ionize and a disruptive discharge takes place as a stroke of lightning.
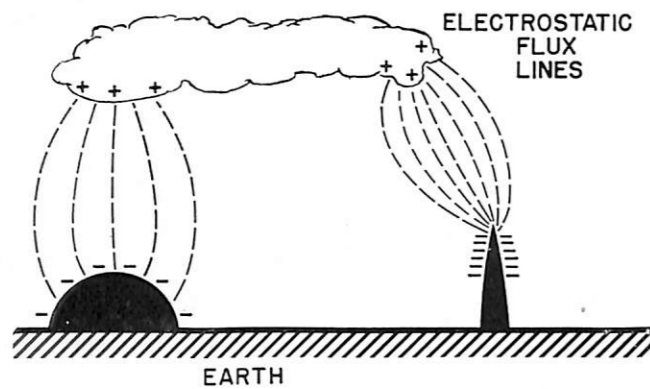

FIGURE 5—*Electrostatic fields between charged cloud and representative pointed and curved surfaces on the earth.*

Figure 5 illustrates the electrostatic field concentration between a charged cloud and two representative objects on the earth's surface. One is a pointed object similar to smokestacks, towers, and tall buildings, while the rounded object represents large low structures of great surface area. An examination of the flux concentration will show that the lightning discharge is more likely to occur between the cloud and the pointed object than with the rounded object. This is due to the greater charge and hence potential difference that exists between the cloud and the pointed object.

This principle is utilized in the familiar lightning rod. Sharp, pointed rods are employed, and are installed at a higher elevation than that of the structure to be protected. The rods are equipped with heavy conducting cables that by-pass the structure and are electrically secured to a good ground connection. Protection against lightning is provided by the tendency of the ionization path to form between the charged cloud and the lightning rod, rather than to the structure. When such discharge takes place, the discharge current is safely conducted to the ground through the connecting cable, and the structure is not harmed.

Losses due to ionization. High-voltage transmission lines and their insulating supports suffer corona losses due to ionization of the surrounding air. These losses are also a source of troublesome radio interference, the same as lightning causes, but on a much smaller scale. In practice, ionization is reduced by the use of conductors of large diameter, which reduce the electrostatic field and thus minimize corona losses. Aluminum is

often used in preference to copper, because its lightness allows the use of larger-diameter wire for transmission of high voltages.

An example of the industrial use of ionization is in the reduction or removal of smoke. A wire of small diameter is usually suspended vertically in the center of smokestacks, and the wire is maintained at a high negative potential. Smoke and dust particles are usually charged negatively, and therefore are repelled by the field about the charged wire and are deposited on the inner walls of the stacks.

Polarization currents. In gases, where there are few "free" electrons, and in solids in which the electrons are not readily detachable from the atoms under the influence of a potential difference, there is little drift of electrons such as occurs in a conductor. The electrons merely undergo a slight shift or displacement. Such a shift, of course, is still a motion of charges and hence a current, and is called a polarization current.

Dielectric strength. When electrostatic phenomena are being considered, the medium between two conductors or charged bodies is called a *dielectric*. The dielectric properties of a medium are determined by the relationship between electrostatic lines and potential difference. On the other hand, the insulating properties of this same medium are determined by the relationship between current flow and potential difference. Practical materials used as dielectrics show the polarization shift referred to above.

No matter how much current flows in a conductor, it is not injured mechanically, provided it is kept below the melting point. Dielectric media, however, have the property of permitting only a limited number of electrostatic lines per unit area without rupture occurring. When the electrostatic flux density exceeds this limiting value, the force is then great enough to overcome the attraction between the atom and its outer electrons. This results in a rupture followed by a dynamic arc that burns and chars solid material.

The ability to resist dielectric breakdown is called the *dielectric strength* of a material and is expressed in volts per unit thickness. For example: Dry air averages 3,000 volts per millimeter as compared to rubber, whose dielectric strength is 16,000 volts per millimeter. Dry air is not so good as a dielectric as far as flash-over is concerned, but it is one of the best insulators because, unless it is ionized, there are very few "free" electrons present. When dielectric breakdown does occur, there is no permanent injury to the medium such as occurs in a solid dielectric medium.

Table II gives the comparative dielectric strength in terms of volts required to cause rupture of the material. These are values obtained under ideal conditions in which the material is in the form of a sheet between flat, parallel, charged plates.

TABLE II—*Dielectric strength of common dielectrics*

Substance	Voltage Breakdown in Kilovolts per Cm
Air, dry	75
Ebonite	300
Fiber	20
Glass	300 to 1500
Linen, varnished	100 to 200
Mica, solid	300 to 700
Mica, laminated	1500 to 2000
Paper, beeswaxed	770
Paper, varnished	100 to 250
Rubber	160 to 500

Insulators. A knowledge of the behavior of electrostatic charges and fields is required for the design and application of high voltage insulation, because the concentration of electrostatic lines of force determines the limits of the potential difference that may be applied across an insulator. By comparing the field concentration that results from the physical shape of the charged bodies as shown in figure 5 with the dielectric strengths of various insulating materials as listed in Table II, the preliminary design specifications of any given insulator may be determined. Other factors, of course, such as operating ranges of temperature, humidity, cost, maintenance, durability, and strength must also be considered.

Ordinarily it is stated that current flows in a wire because it is a good conductor. This is true, but wires are used because we wish to conduct current efficiently along a confined or restricted path. The high conductivity of the wire will give us good efficiency of conduction in the wire, but, in order to restrict the current to the desired path, it is necessary to surround that wire with a good insulator. This insulation may be provided by an insulator such as rubber, glass, or porcelain supports, or the surrounding air itself. Insulators and types of insulation are of great importance, because they actually touch the energized wires, and serve to protect equipment and servicing personnel.

Since the insulation material is always in the electric field produced by the voltage existing between conductors, or between the conductors and other objects at different potentials, the dielectric strength or voltage break-down must be considered. As already mentioned, Table II gives representative values of break-down voltages for the more commonly-encountered types of insulating material.

As has been emphasized in previous pages, a material is a good conductor if it contains many "free" electrons. A material will be good for resistors if it contains relatively few "free" electrons and has a low temperature coefficient of resistance, which keeps its resistance nearly constant as it heats. A material is classified as a good insulator if it has very few "free" electrons, so that only

a very-small current can flow even if a fairly large potential is applied. Of course, many other characteristics enter into determining the qualities of a material as an insulator, but from the "elementary-electron" viewpoint, all that is necessary is that there be very few "free" electrons, and that the application of a potential difference will not liberate, within the material, a sufficient quantity of electrons to carry a current and destroy the property of insulation.

Leakage paths on insulators. When current flows through a conductor, the metal offers such a good conducting path between surfaces that the current flow on the surface is negligible as compared to the flow through the volume of the conductor. When we consider, however, the current flow through an insulator, we must also consider the current path over the surface as well as the path through the insulator itself. The flow of current or leakage current over the surface of an insulating material may often exceed the flow of current through the material. The leakage path is usually due to moisture and impurities on the surface such as salt spray (ETM's please note!), soot, smoke, or dust.
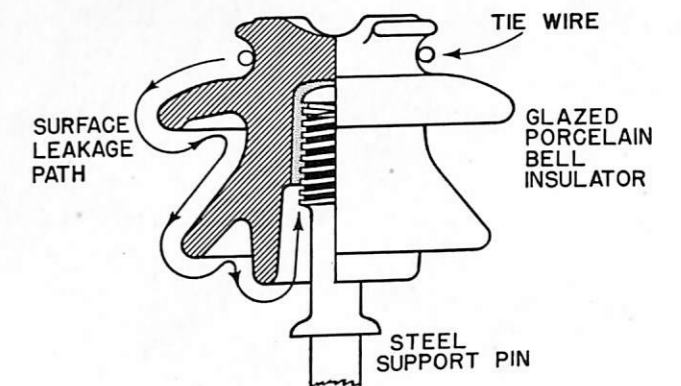

FIGURE 6—*Dielectric and surface leakage paths for the common high-voltage-type insulator.*

A method of overcoming the reduction in insulation resistance because of leakage paths may be simply illustrated by taking as an example the ordinary high-voltage-type support-insulator. The physical shape of such an insulator is that of a bell with an additional inner fluted skirt. This type of construction permits a very long surface path in comparison to the direct path through the dielectric. Figure 6 shows a cross section of the insulator, enabling a visual comparison to be made between the direct path through the insulator from the tie-point to the support-pin, and the surface path between the same points. The bell-like shape also tends to keep the inner path as dry as possible, and the entire surface of the insulator is made water-proof to exclude moisture, which might act as an electrolyte and increase the surface leakage.

THE FRONT COVER OF THIS Electron SHOWS
NEW YORK CITY AS IT APPEARS ON A RADAR P.P.I.
SHOWN ABOVE IS A MAP OF THE SAME AREA.
(Photos by courtesy U.S.N. School, Electronics Engineering, M.I.T.)